National Energy Board | Office national de l'énergie

CANADA'S ENERGY TRANSITION

AN ENERGY MARKET ASSESSMENT

HISTORICAL AND FUTURE CHANGES TO ENERGY SYSTEMS

UPDATE

Canada

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1. Introduction

Over the past two centuries, societies have gone through energy transitions resulting from a combination of technological, economic, and political changes. An energy transition is a shift away from one type of fuel source to another, or the changing composition of primary energy supply.[1] The move in some societies from energy-poor biomass (for example, wood and peat) to coal in the 19th century is one example. This transition was made possible with the development of the steam engine, and coal remained the primary fuel used globally until the middle of the 20th century. The next major transition occurred with the adoption and growth of electrification and the internal combustion engine in the early 20th century. These technological developments drove the demand for new fuel sources, including hydroelectricity, natural gas, and crude oil. Today, over half of the world's primary energy demand is met through abundant and affordable crude oil and natural gas. Coal, now used mostly for electricity generation and steel manufacturing, accounts for a quarter of global primary energy demand.

Changes to the composition of primary energy supply result in tangible changes to energy systems. New sources of energy require new production equipment, new energy transportation infrastructure, and new end-use equipment. Energy transitions also involve intangible changes. These changes include new regulations and policies, and changes to mindsets and belief systems.[2]

Today's energy transition is one that involves a move away from the consumption of carbon-emitting fuels to the consumption of non-carbon-emitting fuels—a process called decarbonization. While the current energy transition is also being driven by technological, economic, and political factors, the current transition is the first being driven primarily by environmental factors based on changing social values—the drive to reduce global greenhouse gas (GHG) emissions.

Global energy demand has doubled since 1980 as populations grow, nations develop, and fuels become more accessible and tradable. Global carbon emissions have increased 52% in the past 25 years. Canada's emissions have increased 33% over the same period.

1 Smil, V. (2017). Energy Transitions: Global and National Perspectives (p. ix). Santa Barbara, California: Praeger.

2 Fattouh, B., Poudineh, R. and West, R. (2018). "The rise of renewables and energy transition: what adaptation strategy for oil companies and oil-exporting countries?" Retrieved from: The Oxford Institute for Energy Studies.

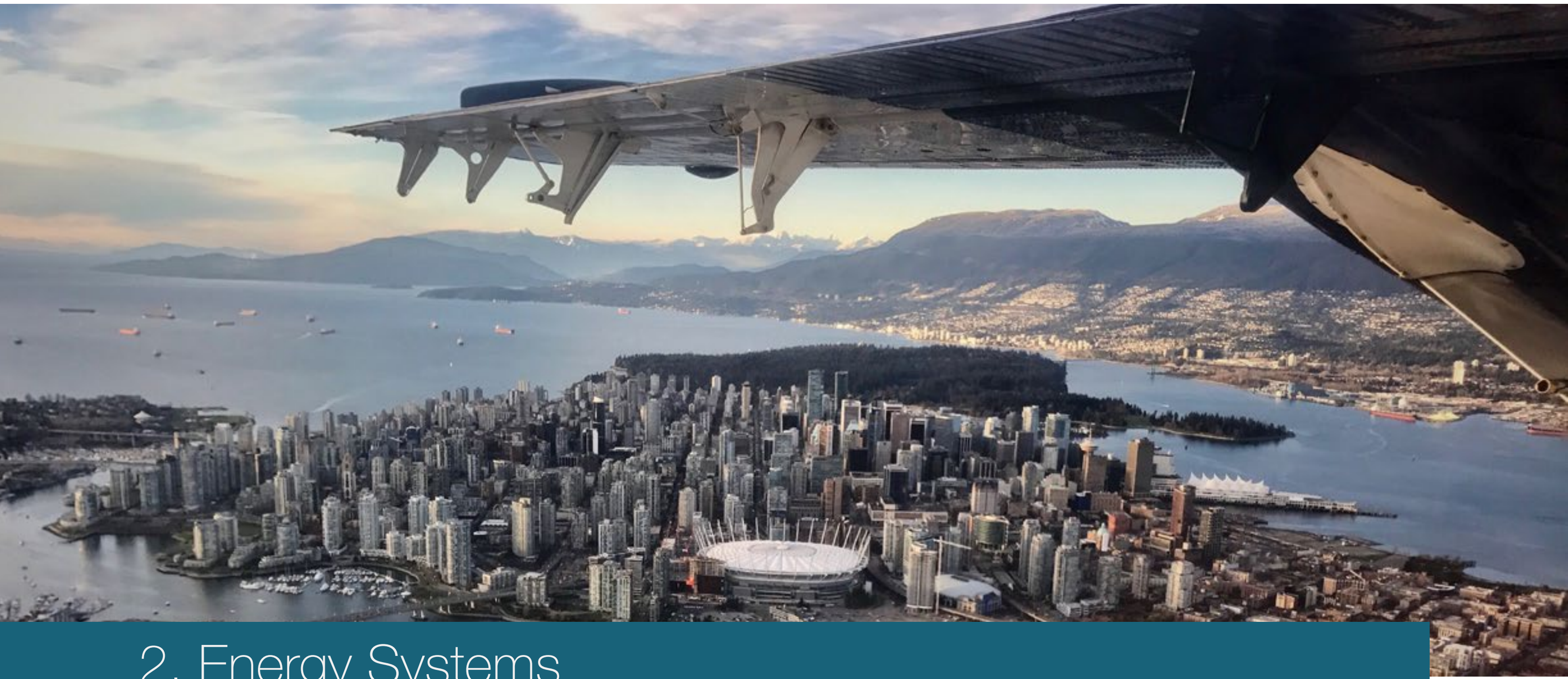
Though Canada generates 1.7% of global GHG emissions, Canada is one of the most energy and emission-intensive[3] nations in the world. The International Energy Agency (IEA) recommends that Canada take action to reduce its emissions and energy intensities in order to strengthen its position as a responsible energy supplier and user. The Organization for Economic Co-operation and Development (OECD) notes Canada's status as one of the most GHG emission-intensive economies in the world, and the fourth largest emitter of GHGs in the group of OECD nations. The Conference Board of Canada ranks Canada in last place compared to 17 peer countries for energy intensity and assigns Canada a "D" grade for its energy intensity and GHG emissions.

Various trends are emerging in Canada that indicate the energy transition is occurring. One indicator is that the pace of renewable energy growth is increasing as the costs of new renewable installations decline. New technologies are emerging, and energy efficiency strategies and programs are expanding. Electrification of transportation is increasingly gaining traction. Carbon pricing and other green policies offer incentives for individuals and organizations to seek out energy efficient methods to reduce wasted energy. Lastly, policy agendas such as the Pan-Canadian Framework on Clean Growth and Climate Change (Pan-Canadian Framework), provincial plans, and municipal and community plans and strategies,[4] are being implemented. These aspects contributing to the energy transition help to not only enable, but also to track the shift towards decarbonization.

This National Energy Board (NEB) report will explore the many plans and actions that are playing a role in Canada's energy transition. It includes an overview of energy systems, a look at past energy transitions, current Canadian energy trends, and ends with perspectives for the future.

3 Energy intensity is a measure of how much energy is used in an economy relative to its production. Most commonly it is calculated as units of energy per unit of gross domestic product. Emissions intensity is a measure of carbon dioxide emitted relative to production, and is often expressed as units of emissions per unit of gross domestic product.

4 Many Canadian cities have developed strategies with respect to climate change or the energy transition in recent years. To name a few, Vancouver (Greenest City), Ottawa (Energy Evolution), Edmonton (Community Energy Transition Strategy), Toronto (TransformTO), and Calgary (Climate Resilience Strategy).



2. Energy Systems

Energy is closely tied to our quality of life as Canadians. Energy keeps us warm in the winter, cool in the summer, and provides us with light 24 hours a day. Energy enables the movement of people, goods, and services across the country and around the globe. It enables nearly all aspects of modern life from refrigerating foods and cooking meals to keeping us alive in extreme environments.

Energy also contributes to our national standard of living; accounting for 10% of our gross domestic product (GDP) and directly employing over 276 000 Canadians.[5] The other 90% of Canada's GDP is highly reliant on energy for the provision of goods and services.[6]

The interaction of the production, conversion, storage, distribution, and end-use of energy is what's called an energy system. Table 1 illustrates the energy systems in Canada—from primary energy sources to the end-use where energy is converted to heat, work, or materials. In this sense, energy is a derived demand. That is, demand for energy comes entirely from our demand for the necessities for life.

5 Natural Resources Canada (2018, 13 September). "Energy Facts: Energy and the economy".

6 Networks of roads, railways, pipelines, and electricity transmission lines across Canada distribute energy from producing regions to demand centres. There are significant regional differences in Canada with respect to where and what type of energy is produced, and where energy is consumed. The NEB's Provincial and Territorial Energy Profiles illustrate the regional differences in Canada's energy systems.

Table 1: Energy Systems in Canada

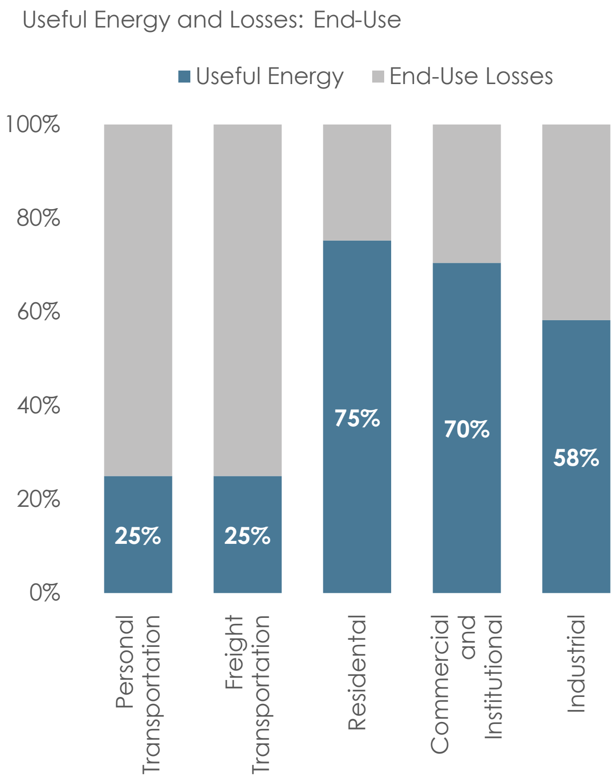
Primary Energy	Production	Conversion	Distribution	End-Use
Renewables	Naturally occurring	Photovoltaic cells, wind turbines, steam turbines, and hydro turbines convert solar, wind, underground heat, and water to electricity.	Electricity grid	Electricity generation and consumption
Natural gas	Drilling and extraction	No conversion, but natural gas processing removes impurities and natural gas liquids. Liquefied natural gas facilities cool natural gas to a liquid for transport.	Pipeline networks, ship (as liquefied natural gas), truck (as liquefied or compressed natural gas)	Space heating, electricity generation and consumption, transportation, non-energy uses
Crude oil	Drilling and extraction	Upgraders convert bitumen into synthetic crude oil. Refineries convert oil into petroleum products, such as gasoline, diesel, heating oil, bunker fuel (for ships).	Pipeline, ship, rail, truck	Transportation, space heating, electricity generation and consumption, non-energy uses
Coal	Mining	No conversion, but coal processing facilities wash and sort coal prior to use in power plants.	Ship, rail	Electricity generation and consumption, some space heating
Uranium	Mining	Uranium processing refines, enriches and converts uranium ore to fuel pellets and bundles for use in reactors.	Ship, rail, truck	Electricity generation and consumption

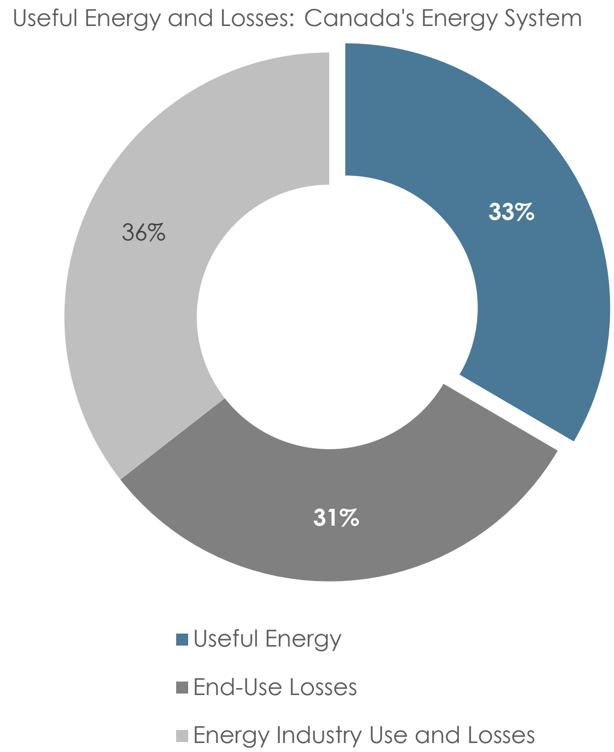
Source: NEB

When energy is used for heat or put to work (gasoline to power a car forward, for example), it is said to be useful. However, as energy is transformed from its primary energy source, transported to the end-user, or consumed by the end-user, losses and inefficiencies occur.

Figure 1 illustrates that the vast majority of energy consumed in Canada is ultimately lost. Energy losses can occur at all points in an energy system; that is, within the processes of production, conversion, and distribution of energy, or with the end-user.

Figure 1: Useful Energy and Losses in Canada, 2013





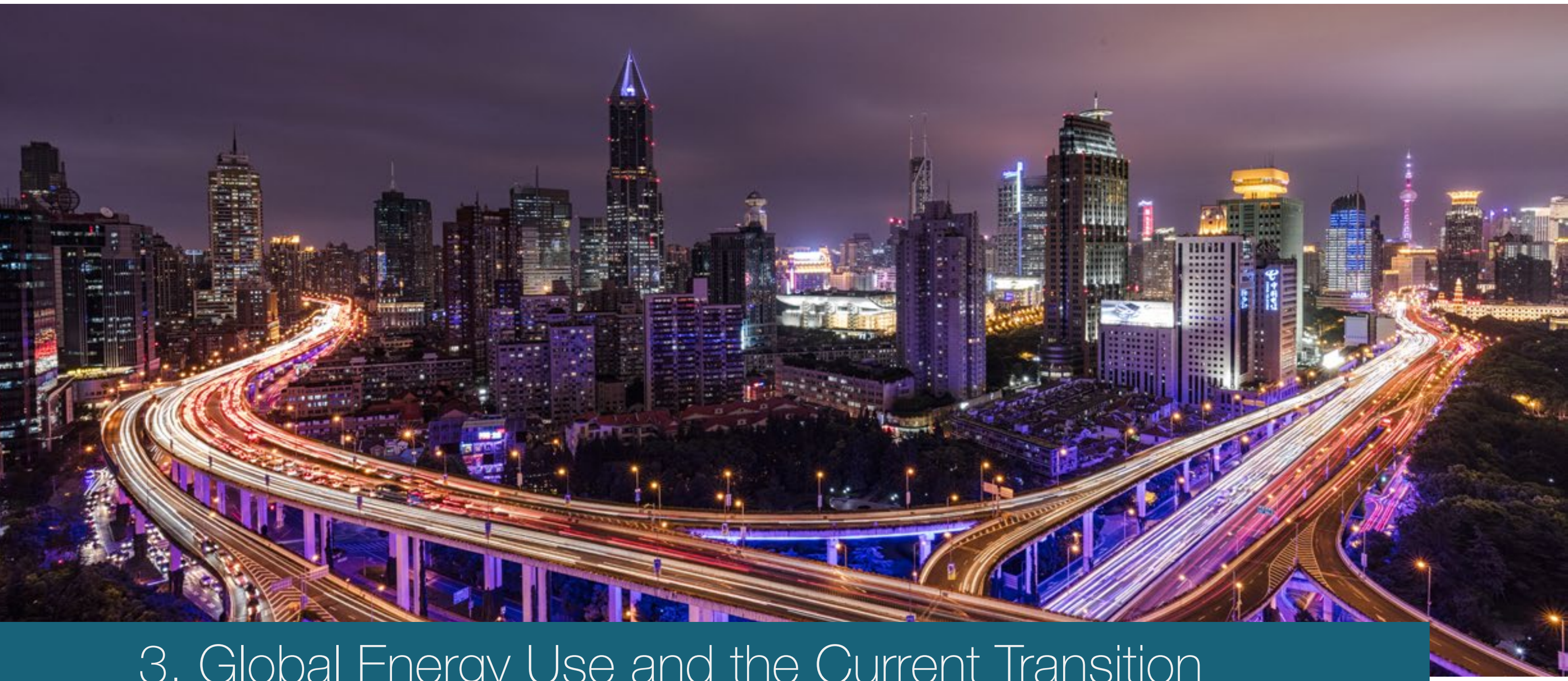
Source: Canadian Energy Systems Analysis Research

Within the energy industry, energy is lost through the use of energy, or through the energy conversion process. Examples of energy that is lost in the conversion process is evident through the fuels and electricity consumed by the petroleum industry along the supply chain, and the losses associated with the generation, transmission and distribution of electricity to end-users.[7]

End-use losses are the differences between the fuel and electricity consumed by the end user and an estimate of the ultimate useful energy that is delivered. For personal and freight transportation, only 25% (on average) of the fuel consumed by vehicles and vessels is ultimately used for movement. The remaining 75% is lost from friction, combustion, exhaust heat, and idling.

Understanding how energy is produced, transformed, and consumed, as well as how to make these processes more efficient is a fundamental element of the energy transition. Other key elements include understanding how much energy we consume, what types of energy we consume, and the environmental effects of our energy needs.

7 Thermal power plants have varying efficiencies, depending on technology. Canadian Energy Systems Analysis Research (CESAR) estimates that 29% of nuclear fuel is converted to electricity, while 26% to 36% of coal and 40% to 60% of natural gas is converted to electricity. CESAR also estimates that transmission and distribution losses on Canadian power grids are less than 10%.



3. Global Energy Use and the Current Transition

Global energy use has grown substantially over the last 50 years. Technological improvements since the early 20th century have resulted in the discovery and eventual use of new forms of energy. Use of energy sources such as coal shifted from transportation (for example, in steam locomotives), space heating, and industrial processes to use in electricity generation. Developments in marine shipping—including speed, efficiency, and economies of scale[8]—resulted in the establishment of a global crude oil trade. Developments in the liquefaction of gasses, in combination with shipping developments, later resulted in the establishment of a global liquefied natural gas (LNG) trade. This movement of energy around the globe allowed, and continues to allow, energy resource-poor societies to develop and grow their economies. To illustrate the impact that the global energy trade can have on an economy, natural gas from LNG now accounts for the source of almost 50% of Japan's electricity production mix.[9]

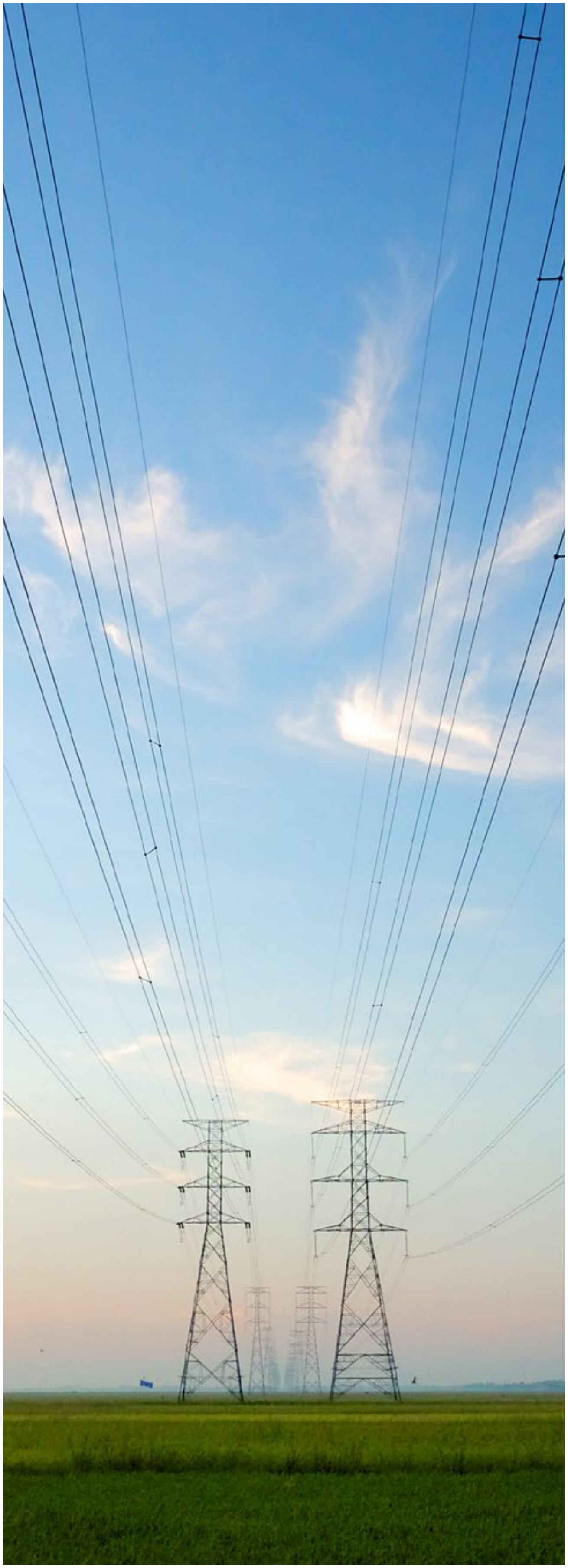
This rapid growth in the production and global trade of crude oil and natural gas also allows nations wealthy in energy resources to monetize their resources and build their economies, and enables nations poor in energy resources to import the fuels required to build modern, developed societies. This abundant supply of energy, coupled with continually growing demand, resulted in the continual growth of global energy consumption. In 2017, global energy consumption reached a record high 566 exajoules (EJ).

Global energy use and economic growth is highly unbalanced. Historically, developed nations (nations who are members of the OECD) were the largest consumers of energy in absolute terms. However, developing (or "non-OECD") nations became the largest consumers of energy after 2007. This change came as a result of industrialization, motorization, economic reforms, urbanization, and other structural transformations that occurred in many of these developing nations in recent decades. This is illustrated in Figure 2.

As economic and population growth in developing nations continues to surpass growth in developed nations, energy demand growth in developing nations is expected to continue outpacing energy demand growth in developed nations.

8 In the late 1940s, the largest crude carrier had a capacity of 30 000 deadweight tonnes (DWT) – a capacity that was limited by the Suez Canal at the time. Modern ultra-large crude carrier tankers have a capacity exceeding 500 000 DWT.

9 Japan is highly reliant on the import of coal, crude oil, and natural gas to meet the energy needs of its 127 million residents. Following the Fukushima Daiichi nuclear accident in 2011, Japan progressively shut down its nuclear reactors for safety reasons. While several reactors have restarted, the majority remain shut down indefinitely. Increased imports of LNG were instrumental in ensuring the reliability of Japan's electricity sector following the shutdowns.



ENERGY UNITS USED IN THIS REPORT

A joule is a unit of energy. Because a joule is a very small unit of energy, it is often expressed in multiples such as:

- One **megajoule** (MJ) = one million joules
- One **gigajoule** (GJ) = one thousand MJ
- One **terajoule** (TJ) = one thousand GJ
- One **petajoule** (PJ) = one thousand TJ
- One **exajoule** (EJ) = one thousand PJ

One GJ is equal to slightly more than two 20 pound propane cylinders or 30 litres of gasoline. The average Canadian household consumes 93 GJ of energy each year.

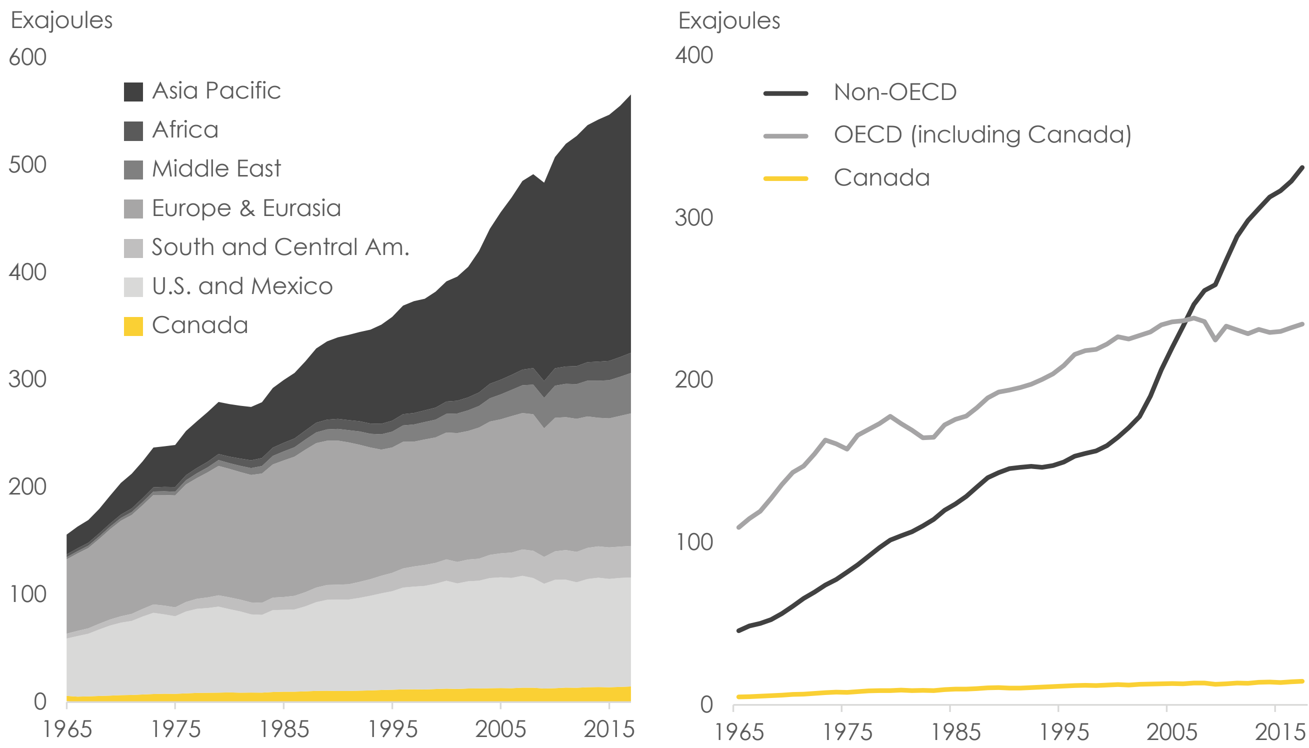
One EJ is equivalent to the energy content in 174 million barrels of oil. In 2017, the world consumed 98 million barrels of oil per day (or 0.56 EJ per day).

A **watt** is a unit of power equal to one joule per second. Similar to joules, watts are also expressed as a multiple, such as megawatts (MW), gigawatts (GW), and terawatts (TW). A typical on-shore wind turbine has a capacity of around two to four MW, the Robert-Bourassa hydro station has a capacity of 5.6 GW, and the Bruce Power Generating Station has a capacity of 6.3 GW.

A **watt hour** is a unit of energy defined as the power in watts delivered over an hour, and is equal to 3 600 joules. Common multiples include the kilowatt hour (kW.h), megawatt hour (MW.h), gigawatt hour (GW.h), and terawatt hour (TW.h). A clothes dryer running for an hour consumes an average three kW.h. The average Canadian household consumes 12 MW.h of electricity each year. In 2017, Canada generated 650 TW.h of electricity.

See the NEB's Energy Conversion Calculator to convert between units.

Figure 2: Energy Consumption: OECD and Non-OECD Nations, 1965-2017



Source: BP Statistical Review of World Energy (2018)

Why Transition?

In addition to a strong link between energy use and social and economic development, there is also a strong link between energy use and the environment. Carbon dioxide (CO_2) is a GHG that results from the combustion of biomass and fossil fuels. GHGs also result from the conversion of land from natural vegetation to urban, industrial, or cultivated land. GHGs are the main cause of climate change, and the shift from carbon-emitting fuels towards non-carbon-emitting fuels is what defines the current energy transition.

Not all carbon-based fuels are equal. Different fuels contain different amounts of energy and consequently, have differing levels of CO_2 after combustion as illustrated in Table 2. Wood and lignite coal are light on energy density[10] (as measured in megajoules (MJ) per kilogram (kg)), but are heavy on emissions relative to refined petroleum products (such as diesel and gasoline) and natural gas.

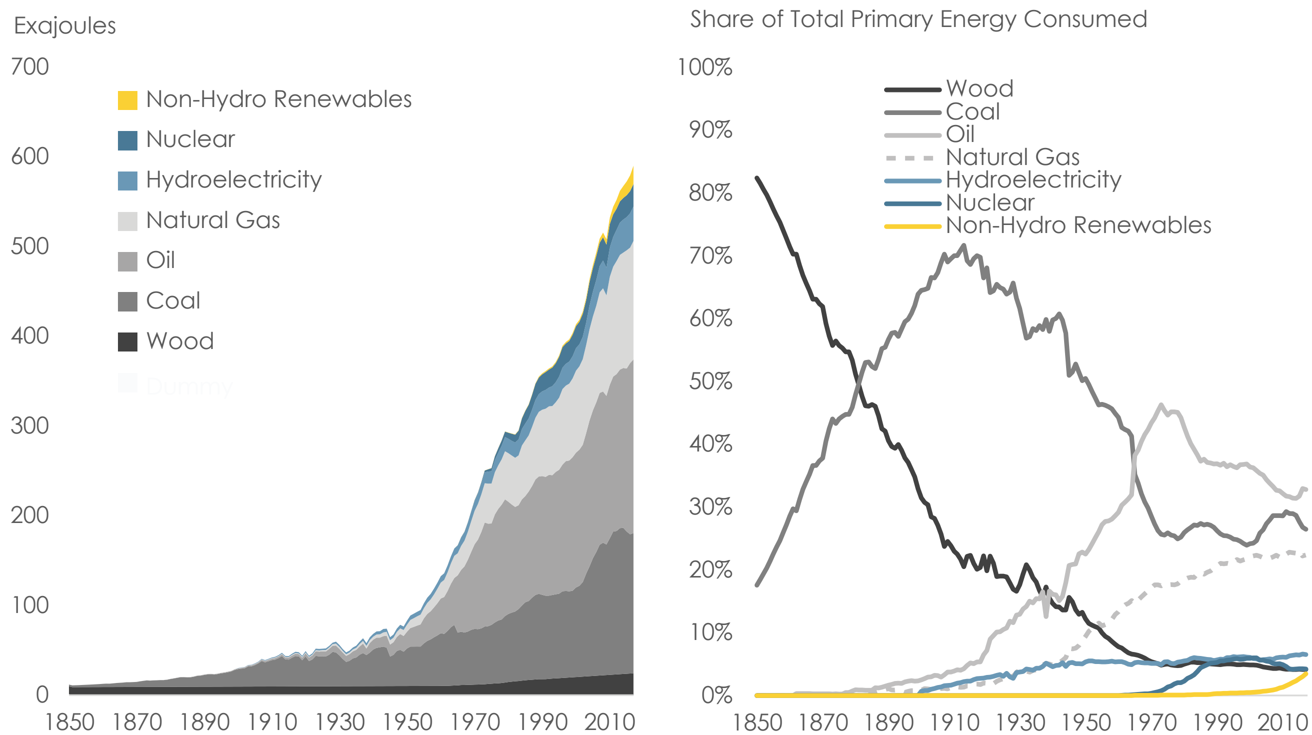
10 **Energy density** is the energy content of a fuel as a ratio of its weight or volume. For example, natural gas (gaseous or liquid) has roughly double the energy density (joules per kilogram) of coal, and coal has roughly double the energy density of peat and wood.

Table 2: Energy Density and Carbon Emissions from Various Fuels

Fuel	Energy density (MJ per kg)	CO_2 emissions from combustion (grams per MJ)	Emissions difference relative to lignite coal
Wood[11]	15 to 22	109.6	+8%
Coal (lignite or ‘brown coal’)	15 to 19	101.2	-
Coal (anthracite or ‘hard coal’)	27 to 30	94.6	-7%
Diesel	42.8 (or 36.4 MJ per L)	74.1	-27%
Gasoline	43.8 to 47.9 (or 32.0 to 35.0 MJ per L)	69.3	-32%
Natural Gas	53.8 (or 23.0 to 26.0 MJ per L of LNG)	56.1	-55%

Source: University of Washington, Volker Quaschning, NEB calculations

Figure 3: Global Primary Energy Consumption by Fuel, 1850 – 2017



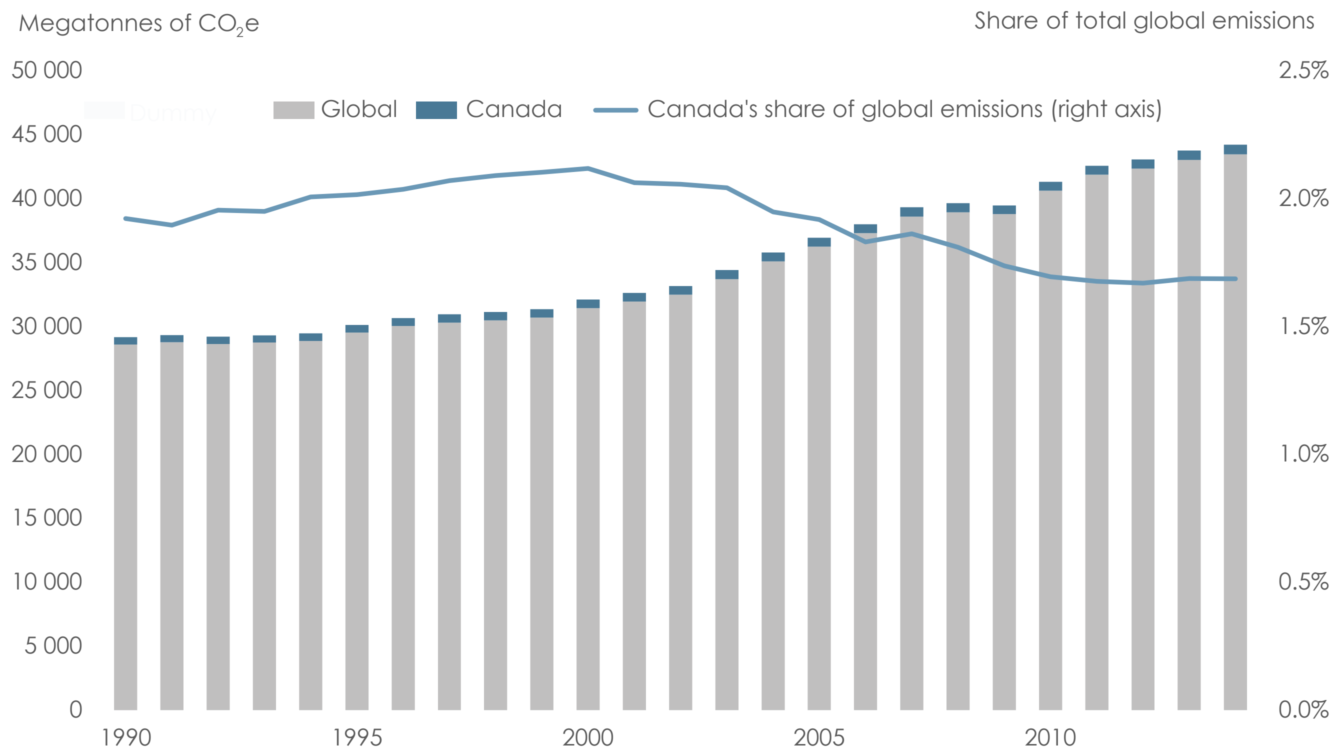
Source: BP Statistical Review of World Energy (2018); Dr. Arnulf Grübler (data appendix from Technology and Global Change)

Figure 3 illustrates a 167 year global history of energy consumption by fuel. Since the 1950s, the majority of growing global energy needs have been met using carbon-emitting fuels (biomass, coal, crude oil, natural gas). Currently, carbon-based fuels account for 85% of the world’s primary energy needs. Non-emitting sources, such as hydroelectricity, nuclear, wind, and solar have historically accounted for only a small percentage of the primary energy consumed globally.

11 The UNFCCC notes that biomass has the potential to approach carbon neutrality, if consumption is done on a sustainable basis. Carbon neutrality refers to a balancing of carbon emissions and carbon removal.

The global economy's growing demand for energy, particularly from abundant and affordable carbon-emitting fuels, has resulted in global GHG emissions reaching new heights with each year. Between 1850 and 2014, GHG emissions grew from an estimated 198 megatonnes of CO_2 equivalent[12] (MT of CO_2e) to over 44 000 MT of CO_2e.[13]

Figure 4: Global GHG Emissions and Canada's Share, 1990 – 2014



Source: CAIT Climate Data Explorer

Figure 4 illustrates the trend in GHG emissions between 1990 and 2014. Over this period, Canada's emissions increased 33% to 745 MT of CO_2e. Though Canada remains a relatively small contributor to global GHG emissions, Canada is one of the most emission-intensive nations in the world. This will be explored more in the next section.

12 In addition to CO_2, GHGs include methane, nitrous oxide, and fluorinated gases. Each GHG type is associated with a "global warming potential". For example, methane is estimated to have a global warming potential of 28 to 36 times that of CO_2, while fluorinated gases have a global warming potential in the thousands relative to CO_2. By quoting GHG emissions as a CO_2 equivalent, it standardizes the global warming effects caused by each gas.

13 Using data from the World Resources Institute (WRI) and WRI's Climate Analysis Indicators Tool (CAIT).

The Current Transition

Figure 3 also illustrates that energy transitions, historically, have occurred slowly. Prior to 1880, biomass was the largest source of primary energy globally. Coal, a major driver of the Industrial Revolution, was more abundant and less labour intensive than wood/charcoal. Coal's share as a primary energy continued to grow as a source of fuel, and peaked in the 1910s when it met 70% of the world's energy needs. While the use of coal grew five-fold over the next century, coal's share as a primary energy source declined to 28% in the 2010s. Starting in the 1930s, global energy needs were being met through increasingly abundant and affordable hydrocarbons.

Nuclear energy, first used for electricity generation in the 1950s, has accounted for 4% to 6% of global primary energy demand since the mid-1980s.[14] As of 2016, there were 450 nuclear reactors operating world-wide and another 60 under construction.[15]

A fundamental component of the current energy transition is increased energy from renewables. Figure 3 illustrates that energy from non-hydro renewables, such as wind and solar, has increased from 2 EJ in 2000 to 20 EJ in 2017. This may seem small, but it is worth noting that no other primary energy source has experienced a ten-fold increase in growth, or has grown in share by that amount in a 17-year timeframe. The growth in non-hydro renewable use is similar to the rise of nuclear in the 1970s and 1980s and many international energy forecasting agencies[16] see the share of renewables continuing to grow into the future. Advancements in technology and improvements in economics have resulted in non-hydro renewables competing with traditional energy systems on a cost per energy generated basis.

What Figure 3 does not illustrate is the pace at which individual economies transition from one energy source to another. Historically, not all societies have transitioned at the same speed, or with the same magnitude. Coal, despite being inferior to oil and natural gas in terms of energy density, still remains an abundant and affordable source of primary energy for many developing and developed nations. Biomass use—higher now than in 1900—continues to be used as a cooking fuel by over 2.5 billion people globally; primarily in rural areas of developing nations.

A History of Global Efforts

The rapid increase in energy-related GHG emissions and the effects of these emissions on the climate are the underpinning of national governments reaching agreements to take action. Typically, these agreements involve governments adopting policies designed to change the behaviours of consumers and producers.

International policies have been the impetus for change, and Canada has a history of involvement in environmental treaties and agreements. The Montreal Protocol[17] is one such international treaty that Canada was party to. Finalized in 1987 and implemented in 1989, the Montreal Protocol resulted in the phasing out of substances that deplete of the ozone layer (primarily chlorofluorocarbons or CFCs). In addition to being the first environmental agreement to achieve universal ratification by all countries, the agreement is widely acknowledged as a success and it illustrated that international cooperation towards a common environmental goal was in fact possible. Three decades later, the Montreal Protocol became an instrument against climate change in 2016 with the Kigali Amendment.[18]

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14 In Canada, nuclear energy accounts for 15% of Canada's electricity generation and 9% of Canada's primary energy demand. Nuclear energy is the largest source of electricity in Ontario and New Brunswick.

15 European Nuclear Society (2016). "Nuclear power plants, world-wide".

16 Including International Energy Agency's World Energy Outlook 2018; BP's Energy Outlook 2019; and Bloomberg New Energy Finance's New Energy Outlook 2018.

17 Full title is the Montreal Protocol on Substances that Deplete the Ozone Layer.

18 The Kigali Amendment to the Montreal Protocol was signed in 2016 and entered into force on 1 January 2019. The Kigali Amendment mandates the gradual phase down of the production and consumption of hydrofluorocarbons (HFCs)—a very potent GHG. HFCs were used as an alternative to CFCs after the Montreal Protocol and the phase down could prevent up to 0.5° Celsius of warming by the end of the century.

In 1992, the United Nations (UN) Framework Convention on Climate Change (UNFCCC) was adopted at the Earth Summit in Rio de Janeiro, Brazil by 154 signatories. It has since been ratified by 197 countries. The treaty set out a goal to stabilize GHG concentrations "at a level that would prevent dangerous anthropogenic interference with the climate system." Under the UNFCCC, the Kyoto Protocol (1997) was the first agreement to set emissions reductions targets, though only for a limited number of parties.[19]

The Paris Agreement was the outcome of the 21st Conference of the Parties (COP21) of the UNFCCC in Paris in December 2015. To date, the Paris Agreement has been signed by 197 nations and ratified by 185.[20,21] The central goal of the Paris Agreement, which includes emissions reduction commitments by a much larger group of parties than the Kyoto Protocol, is to keep the global temperature increase to well below 2º Celsius above pre-industrial levels this century, and to pursue efforts to limit the temperature increase even further to 1.5º Celsius above pre-industrial levels.

As the effects and the costs of climate change increase, the push for action on climate change has also increased. This has resulted in the current energy transition being the first transition where environmental factors are a primary driver of the transition. The transition is being further supported by technological, economic, and political factors.

FROM KYOTO TO PARIS

The Paris Agreement is similar to the Kyoto Protocol in that both build on the goals set out in the UNFCCC, and were developed with the aim of curbing the rise of global temperatures through a reduction in GHG emissions.

The Kyoto Protocol entered into force in 2005 with 192 parties signing on, including Canada.

Canada's Kyoto target was a 6% reduction below its 1990 emissions by 2012. However, by 2010, Canada's emissions had increased 15% from 1990 levels. In 2012, realising it was unable to meet its commitments, Canada withdrew from the agreement.

The Paris Agreement was adopted in 2015 and entered into force in 2016. Paris differed from Kyoto because instead of internationally binding emissions targets, countries set voluntary, nationally determined targets. The targets are expected to represent best efforts and are to be strengthened over time. As well, under the Paris Agreement, both developed and developing countries are required to set emissions reductions targets. In contrast, the Kyoto Protocol only requires targets to be set by developed nations with developing nations given the opportunity to voluntarily comply.

The Pan-Canadian Framework on Clean Growth and Climate Change

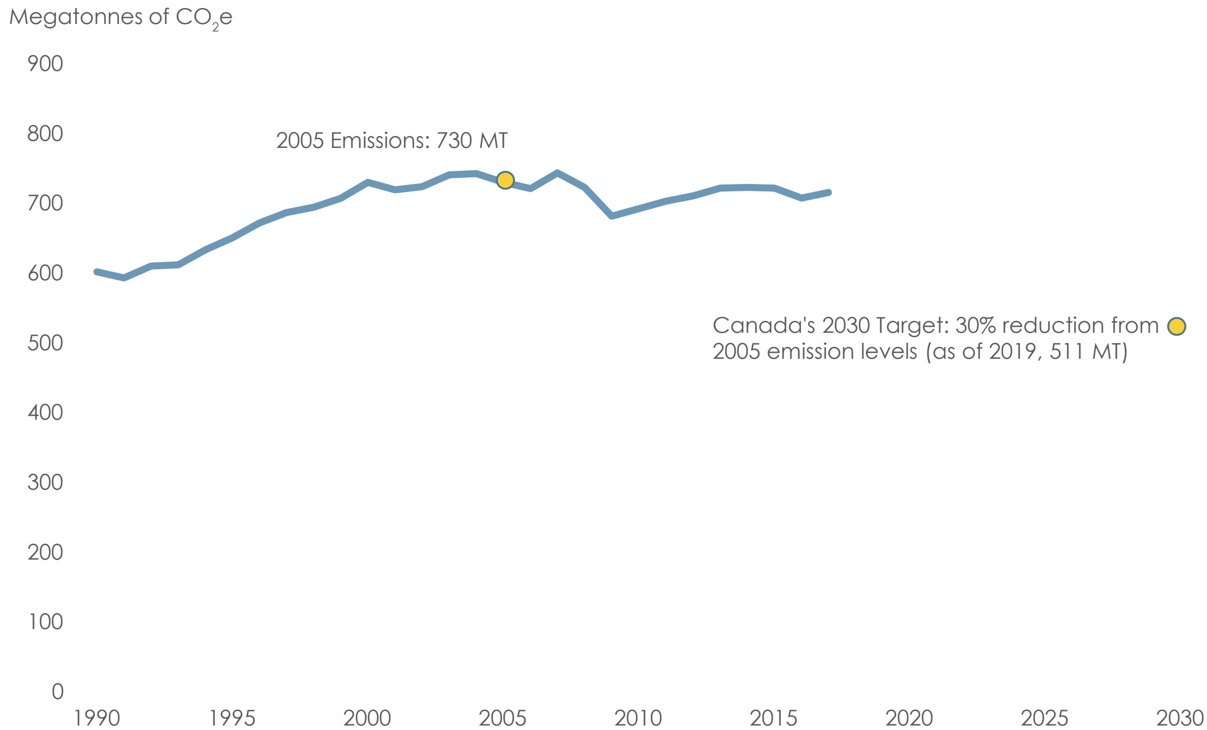
Canada's commitment under the Paris Agreement involves a 30% reduction of its GHG emissions from 2005 levels (730 MT of CO_2e) by 2030, which equates to a target of 511 MT. Canada's emissions in 2017 were 716 MT, which represents a net decrease of 1.9% from 2005 levels. On a per capita basis, GHG emissions have declined from 22.7 tonnes of CO_2e per person to 19.5 tonnes per person, a net decrease of 14.1%.

19 Center for Climate and Energy Solutions (2017). "History of UN Climate Talks".

20 UNFCCC (2019). "Paris Agreement – Status of Ratification".

21 In 2017, President Donald Trump announced that the United States (U.S.) would withdraw from the Paris Agreement as soon as it is legally eligible to do so. The formal notice cannot be submitted until 2019.

Figure 5: Canada's Historical GHG Emissions and 2030 Target



Source: ECCC – National Inventory Report 1990-2017
Note: GHG emissions, including 2005 levels and the 2030 target, are subject to revision.

The Pan-Canadian Framework was developed in 2016 and represents Canada's commitment to fighting climate change.[22] Placing a price on carbon pollution is central to the Framework. Carbon pricing is an efficient way to reduce emissions, drive innovation, and encourage people and businesses to pollute less.[23]

In addition to placing a price on carbon pollution, the Pan-Canadian Framework also includes complementary actions that aim to reduce emissions by addressing market barriers where pricing alone is insufficient or not timely enough to reduce emissions in the pre-2030 timeframe. These actions, for example, include increasing the stringency of energy efficiency standards and codes for vehicles and buildings. The Pan-Canadian Framework also includes actions to help Canadians adapt and become more resilient to the effects of a changing climate and foster clean technology solutions.

Environment and Climate Change Canada's (ECCC) 2018 GHG emission projections estimate that Canada's GHG emissions in 2030 will be 223 MT lower than projected prior to the Pan-Canadian Framework. ECCC estimates that once the Pan-Canadian Framework is fully implemented, it will put Canada on a path towards meeting its 2030 target and to continue to achieve emission reductions beyond 2030.

22 Manitoba and Saskatchewan did not initially adopt the Pan-Canadian Framework in 2016, but Manitoba has since joined.

23 Additional details on the implementation of carbon pollution pricing in Canada is available here.

Placing a Price on Carbon

A carbon price places a cost on activities that result in GHG emissions. In practice, a government can impose a fixed charge based on actual emissions, based on the embedded carbon in fuel, or based on the carbon emitted to produce a product. Therefore, the more an individual or organization emits, the more they pay. Carbon pricing is transparent and predictable, and provides an incentive for energy efficiency and emissions reduction innovations. Decisions about how to return the revenue from carbon pricing can have important impacts, including helping alleviate any regressive effects and further supporting research and development or investments in energy efficiency.[24]

Emissions permit trading and cap-and-trade systems operate differently from a tax, though the objective of reducing emissions remains the same. Under permit trading, governments can set a limit on GHG emissions and issue a fixed number of permits equal to the cap. The trade component allows for polluters to trade permits with other polluters. This trading mechanism allows for polluters who can decrease their emissions most cheaply to sell and profit from the sale of their permits to other polluters who need to increase their emissions or are unable to reduce cost effectively. When governments reduce the cap over time, it is possible to reduce total emissions while creating an incentive to drive lower cost-emissions reductions first.

OVERVIEW OF PAN-CANADIAN FRAMEWORK ACTIONS

In addition to the pricing of carbon pollution, there are numerous other actions that help shape the Pan-Canadian Framework, including:

- The phase-out of coal-fired electricity by 2030.
- Reducing the reliance on diesel-fired generation in northern, remote, and Indigenous communities.
- Improving vehicle efficiency, developing a Clean Fuel Standard, and placing more zero-emission vehicles on the road.
- Reducing methane emission from the oil and gas sector.
- Improving energy efficiency in all sectors.
- Protecting and enhancing carbon sinks (that is, carbon stored in forests, wetlands, and agricultural areas).

The Framework also includes collaboration with Indigenous Peoples and incorporates drawing from their Traditional Knowledge, particularly in the context of adaptation and climate resilience.

The main benefits of permit trading are the certainty of reductions and the ability to link with other permit trading systems in other jurisdictions. The drawbacks of permit trading are higher administrative costs and price uncertainty for emitters.

Other Policy Tools

As recognized by governments party to the Pan-Canadian Framework, multiple actions will be needed in addition to carbon pricing for Canada to reach its 2030 Paris Agreement target and to continue to further decarbonize its economy by mid-century. In the move towards electrification and clean energy, significant investments will be required, as well as a deeper understanding by end-users as to how we produce and use energy.

Complementing market-based instruments are a variety of other policies that contribute to reducing emissions. These policies and regulations typically work by encouraging or discouraging behaviours through non-monetary means. These include, but are not limited to: policies and regulations related to improved practices and standards, investments in research and development for energy efficiency and clean technology, and electricity sector initiatives (such as renewable portfolio standards and coal phase-outs).

Policies are an important part of energy trends. As Canada's energy systems evolve, it will continue to be guided by policy decisions. Furthermore, given the long lifespans of energy-consuming equipment and projects, current policy developments will play a large role in future trends.

24 Government of Canada (2018). "Estimated impacts of the Federal Carbon Pollution Pricing System"

4. Energy and Emissions in Canada

Energy Production in Canada

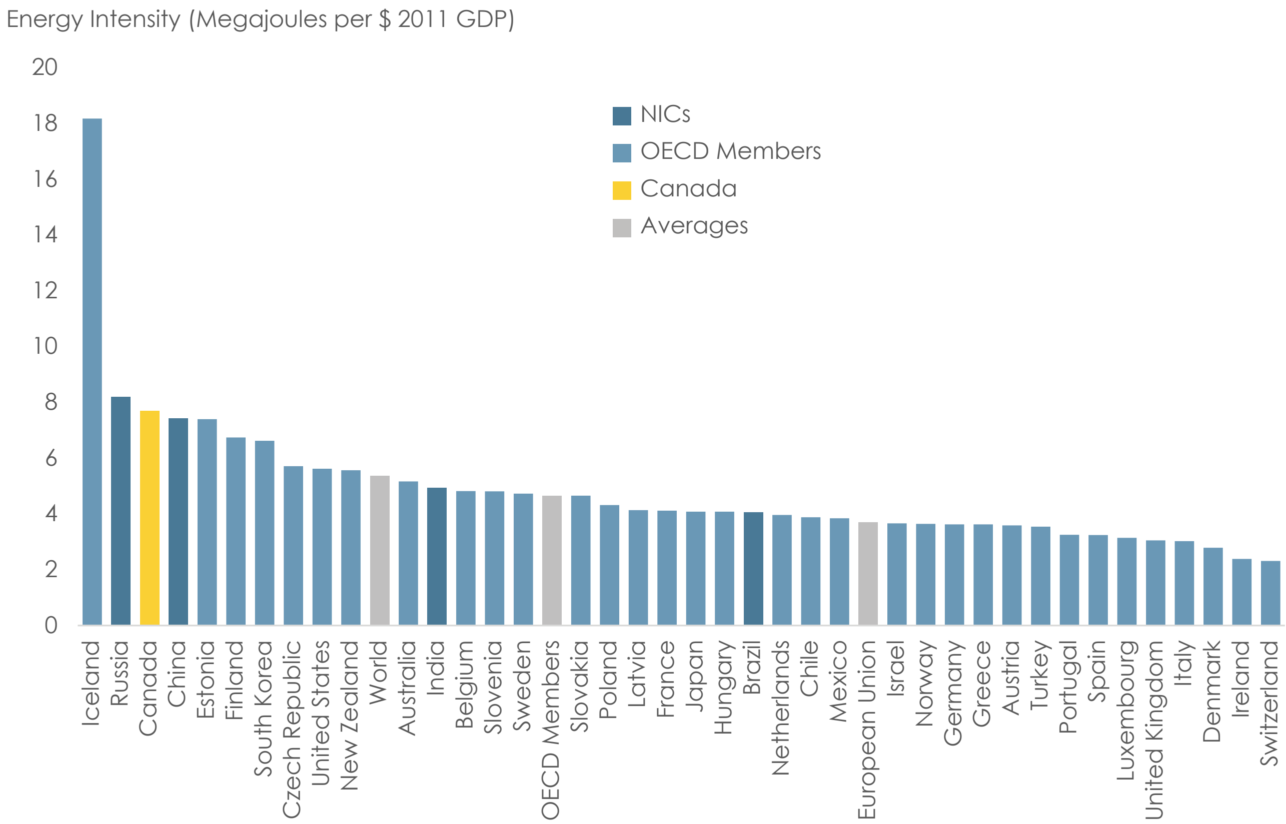
Canada is one of the largest energy producers in the world. Canada's large landmass, paired with diverse geography and geology, allows for numerous types of energy production. Canada is currently ranked the sixth-largest crude oil producer and the fifth-largest natural gas producer in the world. Canada is also the second-largest hydroelectricity producer in the world and is ranked seventh with respect to installed wind power capacity.

Canada is also a large net exporter of energy; exporting production that is surplus to the current and future needs of Canadians. In 2017, Canada's net energy exports were valued at $71.4 billion.

Energy Use in Canada

Canada is one of the largest consumers of energy globally when measured as a ratio to economic activity. Figure 6 illustrates that Canada's energy intensity is second among OECD nations at 7.70 MJ per $2011 GDP. The global average for energy intensity is 5.36 MJ per $2011 GDP, while the OECD average is 4.66 MJ per $2011 GDP.

Figure 6: Energy Intensity for OECD Economies and Select NICs, 2015



Source: World Bank

In addition to a cold climate and dispersed population, Canada has a relatively large industrial base, a growing energy producing sector, a low cost of energy, and a very high standard of living. These factors all contribute to Canada's high energy intensity.

GHG Emissions in Canada

ECCC has estimated Canada's 2017 GHG emissions at 716 MT of CO_2e. Canada's GHG emissions peaked in 2007 at 745 MT of CO_2e. This decline in emissions can be attributed largely to two factors: the phase-out of coal-fired electricity in Ontario and the economic slowdown that resulted from the 2008 financial crisis and recession.

As shown in Figure 7, the largest contributor to GHG emissions in Canada is the oil and gas sector (195 MT of CO_2e in 2017), followed by the transportation sector (174 MT of CO_2e). Emissions from the oil and gas sector are largely from the consumption of natural gas used in the oil sands for bitumen production and upgrading, and for natural gas production and processing.

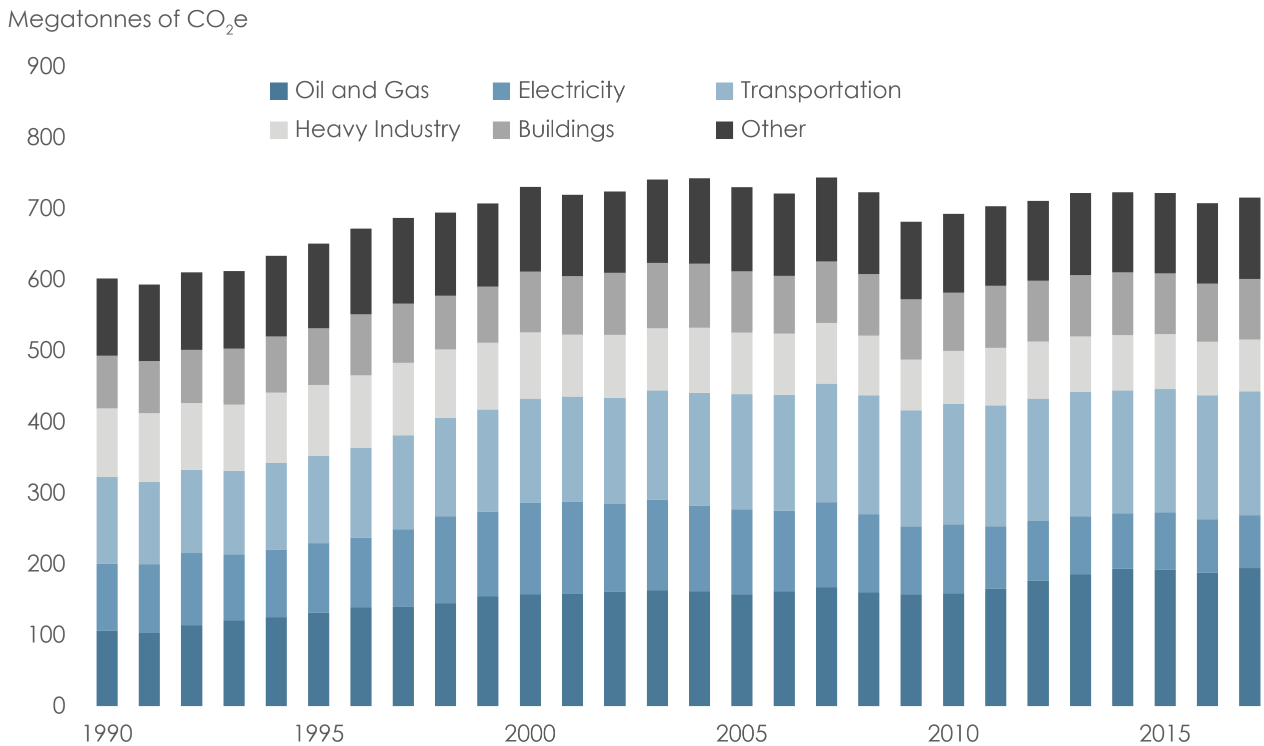
COAL PHASE-OUTS IN CANADA

Ontario was the first jurisdiction in North America with a significant reliance on coal for electricity generation to phase out its use. Between 2003 and 2014, coal went from providing 25% of Ontario's electricity supply mix to 0%. The closure of 19 units totaling 8 800 megawatts (MW) was replaced with the return of two nuclear units at Bruce Power, new natural gas-fired generation facilities, and over 5 500 MW of new non-hydro renewables.

Alberta has committed to end emissions from coal-fired generation facilities by 2030 under its Climate Leadership Plan. The plan also involves coal-to-gas conversions and a 30% target for generation from renewable sources by 2030. In fall 2016, the Government of Canada announced an accelerated phase out of traditional coal-power.

In 2017, 47% of Alberta's electricity was from coal-fired generation.

Figure 7: GHG Emissions by Sector in Canada, 1990 - 2017



Source: ECCC – National Inventory Report 1990-2017

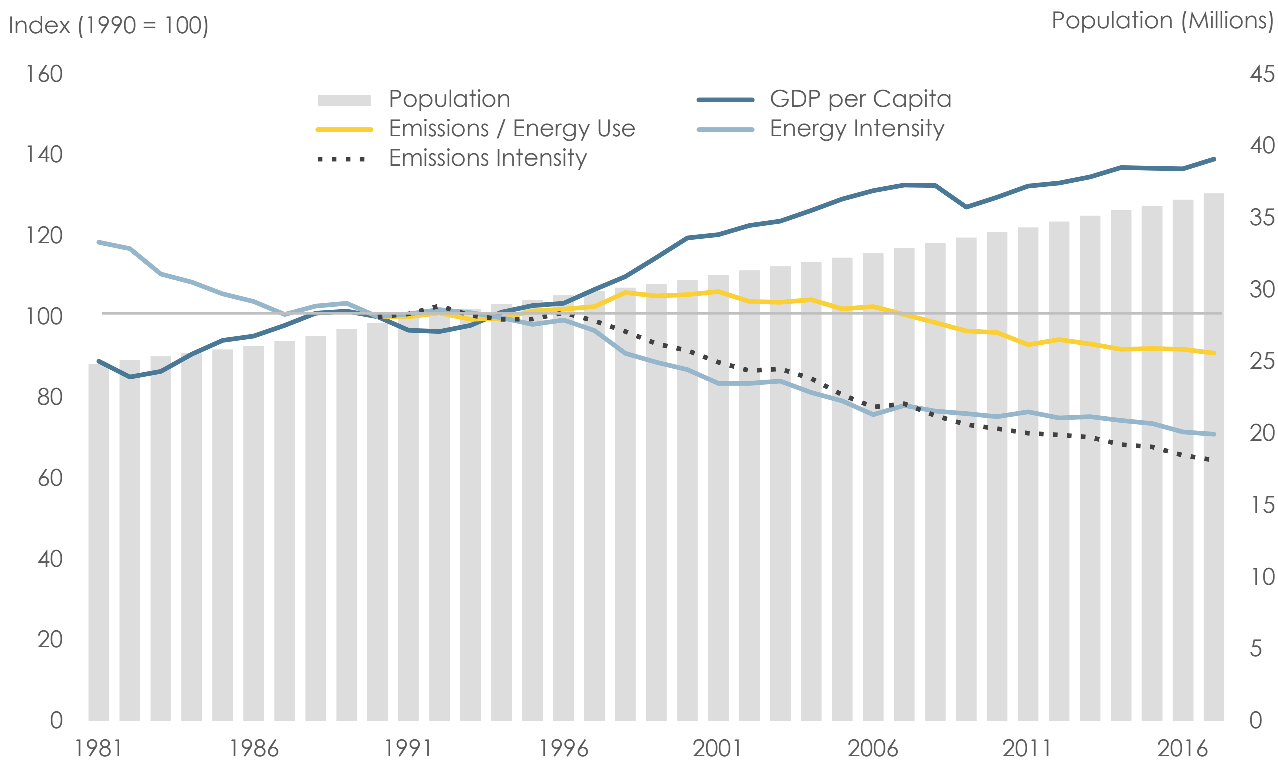
Emissions from the transportation sector are from the consumption of gasoline and diesel—the two fuels that power over 95% of Canada's auto fleet. Diesel fuel also provides the energy for the majority of Canada's freight transportation, including trucking and rail.

The Kaya Identity, Energy Intensity, and Emission Intensity

The link between emissions and energy consumption can be examined through the Kaya identity.[25] The Kaya identity states that the level of GHG emissions are connected through four factors: population, economic activity (real GDP per capita), energy intensity (energy use per GDP), and GHG intensity (GHG emissions per energy use). Using 1990 as a base year, Figure 8 illustrates the link between these factors. Between 1990 and 2017, real Canadian GDP per capita increased 39% while energy intensity decreased by 29% and GHG emissions per unit of energy decreased 9%. Emission intensity (GHG emissions per GDP) decreased by 35%. Though not a Kaya identity component, emission intensity is an important metric nevertheless.

25 The Kaya identity was developed by Japanese academic Yoichi Kaya in 1991. The identity states that emissions from human sources are equal to population multiplied by GDP per capita multiplied by energy intensity multiplied by emissions per energy use.

Figure 8: Index of Economy, Energy, and Emissions Factors in Canada, 1981 – 2017



Source: Statistics Canada (Tables 25-10-0004-01, 25-10-0029-01, 36-10-0222-01, 17-01-0005-01), ECCC – National Inventory Report 1990-2017, NEB Calculations
Note: GHG emissions figures for Canada are only available starting in 1990.

A structural shift in the Canadian economy, and improvements in energy efficiency, are responsible for this decline in Canada's energy and emission intensity.[26] The structural shift was the result of significant economic growth from Canada's commercial and institutional sector. While Canada also experienced significant economic growth from more energy-intensive industries, particularly the oil sands, the growth in contribution to GDP was considerably more from the less energy-intensive commercial and institutional sector relative to the industrial sector.[27] Energy efficiency[28] effects were largest in the residential and passenger transportation sectors.

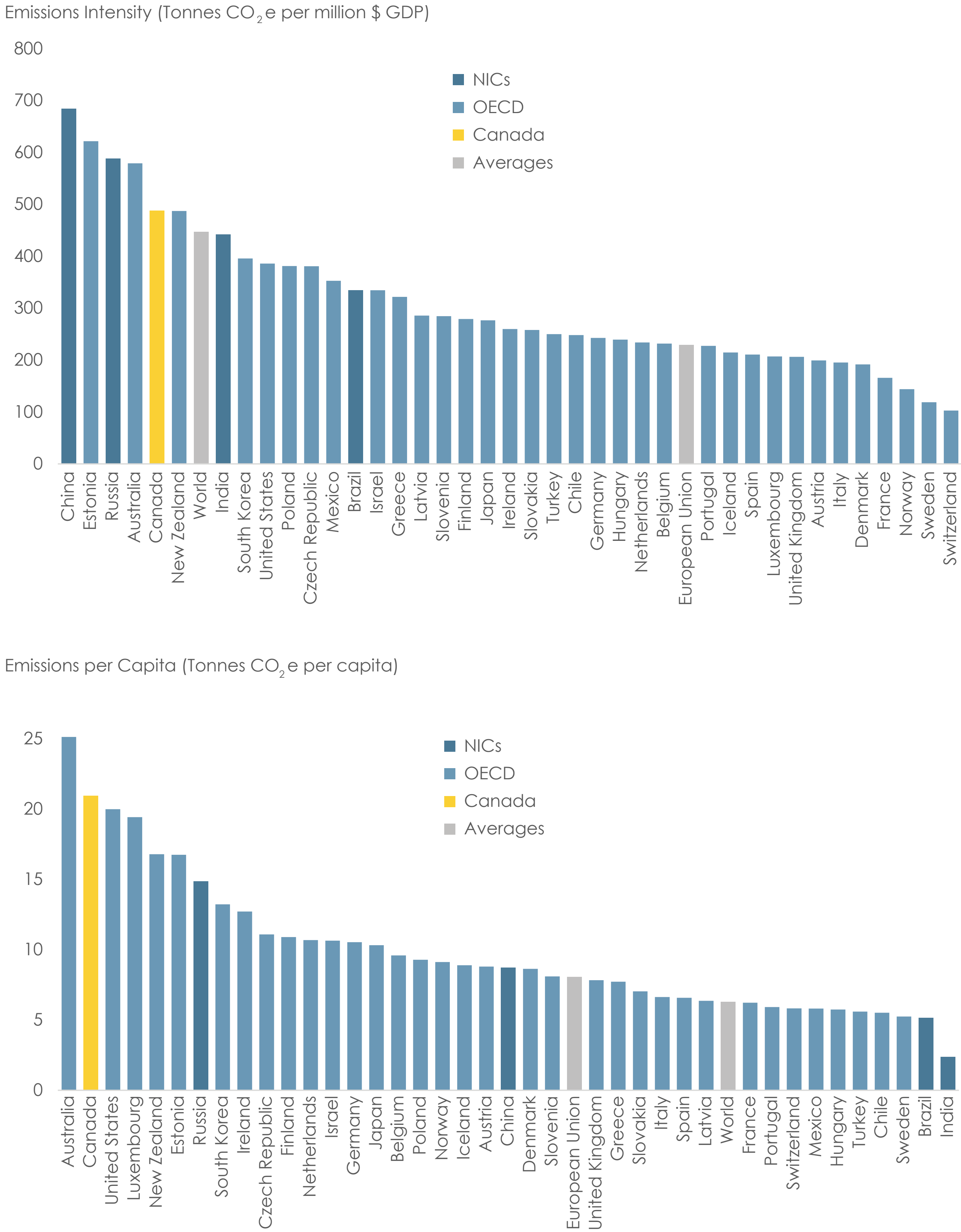
Though Canada's energy and emission intensities have declined over the years, Canada remains one of the most emission intensive nations in the world. This is evident when emissions are compared against GDP or population, as illustrated in Figure 9. However, as Canada continues to use fuel and electricity more efficiently, and as lower-intensity industries grow, the trend of declining energy and emission intensities is expected to continue.

26 Analysis from the Office of Energy Efficiency at Natural Resources Canada illustrate the breakdown of energy efficiency effects and structural effects on changes in energy use between 1990 and 2015. Additional analysis by CESAR suggests that structural changes to the Canadian economy over this period were the major contributor.

27 Energy and emissions intensity data for major industry groups can be found through the Canadian Energy and Emissions Data Centre at Simon Fraser University.

28 The IEA defines energy efficiency as "a way of managing and restraining the growth in energy consumption". A system is said to be energy efficient if one receives the same level of output with less energy input.

Figure 9: GHG Emissions by Country: Intensity and Per Capita, 2015



Source: CAIT Climate Data Explorer

5. Trends in Canada's Energy Transition

Canada's energy transition is occurring in many different areas of the economy and is influenced by various technologies, policies, and market trends. This chapter will discuss three fundamental components of the transition with respect to how Canadians produce and consume energy:[29]

- The decarbonization of electricity – phasing out carbon-emitting electricity generation and increasing non-emitting sources, such as renewables, biofuels, nuclear, and carbon capture and storage.
- Electrification, fuel-switching, and improving the transportation sector – switching carbon-intensive end uses to less intensive or non-emitting fuels, especially in the transportation sector.
- Improving energy efficiency and behavioural changes – improvements to how and when we use energy, and shifting to less energy-intensive activities.

The Decarbonization of Electricity

Canada's electricity generating sector greatly benefits from geography. For a country of its size and population, nearly 80% of generation can be considered non-emitting. Hydroelectricity forms the backbone of the electricity sectors in many provinces and regions, including Yukon, British Columbia (B.C.), Manitoba, Quebec, and Newfoundland and Labrador. In Ontario, nuclear and hydroelectricity dominate.

The OECD average generation intensity was 448 grams of CO_2 per kilowatt hour (kW.h) in 2012. By comparison, Canada's average generation intensity was 160 grams of CO_2 per kW.h.[30] However, Canada's relatively low national average blurs many of the details of provincial-level generation intensity.

29 Non-energy components of decarbonization include altering land-use through the reduction of deforestation and the growth of natural carbon sinks.

30 Bataille, C. et al. (2015). "Pathways to Deep Decarbonization in Canada". Published by: Sustainable Development Solutions Network and Institute for Sustainable Development and International Relations.

Several provinces, including Alberta, Saskatchewan, Nova Scotia, and New Brunswick, generate a significant amount of their electricity from the combustion of fossil fuels.[31] In 2017, these four provinces together generated 93% of Canada's GHG emissions from electricity while generating only 20% of Canada's electricity. Figure 10 illustrates the large variability in generation intensity between provinces and territories. In 2017, Quebec averaged 1.3 grams of CO_2 per kW.h while Alberta averaged 750 grams of CO_2 per kW.h.

Figure 10 also illustrates that between 1990 and 2017, nearly all jurisdictions in Canada have increased their electricity generation. However, nearly all jurisdictions have managed to lower their generation intensity at the same time. This trend is expected to continue as emissions from coal are either phased out or captured through carbon capture and storage (CCS), and renewable energy growth continues.

THE CHALLENGE OF RENEWABLES

Is it possible for an electricity sector to be 100% renewable based? It is a frequently raised issue.

While some regions and nations, such as Yukon, B.C., Quebec, Costa Rica, and Iceland have virtually all of their power coming from renewables, that power is primarily from reservoir hydroelectricity—a consequence of climate and geography. Reservoir hydro is reliable, storable, and incredibly efficient at converting stored energy into electricity.

By contrast, new renewables, such as power from solar and wind, are not as easily (or economically) stored and are not as reliable. Wind speeds often do not match demand periods, and solar only generates when the sun is shining. Run-of-the-river hydro (common in the Northwest Territories) also has limited storage capabilities, and outputs cannot be scaled to meet demand.

A diverse energy supply mix with traditional thermal generation for back-up, battery storage, a modern grid, and grid connections to other regions can mitigate or eliminate many of the challenges associated with new renewables.

WHAT IS CARBON CAPTURE AND STORAGE?

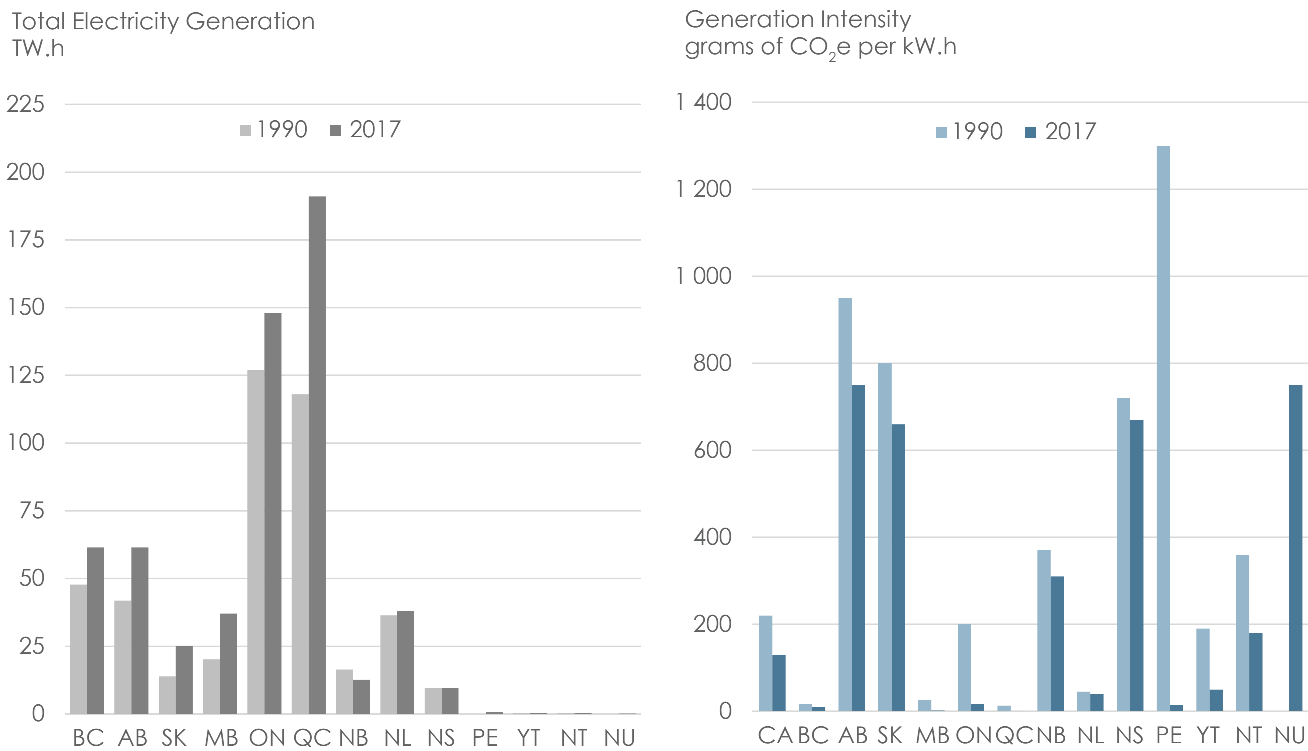
The OECD notes that Canada has become a world leader in CCS technology. CCS is a method of capturing CO_2 emissions from a large emitting power plant or industrial facility and injecting a pure stream of it into an underground reservoir at high pressure. These underground reservoirs can be a depleted oil or gas field, or a salt cavern. In some instances, the injected CO_2 may aid in the recovery of crude oil (known as enhanced oil recovery).

CCS technology has been used in Canada since 2014 with the development of SaskPower's Boundary Dam coal-fired project in Estevan, Saskatchewan. Since Boundary Dam, CCS has been used in Alberta with Shell's Quest project, which captures CO_2 from oil sands upgrading processes. Lastly, the Alberta Carbon Trunk Line (ACTL) is expected to begin operation in late 2019. ACTL will pipe and store CO_2 from the newly constructed Sturgeon Refinery and the Nutrien fertilizer plant, both located near Redwater, Alberta.

The combined capacity of major CCS projects in Canada has the potential to reduce Canada's CO_2 emissions by 6.4 million tonnes per year, representing 3% of the reduction needed to meet Canada's 2030 target.

31 The Northwest Territories is highly reliant on diesel for its electricity generation, while Nunavut is essentially 100% reliant on diesel. However, electricity generation in these two territories contributed just 0.2 MT of CO_2e to Canada's emissions in 2017.

Figure 10: Total Electricity Generation and Generation Intensity by Province, 1990 vs. 2017



Source: ECCC – National Inventory Report 1990-2017

Notes: Nunavut separated from Northwest Territories (NWT) in 1999, therefore no separate data for Nunavut exists prior to that date. Data from NWT in 1990 includes Nunavut. Prince Edward Island's generation data from 1990 includes diesel-fired generation that results in a very high generation intensity figure. By 2017, 25% of PEI's electricity needs were met by local (primarily wind-based) production. The remaining 75% was imported from New Brunswick, which generates primarily from a mix of nuclear, coal, hydro, and natural gas.

Though coal and natural gas still dominate Alberta and Saskatchewan's electricity mix, both provinces have been steering away from coal and towards natural gas for new thermal generation. Both provinces have also increased non-hydro renewable generation too. Alberta's total generation from wind increased from 1.1% in 2005 to 5.4% in 2017. Alberta has the third-highest wind generation in Canada after Quebec and Ontario. Wind power has also grown in Saskatchewan, from 0.5% of total generation in 2005 to 3.8% in 2017. Additionally, southern Saskatchewan and southern Alberta have some of the highest photovoltaic (PV) potential in Canada. Saskatchewan has committed to 60 MW of solar power by 2021.[32] Alberta has 17 MW of utility-scale solar PV installed, with over 500 MW proposed for completion by 2020. With the cost of solar PV modules continuing to decline, there could be a strong future ahead for solar as a resource in Saskatchewan and Alberta.[33]

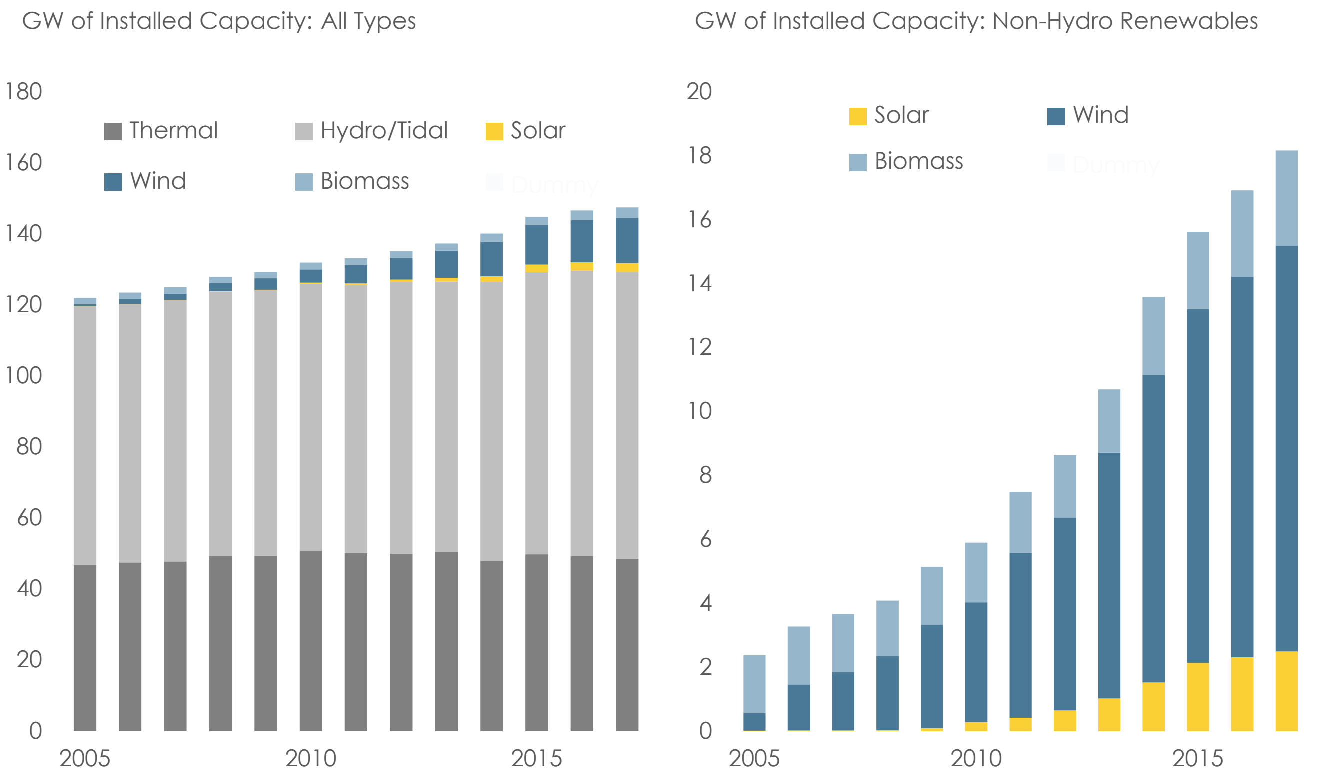
The growth of non-hydro renewables for Canada as a whole over the past decade has been notable, as shown in Figure 11.[34] Between 2005 and 2017, roughly 16 gigawatts (GW) of non-hydro renewable capacity has been added to Canada's electricity mix. The key drivers behind this have been a combination of policy changes and market forces (for example, declining costs).

32 Saskatchewan's first utility-scale solar project, a 10 MW facility just east of Swift Current, is expected to start in early 2019.

33 For more information, the NEB's "The Economics of Solar Power in Canada" (2018) report illustrates the financial viability of solar power projects in over 20 000 Canadian communities.

34 For more information, the NEB has produced a series of reports on renewable generation in Canada.

Figure 11: Installed Electricity Capacity in Canada, 2005 – 2017



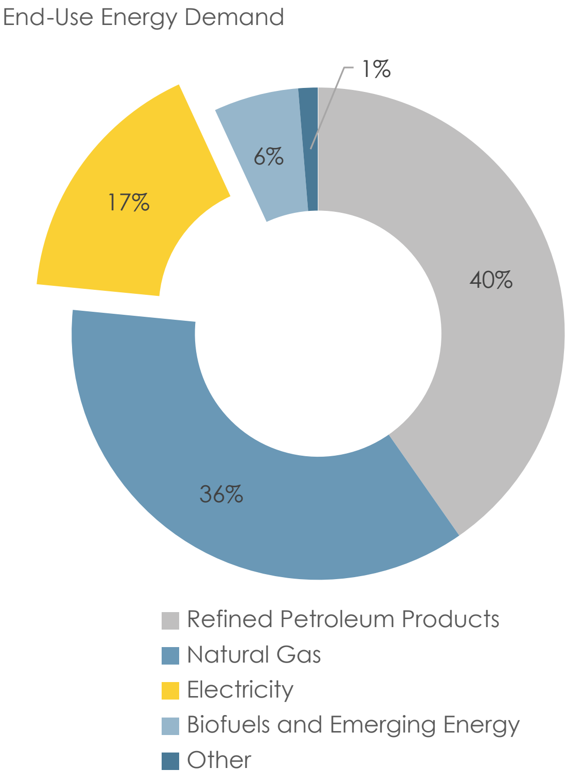
Source: [NEB – Canada's Energy Future 2018]
Note: Thermal includes nuclear, coal and coke, and natural gas.

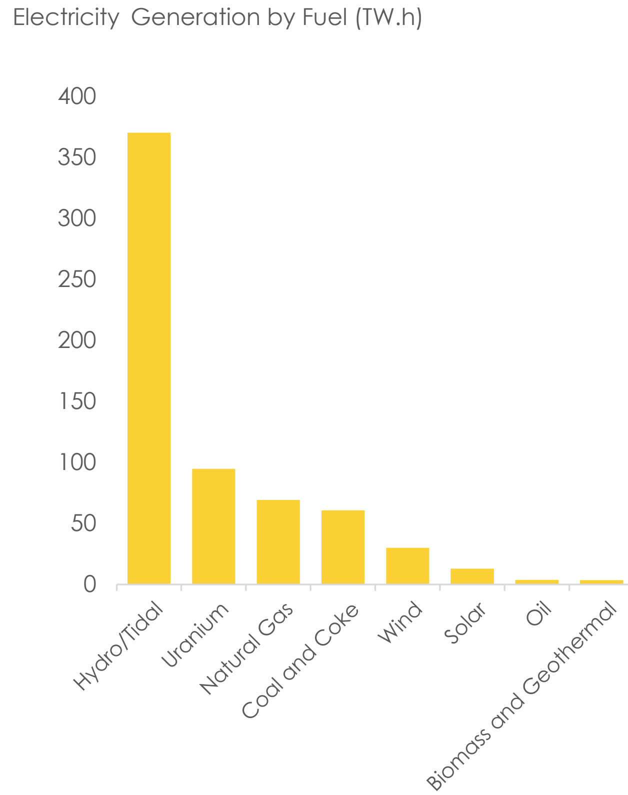
Switching of End Uses and Improving the Transportation Sector

In addition to growth of non-emitting electricity generation, the transition to a low-carbon future will require fuel switching from carbon-based fuels to electricity to take advantage of Canada's low carbon-intensity generation.

Electricity currently provides 17% of Canada's end-use energy needs, as shown in Figure 12. Hydrocarbons—natural gas and products that have been refined from crude oil—provide the majority of the remaining 83%. These hydrocarbons are used primarily in the transportation sector (as fuel), in the industrial sector (for heating and as a feedstock), and the residential and commercial sectors (for space and water heating).

Figure 12: Canadian End-Use Energy Demand and Electricity Generation by Fuel, 2017





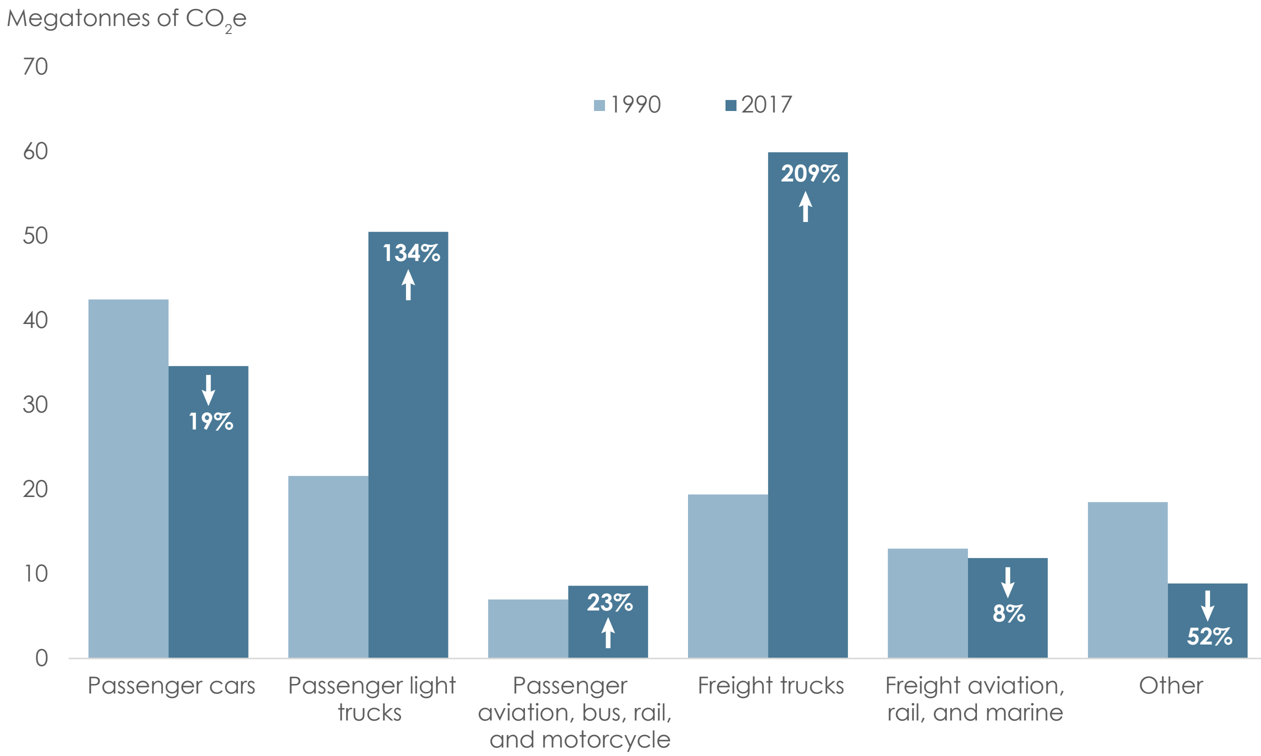
Source: NEB – Canada's Energy Future 2018
Note: Other includes coal, coke, and coke oven gas.

The transportation sector in Canada is the second largest for emissions after the oil and gas sector, and accounted for roughly one-quarter (or 174.4 MT of CO_2e) of Canada's total emissions in 2017. Nearly the entire transportation sector runs on refined petroleum products: gasoline, diesel, jet fuel, and bunker fuel (for ships). These two points suggest that transportation has the most potential for emissions reductions through improved fuel and efficiency standards, the integration of sustainable biofuels, and electrification.

The sector can be divided primarily into two categories: the movement of freight and the movement of people. As shown in Figure 13, the largest growth in emissions from the transportation sector has been from the movement of freight (trucks, aviation, rail, and marine), which has increased 121% between 1990 and 2017. Most notably, emissions from freight trucks have increased 209%, the largest increase in any of the transportation subcategories. Population and GDP growth, as well as stronger international and interprovincial trade and customers' demands to receive goods quickly, have been the primary drivers of the growth in demand for freight movement. Trends including just-in-time delivery (small, rapid deliveries) and an increase in "empty kilometres" on backhaul trips have also contributed to the demand growth, and consequently, emissions growth.[35]

35 Plumptre, B., Angen, E., and Zimmerman, D. (2017, June). "State of Freight: Understanding greenhouse gas emissions from goods movement in Canada". Retrieved from: The Pembina Institute.

Figure 13: Growth of Transportation Sector GHG Emissions, 1990 and 2017



Source: ECCC – National Inventory Report 1990-2017

Between 1990 and 2017, emissions from passenger cars and light trucks combined have increased 33%. Total emissions from passenger cars alone have declined 19% as shown in Figure 13, partially because of improved fuel efficiency standards, but primarily because of the declining popularity of cars relative to light trucks and sport utility vehicles. Total emissions from passenger light trucks (including sport utility vehicles, vans, and light-duty trucks) have increased 138%. Between 1990 and 2016, the number of light trucks on the road have increased from four million to over 11 million.

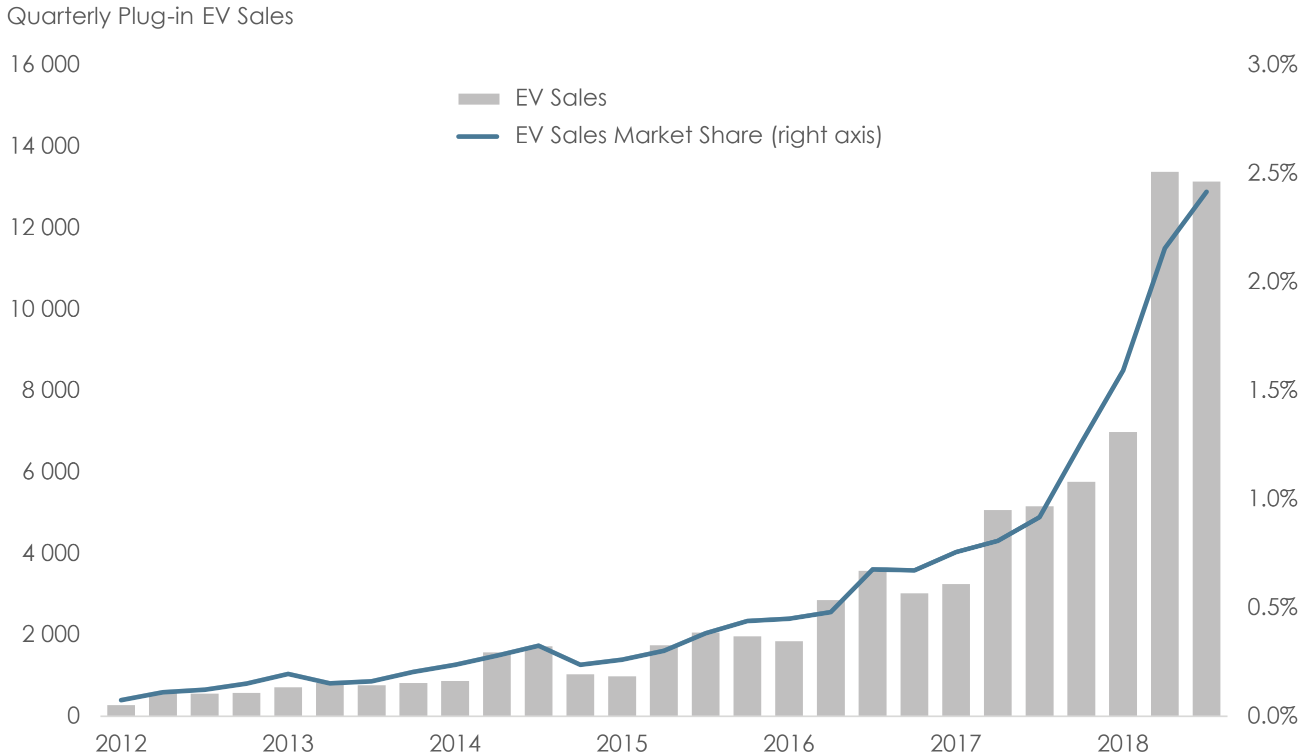
Reducing emissions from passenger and freight transportation would have a significant positive effect towards Canada's climate change commitments. One area where Canada is starting to see significant change is with respect to vehicle electrification. As shown in Figure 14, electric vehicle (EV)[36] sales in Canada have displayed strong momentum in recent years.

The Pan-Canadian Framework includes standards for EV sales and deployment in Canada. Federal, provincial, and territorial governments continue to work collaboratively amongst themselves, and with industry and other stakeholders, to develop a Canada-wide zero-emission vehicle (ZEV) strategy. Collectively, they have made strides towards accelerating the adoption of ZEVs and alternative fuel vehicles. The EVs will still need to compete with traditional internal combustion engines with respect to price and range. Automakers will also need to adjust production of EVs to account for a growing preference from consumers for light trucks and SUVs. Lastly, EVs will require power from a low carbon-intensive electricity grid to achieve a noticeable reduction in GHG emissions.[37]

36 Plug-in electric vehicles include battery electric and plug-in hybrid electric vehicles (PHEVs). Battery EVs have no internal combustion engine, while PHEVs have batteries that can be plugged in to external power for charging. Sales in Canada are roughly evenly split between all battery EVs and PHEVs.

37 NEB (2018, September 12). "Market Snapshot: How much CO_2 do electric vehicles, hybrids and gasoline vehicles emit?"

Figure 14: Growth of Electric Vehicles in Canada, 2012 - 2018



Source: Statistics Canada (Table 20-10-0001-01), Fleet Carma, Canada EV Sales Data (Matthew Klippenstein), NEB calculations

Policy changes and programs, such as governments developing public transit networks and mandating fuel economy standards, can also result in emissions reductions. Individuals can also take measures to reduce their energy consumption and emissions. This can be accomplished by taking alternative forms of transportation, purchasing a more fuel-efficient vehicle,[38] changing driving techniques, choosing not to drive during hours of peak traffic congestion, and driving less.

The Pan-Canadian Framework focuses primarily on the electrification of personal vehicles. However, the Framework also introduces new regulations with respect to heavy-duty vehicles (HDVs), including freight transport and buses. In 2018, the Government of Canada published final amended regulations designed to reduce GHG emissions in Canada from new on-road HDVs. The Government of Canada also created a federal-provincial-territorial working group on HDV retrofits to support the Pan-Canadian Framework commitment to develop new requirements for heavy-duty trucks to install fuel-saving devices.[39] Starting in 2020, emission reduction regulations will become increasingly stringent for HDVs in Canada. The Government of Canada expects that the new standards will reduce annual emissions from HDVs by 6 MT of CO_2e by 2030.

38 Fuel economy standards for model year 1995 to 2018 vehicles are available from Natural Resources Canada.

39 ECCC (2018). "Pan-Canadian Framework on Clean Growth and Climate Change: Annual Synthesis Report on the Status of Implementation".

Increasing Energy Efficiency

Energy efficiency plays a key role in Canada's energy transition and is a component of the Pan-Canadian Framework. The Generation Energy Council report highlighted that wasting less energy is a fundamental pathway for Canada to pursue a low-carbon future. The report notes that "[f]ully one-third of our Paris emissions commitment could be achieved by improving energy efficiency…".[40]

The IEA reported that through energy efficiency, Canada has the potential to keep primary and end-use energy demand on a steady decline for decades, even with growing economic activity.[41] The Conference Board of Canada reported that increasing energy efficiency in Canada could reduce energy demand by as much as 15% by 2035 from 2017 levels.[42]

Industrial Sector

Canada's largest and most energy-intensive sector is the industrial sector. Industry accounted for 28% of Canada's GDP and 52% of Canada's energy demand in 2016. The sector is also emission-intensive, accounting for 39% of Canada's GHG emissions in 2016.

Energy demand from the industrial sector increased by 26% between 1990 and 2016. The industrial sector has undergone substantial structural changes during that time with some industries declining in relative importance (primarily pulp and paper, and manufacturing), and other industries (primarily energy) growing in relative importance. Figure 15 compares the share of energy use and the share of GHG emissions from aggregated industries in Canada. The figure also shows how these shares changed between 1990 and 2016.

ENERGY EFFICIENCY AS A RESOURCE?

When electricity demand exceeds supply, either supply can be increased or demand can be reduced to bring balance. Meeting short-term demand spikes with new supply often involves generating electricity through older and less efficient power units. Meeting long-term demand growth often involves upgrading, refurbishing, or building new generation facilities.

Alternatively, investments can be made in energy efficiency and conservation efforts to reduce demand during peaks, and over the long term.

Studies have found that investments in energy efficiency programs are among the lowest cost solutions for meeting future energy needs.

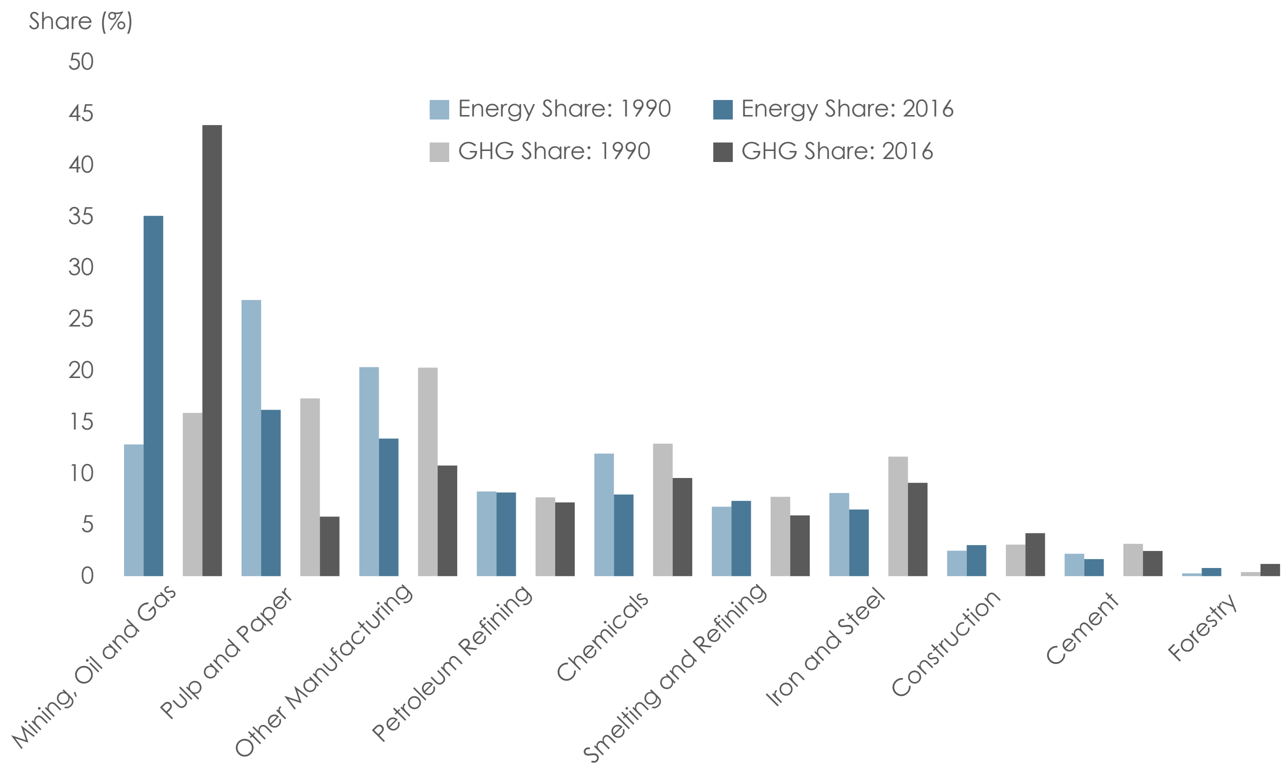
A measure for energy efficiency is the "negawatt"; a theoretical unit of power that measures electrical consumption that has been avoided or saved.

40 Generation Energy Council (2018). "Canada's Energy Transition: Getting to Our Energy Future, Together". Retrieved from: Natural Resources Canada.

41 IEA (2018). "Energy Efficiency Potential in Canada".

42 Robins, A. (2017). "Doing More with Less: Energy Efficiency Potential in Canada". Retrieved from: The Conference Board of Canada.

Figure 15: Share of Energy Use and GHG Emissions from Industry, 1990 and 2016



Source: Natural Resources Canada (NRCan) – National Energy Use Database

The largest energy consuming and GHG emitting subsector in Canada is mining (including upstream oil and gas). In 2016, the mining subsector accounted for 35% of energy consumed and 44% of the GHGs emitted in the industrial sector. Energy use and emissions from this subsector increased substantially since 1990, when mining's energy use share was 13% and GHG emission's share was 16%.

Canada's growth in upstream oil and gas since 1990 has largely been from in situ oil sands production. The extraction of bitumen from in situ oil sands deposits is made possible with steam, and the two most common processes are known as steam-assisted gravity drainage (SAGD) and cyclic steam stimulation (CSS). Both SAGD and CSS use natural gas for the production of steam and the process is energy and emissions intensive.[43]

A key metric for calculating the energy intensity and efficiency of oil sands operations is from its steam-to-oil ratio (SOR). The SOR is the ratio of the volume of steam required to produce one unit of oil. Oil sands innovations have helped improve SOR numbers in recent years, and SOR numbers are expected to continue declining into the future. Reducing GHG emissions remains an area of focus for the oil sands, and producing cleaner oil and gas is a key pathway for transition, as established by the Generation Energy Council report. As new technologies like solvent injections[44] instead of steam-driven bitumen extraction are being explored, additional energy efficiency and emissions efficiency gains are expected.

43 The well-to-combustion emissions from crude oil from the Canadian oil sands are higher than most other streams of crude oil. ARC Energy Institute estimates that Canadian oil sands have well-to-combustion GHG emissions 9% to 24% higher than the average barrel of crude oil refined in the U.S. While production and upgrading emissions from the oil sands are higher than conventional crude oil, it is important to note that the majority (approximately 80%) of well-to-combustion emissions result from the final combustion of refined petroleum products.

44 Solvents are generally natural gas liquids: propane, butane, and pentanes plus. Solvents thin the bitumen and can either reduce or eliminate the amount of steam required to produce a barrel of bitumen.

Energy intensity and emissions intensity do not necessarily need to go hand-in-hand. For example, the smelting process of turning bauxite into aluminium is highly electricity-intensive.[45,46] Consequently, smelters tend to be located near inexpensive electricity sources. It follows then, that nine of Canada's aluminium smelters are located in Quebec and one in B.C. where abundant and low-cost hydroelectricity allows the smelting industry to lower its costs and emissions.

Between 1990 and 2015, Canada's aluminium production increased 123%. Over the same period, absolute carbon emissions declined 38%, and carbon intensity (as measured by tonnes of CO_2e per tonne of aluminium) declined 66%.[47] These efforts made to reduce emissions have resulted in Canada's aluminium smelting sector having the lowest carbon footprint in the world.[48] Furthermore, new processes being advanced in Canada could eliminate all carbon emissions from smelters.

In addition to improving energy efficiency and emissions reductions in industry, the Pan-Canadian Framework includes commitments to reducing emissions of methane from the oil and gas sector by 40 to 45% below 2012 levels by 2025.[49] Methane has a global warming potential 25 times that of CO_2 that can unintentionally be released into the atmosphere from oil and gas well leaks, or by venting.

Residential and Commercial Sectors

Canada's residential sector accounted for 14% of our energy use in 2016, while the commercial and institutional sector accounted for 12% of our energy use.

In the average Canadian household, the largest uses of energy are for space heating (62.4% of total end-use demand) and water heating (18.7% of total end-use demand). Energy use for appliances, lighting, and space cooling account for the remaining 18.9%.[50]

As Figure 16 illustrates, just over half of Canadian households heat with natural gas or heating oil. The remaining households heat with electric, dual systems, or other (heat pumps, wood, coal, and propane). Dual systems include wood and oil, oil and electric, and gas and electric.

Of those households that heat with natural gas, high efficiency furnaces account for 62% while mid-efficiency furnaces account for 37%, and normal efficiency furnaces the remaining 1%. In 1990, normal efficiency gas furnaces accounted for the vast majority in operation at 89%.[51] Similarly for heating oil, normal efficiency furnaces accounted for 98% share in 1990. By 2016, the share held by normal efficiency furnaces had declined to 1% as mid- and high efficiency furnaces took hold.

45 In North America, the average smelter requires 14.7 MW.h per tonne of aluminium.

46 The energy intensity of aluminium production from bauxite results in the metal being one of the most valuable components of the recycling stream. The secondary production of aluminium from recycled aluminium requires 90% less energy than production from bauxite.

47 Aluminium Association of Canada (2017, 28 March). "Position of the Aluminium Association of Canada as Part of Canada's Transition to a Low-Carbon Economy".

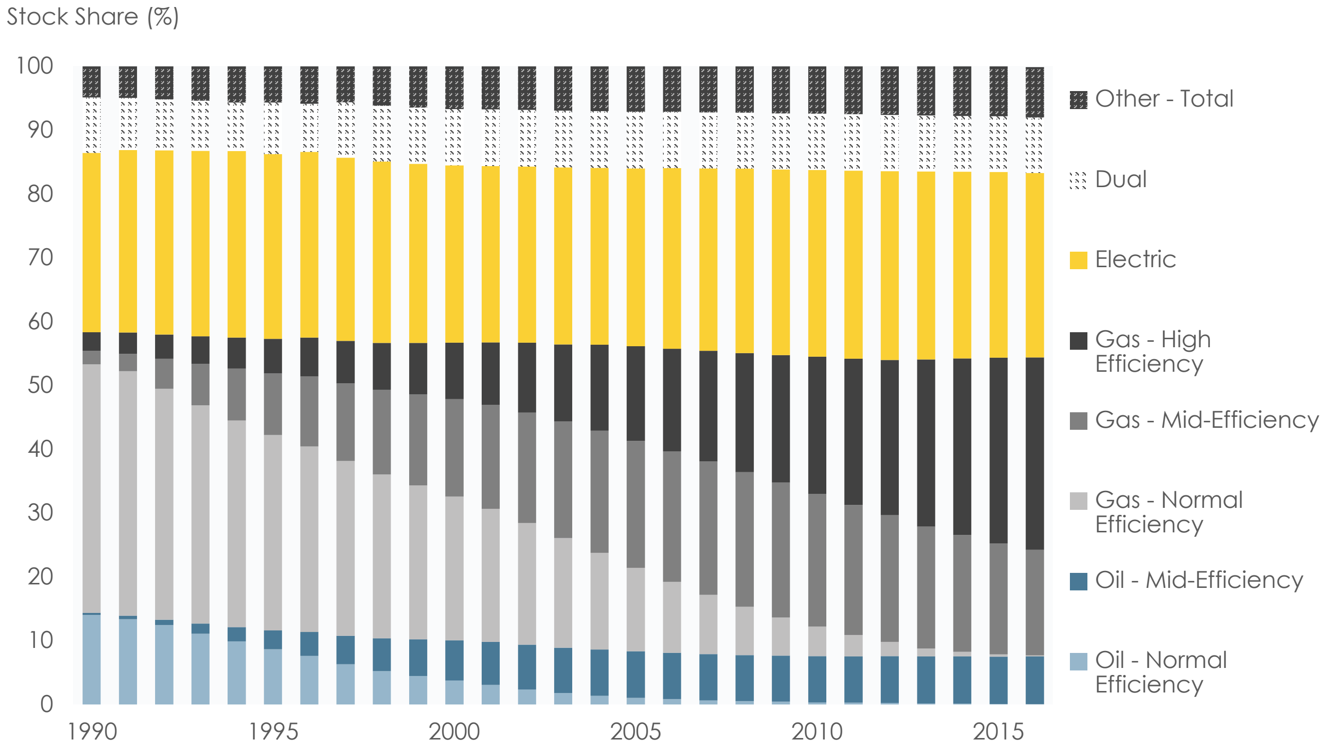
48 NRCan (2018). "Aluminium Facts".

49 ECCC (2018). "Pan-Canadian Framework on Clean Growth and Climate Change: Annual Synthesis Report on the Status of Implementation". (pp. 15-16).

50 NRCan. "Comprehensive Energy Use Database". Residential Sector Table 2.

51 High-efficiency gas furnaces convert over 90% of the energy content of natural gas to heat, with some newer models achieving 97% efficiency. Mid-efficiency gas furnaces convert between 80% and 90% of the energy content of natural gas to heat, while normal efficiency furnaces (common in the 1970s), converted around 65%.

Figure 16: Residential Space Heating System Stock Share, 1990 - 2016



Source: NRCan – National Energy Use Database: Residential Space Heating System Stock Share

Note: Other – Total includes heat pump (5% of total stock share in 2016), wood (1.9%), and coal/propane (1.0%). Dual systems include wood/electric (4.7% of total stock share in 2016), wood/oil (2.2%), oil/electric (1.3%), and gas/electric (0.5%).

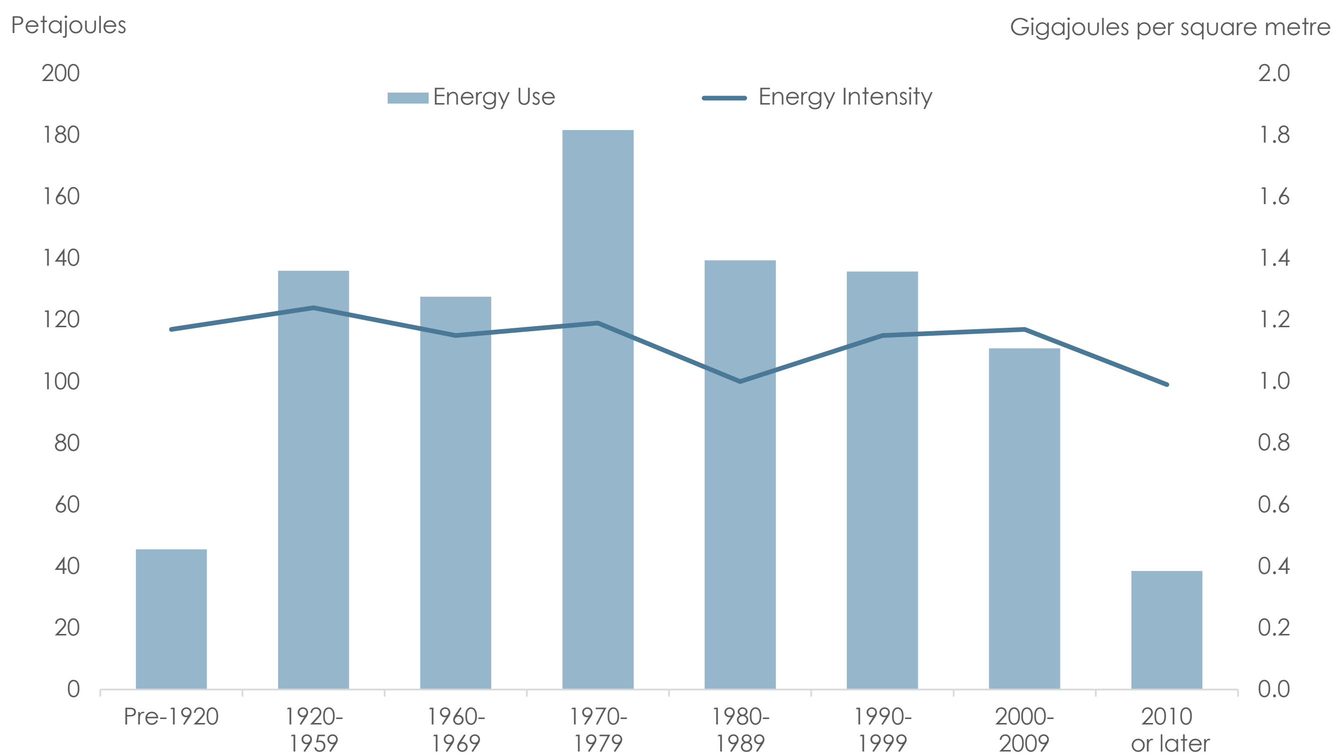
Recent developments in lighting provide another notable example of improved energy efficiency. Compact fluorescent lights (CFL) and light-emitting diode (LED) lights consume 80% to 85% less energy per lumen emitted when compared against a traditional incandescent bulb. Modern front-loading clothes washers consume up to 80% less electricity versus older, large capacity, top-loading washers. Developments in windows and insulation are increasing the energy efficiency of newer homes, and of older homes through retrofit projects. These advancements in consumer appliances have been fundamental in reducing household energy use, and in saving consumers money.

NRCan's Office of Energy Efficiency estimates that between 1990 and 2015, the energy efficiency effect in the residential sector has reduced energy consumption by 656 PJ—a substantial reduction for a sector that consumed 1 544 petajoules (PJ) in 2015. By comparison, the energy efficiency effect in the commercial/institutional sector resulted in a reduction of 169 PJ between 1990 and 2015. In 2015, the commercial/institutional sector consumed 1 009 PJ.

The diverse commercial/institutional sector consists of the offices, retail spaces, warehouses, and institutional buildings[52] that play a fundamental role in our society and economy. Similar to residential buildings, the majority of energy consumed in the commercial sector in Canada is for space heating (54.7%). The running of auxiliary equipment accounts for 14.4% of the energy consumed by the sector, followed by lighting at 11.1%, and water heating at 7.8%. Energy use in the commercial sector increased 35% between 1990 and 2015.

The fragmented and diverse nature of the commercial/institutional sector results in barriers that limit the adoption of energy efficiency technologies.[53] Figure 17 illustrates the slow decline in energy intensity (as measured in gigajoules (GJ) per square metre of floor space) for commercial buildings constructed in Canada. The energy intensity of commercial buildings, measured in units of energy consumed per square metre of floor space, is highest for buildings constructed between 1920 and 1959. Commercial buildings constructed after 1960 show small reductions in energy intensity.

Figure 17: Commercial Building Energy Use and Intensity by Age of Construction, 2014



Source: NRCan – National Energy Use Database: Survey of Commercial and Institutional Energy Use

Advancements in building standards and certifications such as the LEED certification process[54] have contributed towards a reduction in the energy intensity of commercial buildings. Buildings constructed after 2009 are 15% less energy intensive, on average, than buildings constructed between 2000 and 2009.

52 For example, hospitals, schools, and public administration buildings.

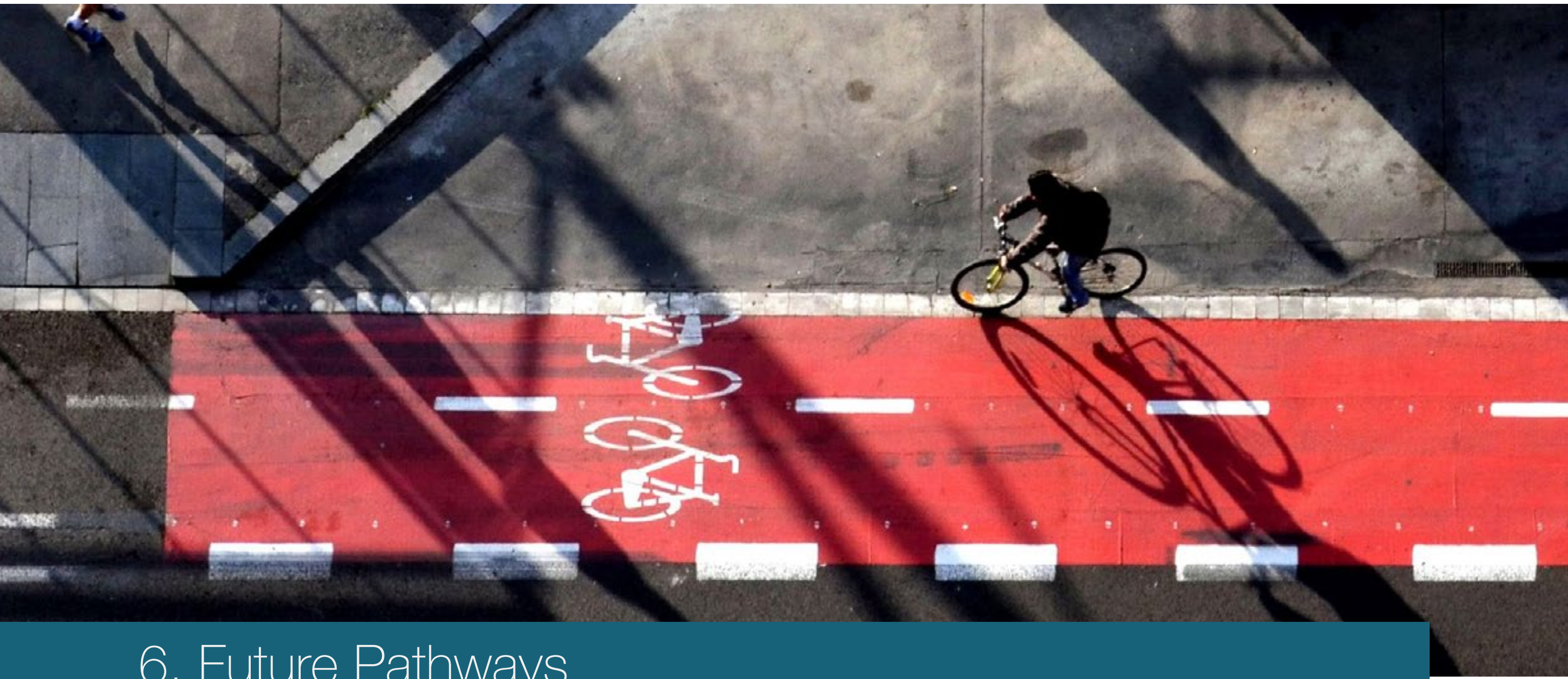
53 National Round Table on the Environment and the Economy and Sustainable Development Technology Canada (2009). "Geared for Change: Energy Efficiency in Canada's Commercial Building Sector".

54 LEED, or Leadership in Energy and Environmental Design, is an internationally recognized rating system assigned to buildings. The rating systems are based on the design, construction, operation and maintenance of commercial buildings, homes, and neighbourhoods.

Canada's Buildings Strategy is a component of the Pan-Canadian Framework that commits federal, provincial, and territorial governments to develop and adopt building codes with increasing levels of energy efficiency. Canada's Building Strategy includes pathways for improving the efficiency of new buildings, modelling Net-Zero Energy Ready homes and commercial buildings,[55] retrofitting existing buildings, collecting and sharing energy-use data, and improving the energy efficiency of appliances, equipment, and windows. Starting in 2020, governments in Canada will develop and adopt more stringent building codes with the ultimate goal of a Net-Zero Energy Ready building code for the provinces and territories starting by 2030.

ECCC estimates that the adoption of the pathways in Canada's Building Strategy by all provinces and territories could amount to a potential emissions reduction of 21.6 MT of CO_2e per year—an 11% contribution towards Canada's 2030 commitment to the Paris Agreement.

55 Net-Zero Energy Ready (NZER) homes and commercial buildings use energy efficiency design to ensure a building consumes less or equal to the amount of energy that it produces from on-site renewable energy on an annual basis. Between 2013 and 2016, 23 NZER pilot project homes were constructed in three provinces and later sold. The first commercial NZER building in Canada was a library in Varennes, Quebec that was constructed in 2014.



6. Future Pathways

It is challenging to predict exactly how the energy transition will unfold in Canada. Canada's transitioning energy system may involve familiar methods of energy used in new ways. For example, using fossil fuels in more efficient ways, and developing more renewable sources of electricity for powering end-uses. The transition may also involve entirely new energy systems, such as advanced biofuels and electrolysis for hydrogen production. The pace of the transition will also place pressure on governments to develop regulations for new technologies as they emerge.

This section explores the current energy transition in a few ways. First, it looks at how past developments have influenced future expectations. This underscores that change from current perspectives should be expected. Second, it looks at what a low-carbon energy transition might mean for Canada's current energy systems. Finally, this section explores possible future energy systems.

Changing Projections and New Perspectives

Chapter 5 described examples of the energy transition in Canada using historical data. Another way that current transitions can be measured is through how they have influenced future expectations. Over the last decade, many policy and technology trends have altered outlooks for energy supply and demand in Canada and beyond.

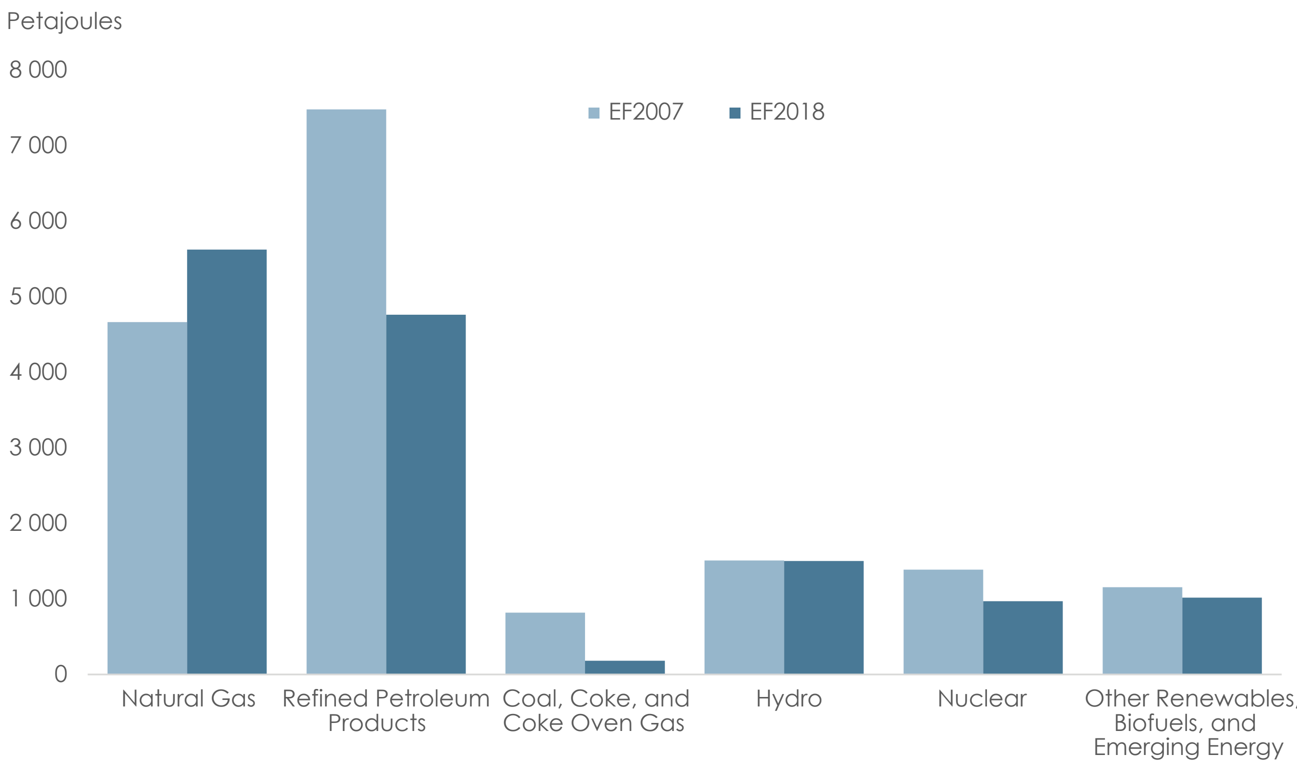
Several notable developments include:

- Coal phase-outs in power generation and falling natural gas prices reduced the expected role of coal.
- The emergence of fracking changed the outlook for oil and gas supply from scarcity to abundance.
- The combination of crude oil supply growth with improved vehicle efficiencies changed the discussion from peak oil supply to peak oil demand.
- Rapidly falling cost of renewables now allows them to compete on an energy basis with natural gas.

These changes have had significant implications for future perspectives on energy. Baseline energy supply and demand scenarios from BP and the IEA are projecting oil and coal demand either slowing considerably or peaking before 2040. Wind and solar PV, previously considered fringe energy sources or too expensive to compete with more traditional sources of energy, are now cost competitive with natural gas-fired generation.[56]

The outlook for energy demand in Canada has changed considerably over the past decade too. The NEB's Canada's Energy Future (EF) report examines supply and demand fundamentals for Canadian energy under various scenarios. Figure 18 illustrates baseline ("Reference Case") projections of primary energy demand mix by fuel for 2030 from projections made in 2007 and 2018. These projections trace how expectations of energy demand in Canada have evolved over the past decade. Most notably, the projection for 2030 demand for refined petroleum products has changed from 7 481 PJ in 2007 to 4 764 PJ in 2018.

Figure 18: Primary Energy Demand Projections for 2030: EF2007 vs. EF2018



Source: NEB – Canada's Energy Future (2007 and 2018)

56 NEB (2018). "Canada's Energy Future 2018: Energy Supply and Demand Projections to 2040"; Bloomberg New Energy Finance (2018). "New Energy Outlook 2018"; Roberts, D. (2018, 26 October). "Clean energy is catching up to natural gas". Retrieved from: Vox.

The EF2018 Reference Case projects a very different energy system in Canada in 2030 from the EF2007 Reference Case. In brief, these differences are:

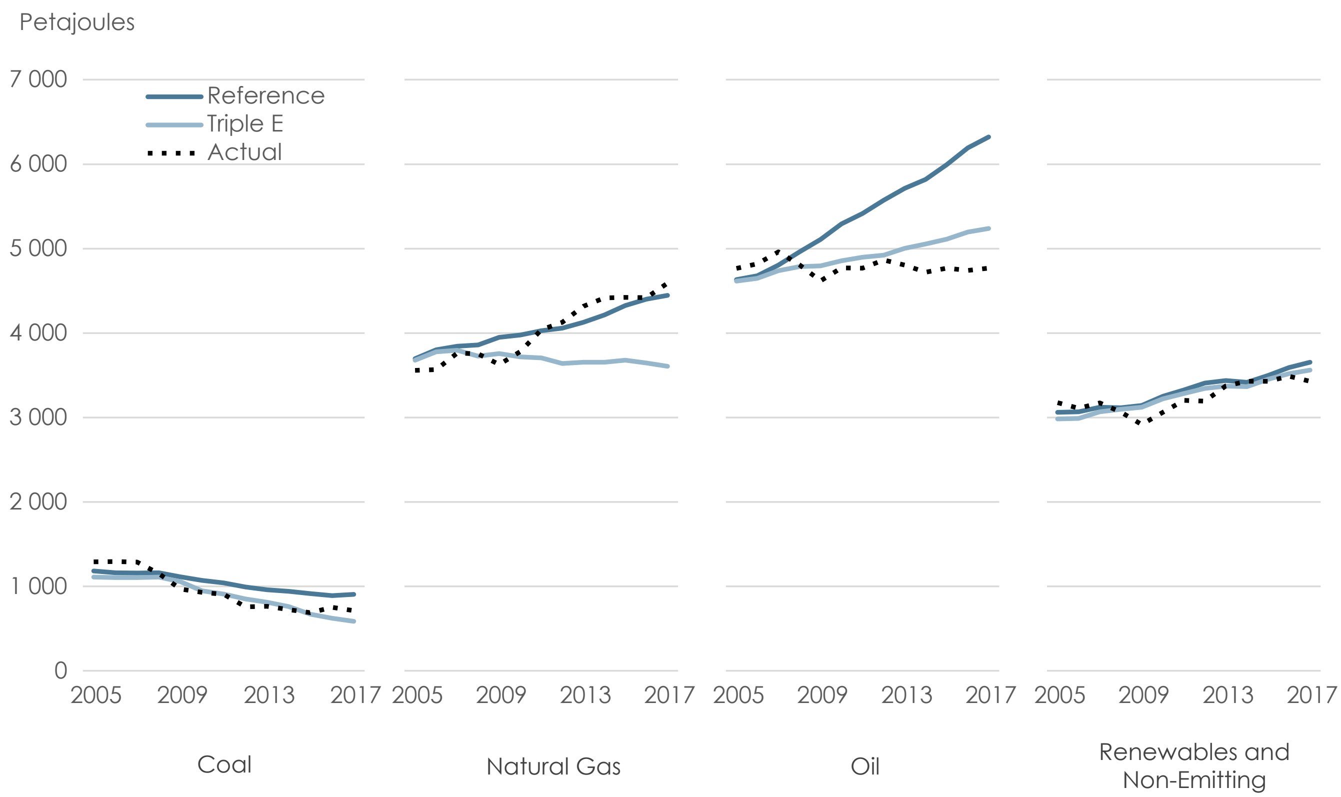
1. **Canadians use less energy**: The projection for 2030 primary energy demand in EF2018 is 17% lower than in EF2007. This is a result of many factors including lower economic growth, policies and programs, energy efficiency regulations, and technological development.
2. **Coal is nearly phased out**: Policy developments and the improved economics of natural gas lead to a large reduction in expected 2030 coal use between the two reports.
3. **Less energy from oil products**: New vehicle fuel emission regulations are expected to improve average vehicle fuel economy. The EF2007 Reference Case did not include any future standards, while the EF2018 Reference Case includes passenger car and light duty standards covering 2012 to 2027 model years, and heavy freight standards covering 2014 to 2028 model years.
4. **More energy from natural gas**: Natural gas prices fell substantially after the 2007 report, driven by technology changes. Growth in Canadian demand is related to use across the economy, with key demand areas being power generation to replace retiring coal units, and demands related to oil sands production growth.
5. **Less energy from nuclear**: Nuclear is somewhat lower, as EF2018 includes Hydro-Quebec's decision to decommission Gentilly Nuclear Generating Station in 2012, and Ontario Power Generation's decision to retire Pickering Nuclear Generating Station by 2024 and only refurbish existing plants.[57]
6. **Less energy from renewables, but more wind and solar**: The EF2018 Reference Case projects over 36 PJ (or 10 TW.h) more wind and solar generation than the EF2007 Reference Case in 2030. However, this growth in wind is somewhat offset by lower expectations of biomass use in the industrial sector. Biomass use fell significantly after several closures in the pulp and paper industry following the 2008 recession.[58]

While Figure 18 compares baseline Reference Case outlooks, it is also interesting to compare actual data against alternative scenarios. EF2007 included a scenario that balanced energy, environment, and economic outcomes (the "Triple E" scenario). This scenario envisioned a policy and technology push in Canada towards a lower carbon energy system. Figure 19 traces primary energy demand by fuel type from 2005 levels to 2017 actuals, and compares them to EF2007 Reference Case and Triple E projections. The graph shows that coal and oil demand followed the Triple E pathway more closely, while natural gas use followed the Reference Case pathway more closely. Renewable and non-emitting is moderately lower than projected, as declines in nuclear and industrial biomass offset growth in solar, wind, and transportation biofuels.

57 For more information on nuclear energy in Canada, please visit the NEB's Nuclear Energy in Canada report.

58 Industrial biomass use fell 22% from 2007 to 2010.

Figure 19: Primary Energy Demand: EF2007 Cases vs. Historical, 2005 – 2017



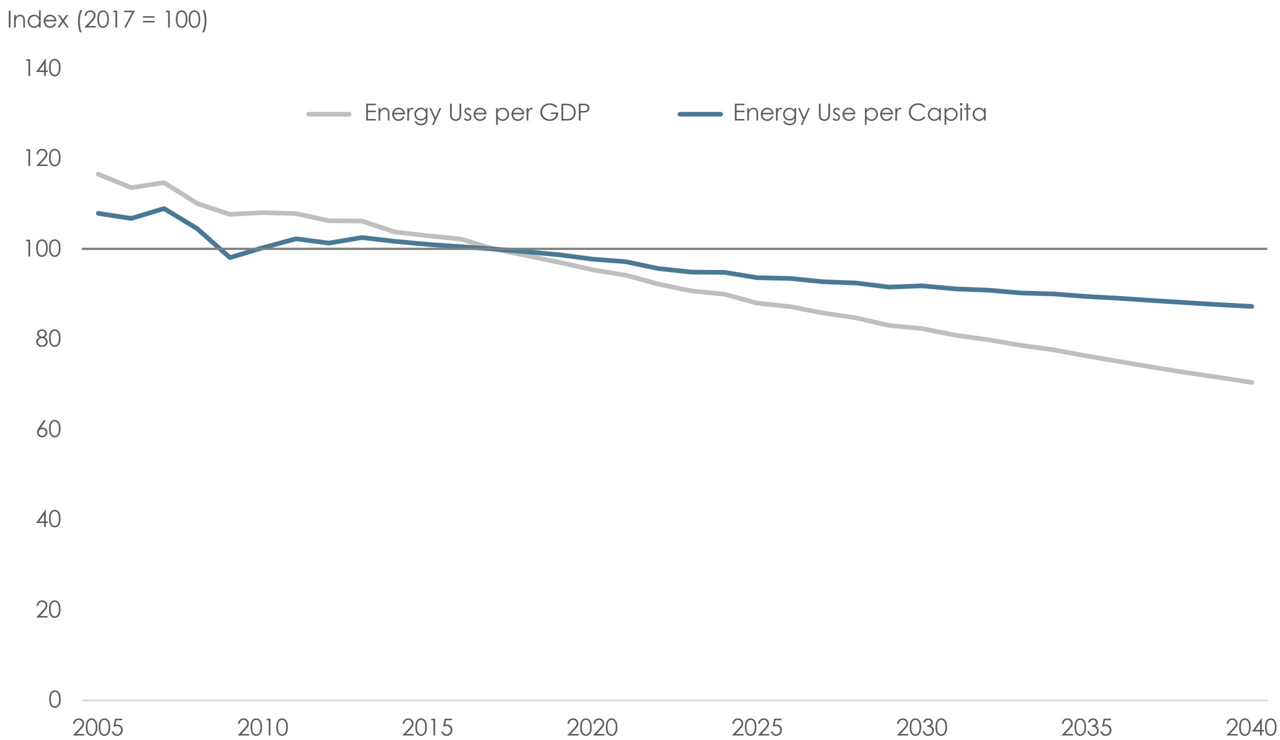
Source: NEB – Canada's Energy Future (2007 and 2018)

Moving to a Low Carbon Future

EF2018 shows various possibilities for future energy supply and demand. The EF2018 Reference Case reflects many of the transitions previously discussed in this report. Energy use is expected to slow relative to historical growth in all scenarios. This change in energy use is driven by energy efficiency improvements, technology, policy, and economic factors.

A noticeable shift is the decoupling of energy use from economic growth. The EF2018 Reference Case assumes a 20% increase in population and a 50% increase in real GDP between 2017 and 2040. However, total primary energy demand over that period increases only 5%. Figure 20 illustrates the continuing trend of declining energy demand per GDP and energy demand per capita from 2005 to 2040.

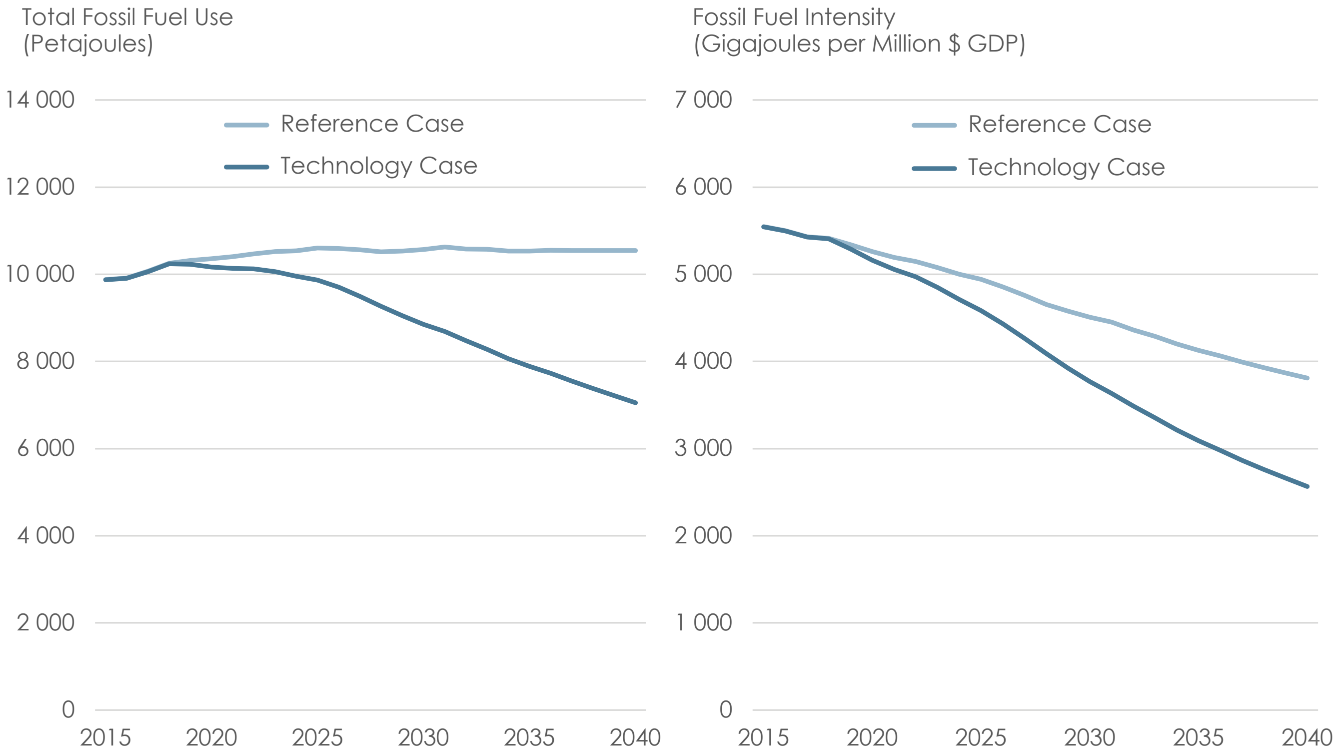
Figure 20: Primary Energy Demand Intensity: EF2018 Reference Case, 2005 – 2040



Source: NEB – Canada's Energy Future (2018)

Similar to EF2007's Triple E scenario, EF2018's "Technology Case" explores a scenario where a global move towards reduced GHG emissions is driven by stronger policies and a faster adoption of low-carbon technologies. This scenario has significant implications for Canadian energy systems, as illustrated in Figure 21. Under the Technology Case, Canada is projected to use 30% less fossil fuels than current levels by 2040. With real GDP assumed to grow by 50% between 2017 and 2040, fossil fuel use per GDP falls by 53% in the Technology Case versus a 30% decline in the Reference Case. The phase out of coal in Canada by 2030 and the further adoption of carbon sequestration technology reduces the emission intensity of the remaining fossil fuel mix. This implies that emissions will fall even faster than fossil fuel use.

Figure 21: Fossil Fuel Use and Intensity: EF2018 Reference vs. Technology Cases



Source: NEB – Canada's Energy Future (2018)

The Technology Case is not a prediction or recommendation of certain policies, technologies, or outcomes. Rather, it is a scenario that looks at the effects of an accelerated transition towards a low-carbon economy on energy demand and supply for Canada.

Canada's only official analysis of emissions performance and performance against climate commitments is published by ECCC. ECCC's "Pathway to Canada's 2030 Target" projects that measures under the Pan-Canadian Framework would result in an emissions reduction of 175 MT of CO_2e by 2030. This represents a 23% reduction from Canada's 2005 level of emissions—a shortfall of 44 MT. ECCC notes that its 175 MT estimate does not include emissions reductions that would result from other Pan-Canadian Framework commitments, such as investment in public transit, green infrastructure, innovation, and clean technologies. ECCC notes that these additional measures would put Canada on track to meet its Paris Agreement commitments.

The Transition Beyond 2030

EF2018's Technology Case projects considerable progress towards a lower-carbon economy in Canada compared to past trends. However, it represents just one possible pathway towards a lower-carbon economy.[59] It is uncertain what the ultimate pathway will be. A shift towards the aspirational 1.5 degrees Celsius target[60] in the Paris Agreement likely means an even faster and more drastic shift away from current trends by 2040. Importantly, Canada's 2030 emissions target, and the 2040 horizon for the EF projections, only represent milestones in a longer transition. As noted in the IEA's "Sustainable Development Scenario", these 2040 projections only get the world on track for necessary emission reductions and imply further, and likely deeper, reductions beyond 2040.

59 It is important to note that the EF2018 Technology Case is strictly focused on Canada. Since climate change is a global issue, it is difficult to assess global climate implications without undertaking an integrated global climate modelling exercise. This type of modelling is beyond the scope of this report.

60 The Paris Agreement seeks to limit the global average temperature increase to "well below two degrees Celsius above pre-industrial levels and pursuing efforts to limit the increase to 1.5 degrees Celsius above pre-industrial levels".

In the Canadian context, several studies have looked at deep emission reductions by 2050 and beyond. These include the Deep Decarbonization Pathways Project (DDPP), the Institut de l'énergie Trottier, and ECCC's Mid-Century Strategy.[61] The DDPP and Trottier reports illustrate that deep emission reductions are technically possible and will involve drastic changes to Canadian energy systems and the economy. The DDPP report cites Canada's preparedness for deep decarbonization as "mixed"—while Canada is on the right path for electricity, buildings, and personal transportation; challenges remain with the decarbonization of heavy industry and oil and gas extraction.

In scenarios that show decarbonizing energy systems, fossil fuels continue to play an important, but declining, role in the global energy mix. For example, the IEA's 2018 Sustainable Development Scenario shows that by 2040, global coal demand is less than half of current levels, global oil demand is 25 million barrels per day less than today, and natural gas use is higher than current levels (although lower than their baseline "New Policies Scenario").[62] Analysis from DDPP and Trottier shows that even in deep decarbonization scenarios, fossil fuel use remains in certain sectors where alternatives are more costly or technologically more difficult.

There is an important trade-off between the pace of transition in the near term and the longer-term need for negative emissions technology.[63] An important dynamic in many decarbonizing scenarios is that the longer it takes to switch away from emitting energy sources, the greater the need for negative emissions in the longer term. For example, the Shell "Sky" scenario shows the globe getting to net-zero emissions by 2070, and removing approximately net 10 000 MT of CO_2 per year to 2100 in order to keep global temperatures at levels consistent with the Paris Agreement.

Energy Systems of the Future

Projections of future energy supply and demand, even in scenarios such as the EF2018 Technology Case, are often grounded in current energy system realities. Energy systems are complex and it can be difficult to imagine how disruptive demand side or supply side changes will be. It is possible that new energy systems will emerge in Canada's energy transition. Likewise, disruptions in energy use could affect Canada's energy transition as well.

Table 3 provides an overview of several potential energy systems that are largely still in the research and development phase. Significant breakthroughs and cost reductions could lead to one or more of these individual systems increasing in the energy mix. There are a variety of energy options, some of which have been discussed for many years but currently have limited commercial implementation. If these technologies gain traction, they may provide alternate pathways in a transition towards a lower carbon future. Barriers to the adoption of these systems include costs, proven performance at a commercial scale, available feedstock, land-use implications, and infrastructure requirements.

61 Full title is Canada's Mid-Century Long-Term Low-Greenhouse Gas Development Strategy.

62 In the IEA's World Energy Outlook 2018, the New Policies Scenario includes policies and targets currently announced governments, while the Sustainable Development Scenario shows a clean energy transition on track to meet climate and other sustainable development goals.

63 Negative emissions occur when more GHGs are removed from the atmosphere than emitted, for example by employing bio-energy with CCS or direct air capture and carbon storage.

Table 3: Future Energy Systems in Canada

Energy	Production	Conversion	Distribution	End-Use
Next generation biofuels	Sustainable biomass from agricultural, municipal, and forestry waste	Thermochemical and biochemical processes convert biomass into ethanol.	Pipeline networks, truck, and rail.	Transportation, space heating, electricity generation
Renewable natural gas / biogas	Waste capture	No conversion required, but similar to natural gas, renewable natural gas would require processing to remove impurities.	Pipeline networks, truck or train (as liquefied or compressed natural gas)	Space heating, electricity generation, transportation, non-energy uses
Hydrogen	Electrolysis	Fuel cells convert hydrogen to electricity.	Pipeline or truck for use in combustion engines; electrical grid	Transportation, industry, electricity generation
Uranium	Mining	Uranium processing refines, enriches and converts uranium ore to fuel pellets and bundles for use in small modular reactors or in nuclear fusion.	Ship, rail, truck	Electricity generation, electricity generation in remote off-grid communities

Source: NEB

End-Use Transitions

The energy transition will involve more than just changing the composition of where our energy comes from. There are also possibilities for changing how consumers use energy in the future. These changes could include technological changes to energy-using equipment, changes to how consumers use energy, or having consumers become energy producers themselves.

Table 4 provides several examples of potential changes that could occur to end-use demand. Future energy systems will involve connections between the changes too.[64] For example, the outcome on energy systems from autonomous vehicles could be quite different if EVs continue to gain ground relative to conventional-fuelled vehicles. Likewise, a large uptake of EVs would look different if accompanied by greater solar PV adoption. The advent of new digital technologies to manage electricity supply and demand more efficiently could further affect how energy systems are changed by autonomous vehicles and EVs.

64 For more information on new end-use technologies and trends, see:

- IEA (2017). "Energy Technology Perspectives".
- IEA (2017). "Digitalization and Energy".
- NRCan (2018). "Paving the Road to 2030 and Beyond: Market transformation road map for energy efficient equipment in the building sector".
- Bataille, C. et al. (2018). "A review of technology and policy deep decarbonization pathway options for making energy-intensive industry production consistent with the Paris Agreement", Journal of Cleaner Production, 187, pp. 960-973.

Table 4: Examples of End-Use Transitions

Energy-Using Technology	Changing Energy Services	Consumers Producing Energy
• Electric vehicles • Cold-climate heat pumps • Enhanced demand optimization • Electrothermal industrial demands • Carbon capture, use, and storage	• Ride sharing • Autonomous vehicles • New demand sources (for example, cryptocurrency mining) • New energy markets and marketing options (for example, blockchain-powered renewable energy trading)	• Residential solar • Commercial building solar • On-site industrial generation of renewable natural gas • District energy systems • Distributed storage • Net metering

Source: NEB

The increased role of electrification will also likely involve a modernized electricity grid. Through its analysis of increased digitalization and energy, the IEA noted[65] that electricity is the key sector for transforming energy systems in four key areas:

- Digitally-enabled "smart demand response"; where smart appliances connected to grids improve system flexibility and shift loads away from peak times.
- Integration of intermittent renewables, such as wind and solar.
- Optimizing EV charging for when there is excess supply and low costs.
- Facilitate development of distributed energy resources such as household solar photovoltaic and storage, and peer-to-peer electricity trading via new digital platforms such as blockchain.

The Pan-Canadian Framework supports the modernization of electricity systems in Canada. The Framework includes funding for projects that help electric systems use renewable energy better, expand renewable capacity, and facilitate the integration of energy storage for renewables.

65 IEA (2017). "Digitalization and Energy".

7. Conclusion

Challenges and Uncertainty

The current transition has plenty of challenges and uncertainties ahead. Factors that play a role in the transition will involve aspects such as technological developments, policies, consumer preferences, new forms of energy, and new ways of using energy.

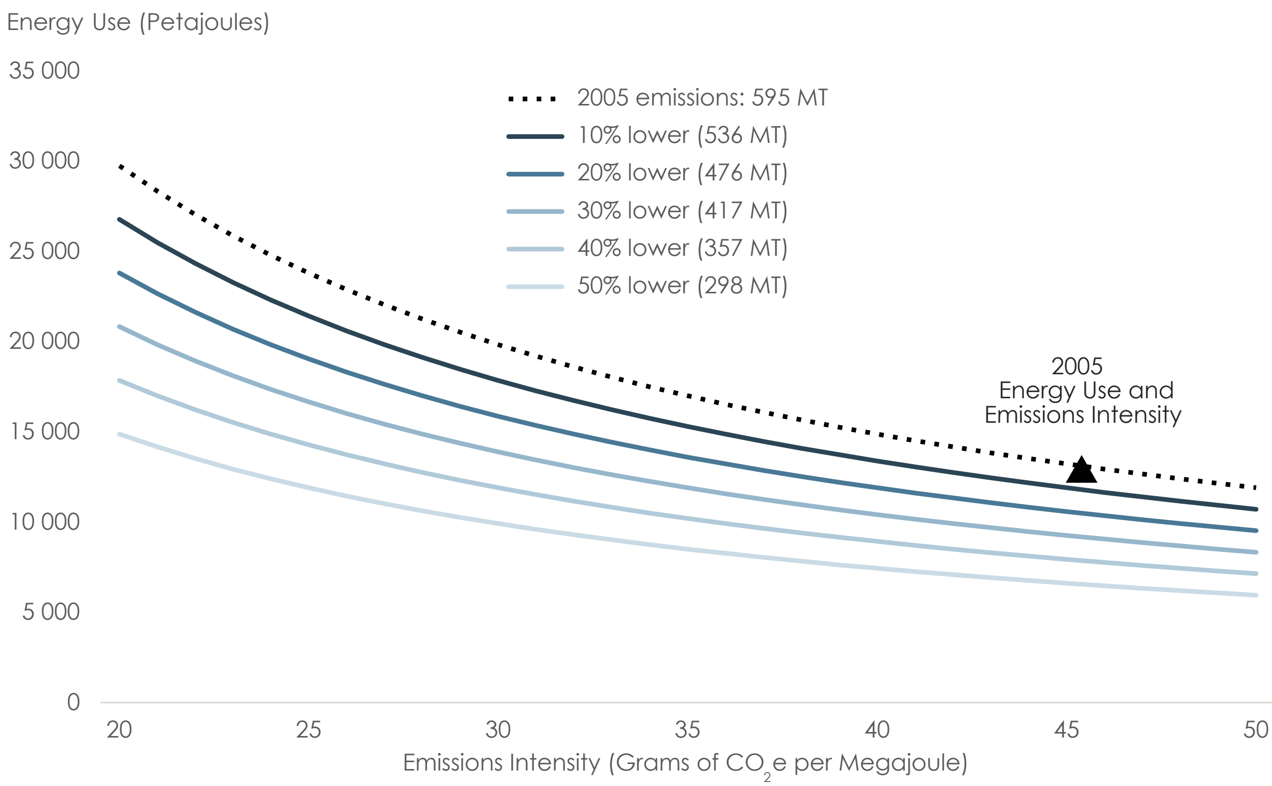
A transition to a lower-carbon economy will affect all of our existing energy systems. The transition will affect what types of energy are used, in what applications types of energy are used, how efficiently energy is used, and what role technologies will play in offsetting or storing carbon emissions.

Ultimately, energy-related emissions are a function of how much energy is used and the overall emission intensity of that energy. Recalling the links between energy use, the economy, and emissions described in Section 4, there are an infinite number of combinations of energy use and emission intensity that an economy can strive for with the goal of reducing emissions by a given amount.

Figure 22 shows various alternative pathways, assuming lower annual energy-related emissions.[66] It illustrates the challenges that lie ahead for Canada to reduce its energy-related emissions, including the substantial changes that are required to the ways we produce and consume energy. For example, achieving a 30% reduction in annual energy-related emissions (that is, reaching 417 MT of CO_2e) would require: reducing average emissions intensity to 33 grams per MJ (holding total energy use constant), or reducing total energy use to 8 860 PJ (holding average emissions intensity constant), or any of the combinations between these two points.

66 Energy-related emissions are those related to the combustion of fossil fuels and do not include GHG emissions such as fugitive methane emissions and nitrous oxide.

Figure 22: Pathways to Achieving Emissions Reductions in Canada



Source: NEB

All energy transitions come at a cost, and the current transition is no exception. The Conference Board of Canada notes that carbon pricing and decarbonization of electricity generation will have a small negative effect on the economy and that investments in clean energy technology will reach into the trillions of dollars.[67] ECCC projects that the Pan-Canadian Framework will reduce the level of GDP by about 0.35% in 2022. ECCC also states that this figure is likely an overestimate and that the costs of not taking action to address climate change are greater than the costs of addressing it.[68]

The largest uncertainty is the pace of the transition. The transition could be swift and dramatic,[69] or gradual and uneven. While history suggests that energy transitions are generally slow paced, the drivers of the current transition are different from the drivers of past transitions.[70] In *Energy Transitions*, Vaclav Smil concludes:[71]

> *"Energy transitions have been, and will continue to be, inherently prolonged affairs… How far we will advance into the postfossil future in three or four decades will not be determined only by the commitment to innovation but also by our willingness to moderate our energy expectations and to have our energy uses following a more sensible direction…"*

67 Coad, L. et al. (2018). "The Cost of a Cleaner Future: Examining the Economic Impacts of Reducing GHG Emissions". Retrieved from: The Conference Board of Canada

68 Government of Canada (2016). "Economic analysis of the Pan-Canadian Framework".

69 Tsafos, N. (2018, September). "Must the Energy Transition Be Slow? Not Necessarily". Retrieved from: The Center for Strategic and International Studies.

70 Fattouh, B., Poudineh, R. and West, R. (2018). "The rise of renewables and energy transition: what adaptation strategy for oil companies and oil-exporting countries?" Retrieved from: The Oxford Institute for Energy Studies.

71 Smil, V. (2017). Energy Transitions: Global and National Perspectives (pp. 237-238). Santa Barbara, California: Praeger.

The Transition is Happening Now

The energy transition is happening right now, as energy systems in Canada and around the world are changing. The fundamental components of the energy transition, as described in Section 4, illustrate that:

- Canada's electricity grid has one of the lowest carbon intensities in the world. In provinces and territories that rely heavily on fossil fuels for electricity, efforts to decarbonize continue with coal phase-outs and higher deployment of renewables.
- Though still in its early stages, end-use fuel switching with respect to personal transportation, continues to grow. Fuel and fuel economy standards continue to strengthen.
- Canadians are using energy more efficiently, and the trend of using energy more efficiently is expected to continue into the future.
- Policy initiatives at all levels of government are helping Canada move forward with the energy transition.

While the progress made to date is noteworthy, additional action is required by governments, businesses, and citizens for Canada to achieve its existing climate commitments. Canada's emission intensity is among the highest in the developed world due largely to its landscape, climate, and industrial structure. However, as ongoing progress has shown, these factors do not preclude Canada from doing more to further alter its emission trajectory in the future.

This report has shown that the future will likely look very different than the past. Over the last 100 years, global energy use increased dramatically—driven mostly by abundant and affordable fossil fuels. Most indications are that global energy demand growth will slow and will include a more diverse slate of energy sources. Finally, if the world is successful at meeting its long-term climate change objectives, the next 100 years in energy could be just as dynamic and transformative as the last century.

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Data Sources

Figure 1: Useful Energy and Losses in Canada	CESAR: Sankey diagrams associated with fuel and electricity production and use in Canada NRCan: Generation Energy Council Report
Figure 2: Energy Consumption: OECD and Non-OECD Nations, 1965-2017	BP: Statistical Review of World Energy 2018
Table 2: Energy Density and Carbon Emissions from Various Fuels	University of Washington Quaschning, V.: Specific Carbon Dioxide Emissions of Various Fuels
Figure 3: Global Primary Energy Consumption by Fuel, 1850 - 2017	Data from 1850 – 1959: Grübler, A.: data appendix from "Technology and Global Change" Data from 1960 – 2017: BP: Statistical Review of World Energy 2018
Figure 4: Global GHG Emissions and Canada's Share, 1990 – 2014	CAIT: Climate Data Explorer
Figure 5: Canada's Historical GHG Emissions and 2030 Target	ECCC: National Inventory Report 1990-2017
Figure 6: Energy Intensity for OECD Economies and Select NICs, 2015	World Bank: Energy intensity level of primary energy
Figure 7: GHG Emissions by Sector in Canada, 1990 – 2017	ECCC: National Inventory Report 1990-2017
Figure 8: Index of Economy, Energy, and Emissions Factors in Canada, 1981 - 2017	Statistics Canada: Tables 25-10-0004-01, 25-10-0029-01, 36-10-0222-01, and 17-01-0005-01 ECCC: National Inventory Report 1990-2017
Figure 9: GHG Emissions by Country: Intensity and Per Capita, 2015	CAIT: Climate Data Explorer
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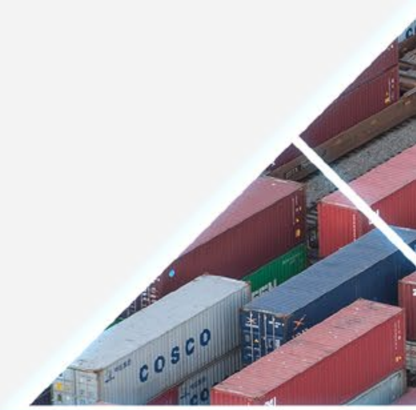
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