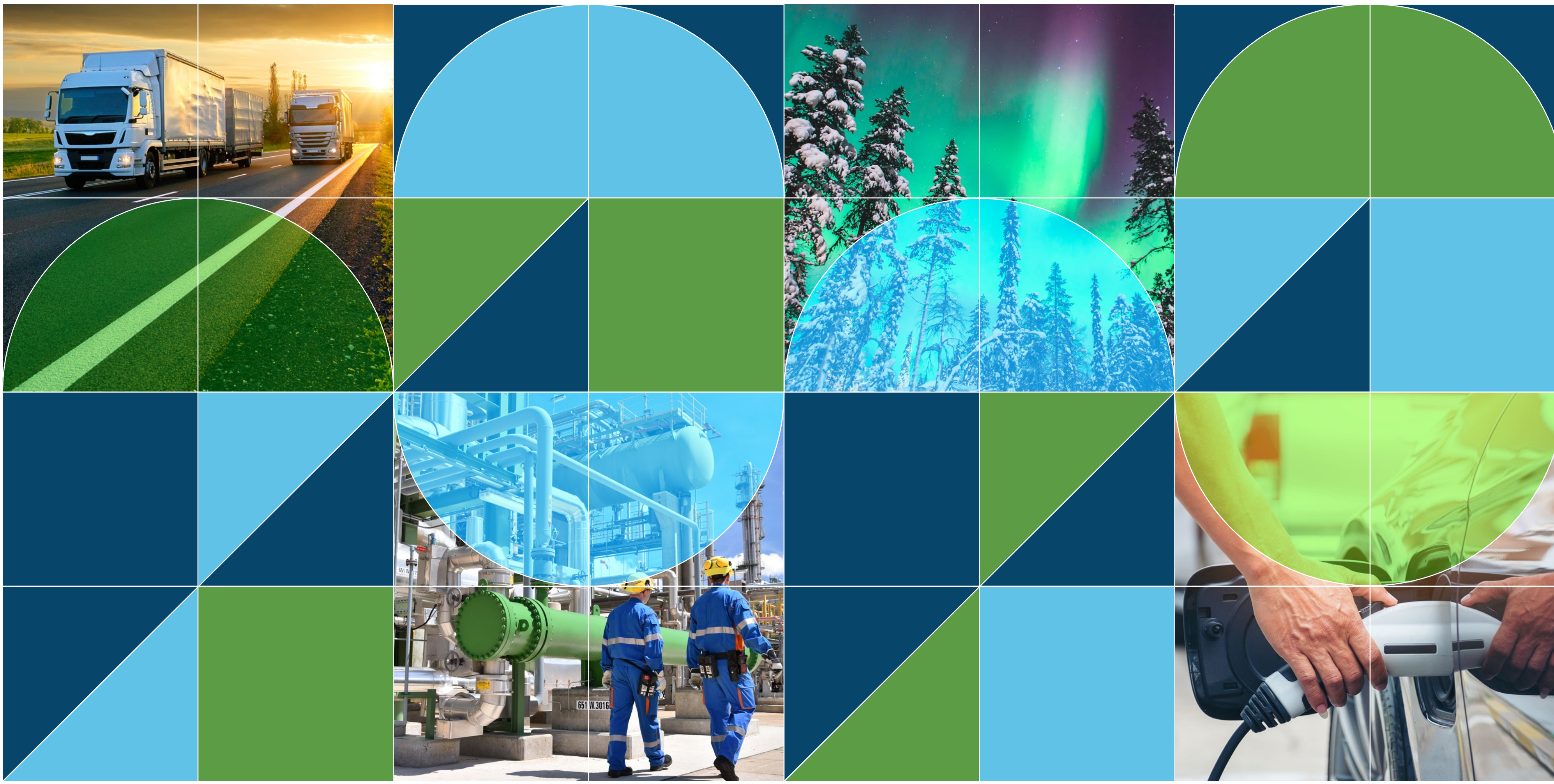
Canada Energy Regulator
Régie de l'énergie du Canada

Canada

Canada's Energy Future 2020



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Introduction

Canada's Energy Future 2020: Energy Supply and Demand Projections to 2050 (EF2020) is the latest long-term energy outlook from the Canada Energy Regulator (CER). Like many activities of the CER, it builds on the 60 year history of the National Energy Board, which began releasing long-term projections in 1967.

The *Energy Futures* series explores how possible energy futures might unfold for Canadians over the long term. *Energy Futures* uses economic and energy models to make these projections. We base the projections on assumptions about future trends in technology, energy and climate policies, energy markets, human behaviour and the structure of the economy.

The *Energy Futures* series includes long-term projections of the Canadian energy system. At the same time, the COVID-19 pandemic has created significant near-term uncertainty for Canadians, including energy supply and demand trends. Because of this, EF2020 includes more focus on the near term than is typical of the *Energy Futures* series. See the "Energy Supply and Demand in a Pandemic: Effects of COVID-19" section to explore this analysis.

EF2020 is the first *Energy Futures* report to extend the projection period to 2050. EF2020 also introduces a new scenario, the Evolving Energy System Scenario (Evolving Scenario), to complement the traditional baseline projection in the *Energy Futures* series, the Reference Energy System Scenario (Reference Scenario). Finally, EF2020 explores what going beyond an evolving energy system could mean for Canada in the "Towards Net-Zero" section.

Several important assumptions and caveats underpin the analysis in EF2020. The "Scenarios and Assumptions" section outlines the specific assumptions underlying the projections for each of the scenarios. The "Results" section provides an overview of the projections for various parts of the Canadian energy system, focusing on the Evolving Scenario. The "Towards Net-Zero" section explores what a net-zero energy system could mean for Canada broadly, and for three different segments of the Canadian energy system. Finally, the "Access and Explore Energy Futures Data" section provides links to access data and tools for further use and exploration of EF2020.

Executive Summary

Overview and Background

The *Energy Futures* series explores how possible energy futures might unfold for Canadians over the long term. *Canada's Energy Future 2020: Energy Supply and Demand Projections to 2050* (EF2020) is our latest long-term energy outlook. It is the first outlook in the series to provide projections to 2050. It covers all energy commodities, and all provinces and territories. We use economic and energy models to develop this outlook. We also make assumptions about technology, energy and climate policies, energy markets, human behaviour and the economy.

In the long-term, global and Canadian ambition to reduce greenhouse gas (GHG) emissions will be a critical factor in how energy systems evolve. EF2020 considers two main scenarios, where energy supply and demand projections differ based the level of future action[1] to reduce GHG emissions. We complement this analysis with a discussion of what further transformation of the energy system could mean.

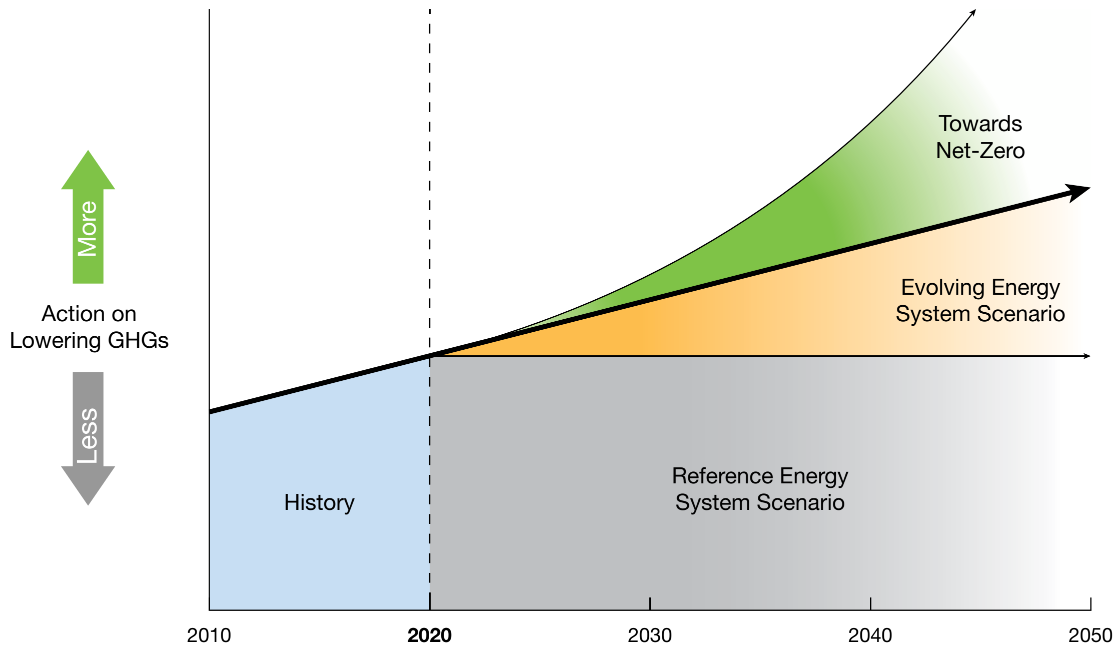
The Evolving Energy System Scenario **(Evolving Scenario)** considers the impact of continuing the historical trend of increasing global action on climate change throughout the projection period. Globally, this implies lower demand for fossil fuels, which reduces international market prices. Advancements in low carbon technologies lead to improved efficiencies and lower costs. Within Canada, we assume a hypothetical suite of future domestic policy developments that build upon current climate and energy policies.

The Reference Energy System Scenario **(Reference Scenario)** provides an update to what has traditionally been the baseline projection in the *Energy Futures* series, the Reference Scenario. The scenario considers a future where action to reduce GHG emissions does not develop beyond measures currently in place. Globally, this implies stronger demand for fossil fuels, resulting in higher international market prices compared to the Evolving Scenario. Low carbon technologies with existing momentum continue to improve, but at a slower rate than in the Evolving Scenario.

EF2020 also explores what going beyond an evolving energy system could mean for Canada in the "Towards Net-Zero" section. This section does not provide a projection of the future, but rather a discussion of some of the key issues in transitioning towards a net-zero energy system. It provides an overview of the implications of moving to a net-zero energy system at a high level. It complements this with a more detailed discussion on what moving towards net-zero could mean for specific segments of the energy system. These segments are personal passenger transportation, oil sands production, and remote and northern communities.

Figure ES.1 provides a conceptual illustration of the two scenarios included in EF2020, as well as of a net-zero future. Table ES.1 provides an overview of key differences between the Evolving and Reference scenarios.

Figure ES.1:
Conceptual Illustration of EF2020 Scenarios and a Net-Zero Future



Towards Net-Zero
The pace of action on addressing climate change increases from current levels.

Evolving Energy System Scenario
Continues the historical trend of increasing action on climate change throughout the projection. Policies and agreements are strengthened after they sunset. Low carbon technologies continue to be developed.

Reference Energy System Scenario
Climate change actions limited to only the measures that are currently in place. Technological development is modest, and generally limited to those with existing momentum and/or market share.

History
Gradually increasing action on climate change, including policies, regulations, and development of low carbon resources and technologies.

Table ES1: **Evolving and Reference Scenario Comparison**

		KEY ASSUMPTIONS					
				% Change in Select Technology Costs (2020 to 2050) (c)			
	SCENARIO PREMISE	**Global Crude Oil Price (a)**	**North American Natural Gas Price (b)**	Solar Power	Onshore Wind	EV Batteries	**Canadian Energy and Climate Policies**
Evolving Scenario	Continually increasing global and Canadian action to reduce GHG emissions. The pace of increase in future action continues the historical trend.	$54	$3.52	-75%	-50%	-50%	Builds on current climate and energy policies with an illustrative suite of future developments. Includes a rising economy-wide carbon price reaching $75 per tonne in 2040 and $125 per tonne in 2050.(d)
Reference Scenario	Global and Canadian action to reduce GHG emissions generally stops at current levels.	$75	$3.77	-60%	-11%	-30%	Only policies currently in place are included. Carbon prices remain unchanged from current programs.(e)

(a) Brent, average 2019 US$, 2025-2050.
(b) Henry Hub, average 2019 US$, 2025-2050.
(c) Capital costs only.
(d) 2019 C$ per tonne CO_2 equivalent.
(e) For example, the current federal backstop price increases to C$50 nominal per tonne CO_2 equivalent by 2022 and stays at C$50 nominal for the rest of the projection.

Key Findings

1. The COVID-19 pandemic has significantly impacted the Canadian energy system. We estimate that energy use in 2020 will fall by 6% from the year prior, larger than the decrease experienced during the 2009 financial crisis. We estimate that 2020 crude oil production will decrease by 7% or 335 thousand barrels per day (Mb/d) compared to 2019.

The global pandemic and efforts to stop it will evolve over the coming months and years. This creates added uncertainty for Canada's energy outlook. EF2020 assumes that acute effects of the pandemic slowly dissipate over the next two to three years.

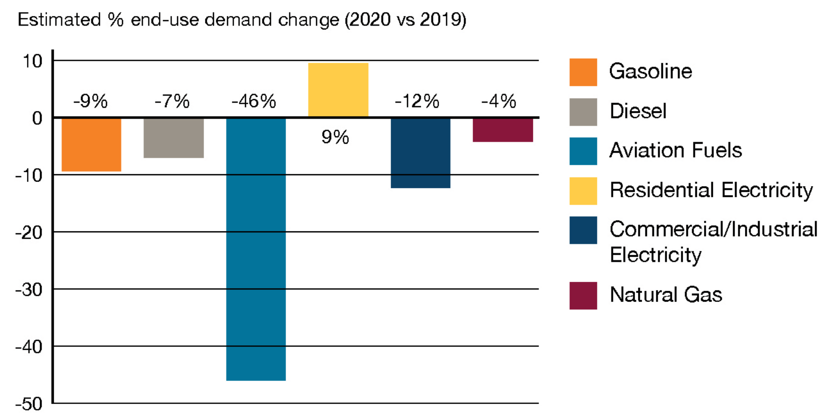
In Canada and around the world, COVID-19 has impacted all facets of daily life. The effect on Canadian energy use and production has been significant and widespread.

Actions to reduce the spread of COVID-19 have changed energy demand patterns in Canada. Actions such as travel restrictions, prevalent working from home, and the broader economic impact of the pandemic all affect the energy system in various ways. We estimate that Canadian end-use energy demand will fall by 6% in 2020 compared to 2019, the biggest annual drop since at least 1990. Energy to move people and goods will fall the most due to less travel and increased remote work and learning. Industrial energy use will also decrease, as many industries scaled back in response to lower demand for their goods. Energy use in the commercial sector will fall because of lower occupancy of buildings like offices, restaurants, and schools, while residential energy use increases as people spend more time in their homes.

COVID-19 is also impacting Canadian energy producers, although the effects vary across commodities. We estimate crude oil production in Canada will fall by 335 Mb/d in response to lower crude oil prices. We estimate natural gas production will remain relatively stable through 2020 as western Canadian natural gas prices are higher than last year. In response to overall lower electricity use in Canada, we estimate that electricity generation will fall by 3% in 2020.

Figure ES.2:
Impacts of COVID-19 on the Canadian Energy System

Demand Impacts



Demand for road transportation fuels decreased, driven by restrictions and actions related to COVID-19.

Demand for jet fuel declined to historic lows because of reduced commercial air travel.

Public health measures led to more people working from home, which resulted in flattening of daytime electricity demand profiles, and increasing residential consumption.

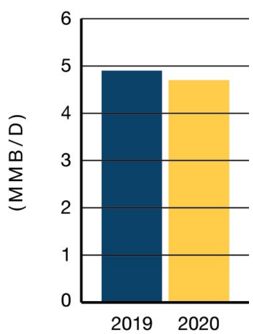
The increase in residential electricity demand partly offsets reduced demand in the commercial and industrial sectors. We estimate total electricity demand declines 5%.

Demand for natural gas fell, particularly in the oil and gas sector, which is the largest consumer in Canada.

Production Impacts

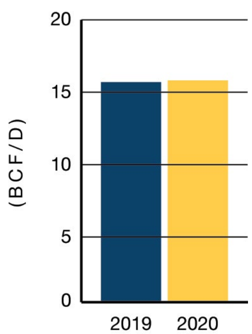
2019 | 2020

Crude Oil



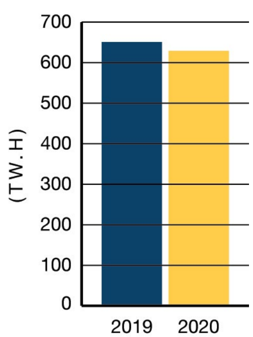
We estimate that 2020 crude oil production will decrease by 7% or 335 thousand barrels per day (Mb/d) compared to 2019. In the spring, Western Canadian producers shut in oil production due to low prices, eventually cutting almost 1 MMb/d of oil supply by mid-May 2020. Production increased in the latter half of 2020 along with rising prices.

Natural Gas



Natural gas production was relatively stable in 2020. Prices in western Canada have been higher in 2020 compared to the past several years, due to increases in the fall of 2019. These high prices sustained Canadian natural gas production through the first half of 2020 at levels similar to 2019.

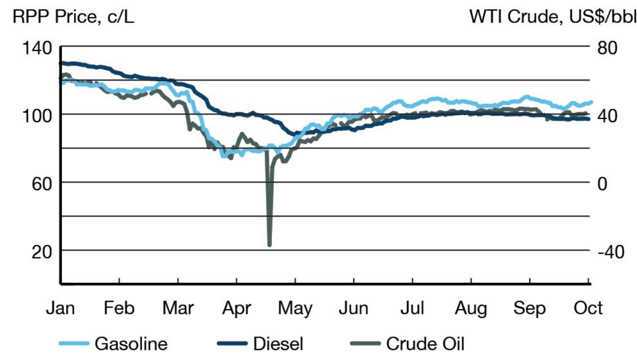
Electricity



The impacts on electricity demand and supply trends have also been significant, and vary by province. Overall we estimate electricity generation will fall by 3% in 2020, or 19 TW.h, driven by declining electricity use.

Energy Market Indicators 2020

Commodity Prices

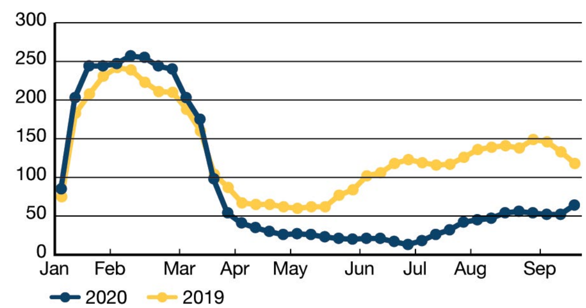


Source: Natural Resources Canada, Energy Information Administration

Reduced demand for RPPs, and hence crude oil, combined with Russia and Saud Arabia increasing the world's oil supply, caused oil prices to decline rapidly starting in February 2020.

Lower demand for RPPs and lower prices for crude oil resulted in Canadian consumer prices for gasoline and diesel in April that were the lowest since 2008 and, when adjusted for inflation, at least since 2002.

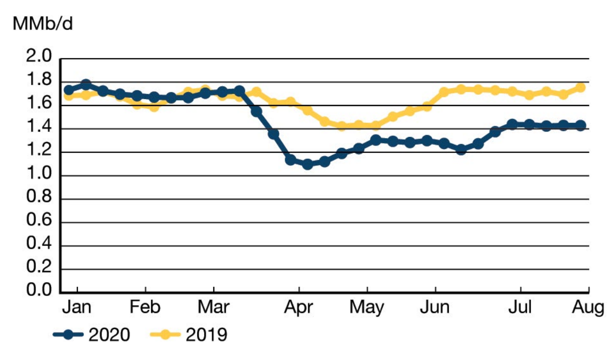
Active Drilling Rigs



Source: Baker Hughes

The number of drilling rigs active in Canada fell to levels not seen for over 50 years and some drilling projects in Newfoundland and Labrador's offshore were suspended.

Crude Oil Refining



Source: Canada Energy Regulator

The Come-by-Chance refinery in Newfoundland and Labrador was temporarily shut down and other Canadian refineries reduced output.

2. Canada's domestic fossil fuel consumption peaked in 2019 in the Evolving Scenario. By 2030, it is 12% lower, and 35% lower by 2050. At the same time, renewables and nuclear grow by 31% by 2050 and become a larger share of the energy mix.

Increased climate action in the Evolving Scenario impacts future Canadian energy use. In 2018, over 82% of Canada's total GHG emissions were energy related. The vast majority of these came from fossil fuel combustion.

In the Evolving Scenario, consumption of fossil fuels in Canada remains below its 2019 peak. By 2030 it is 12% lower, and 35% lower by 2050. Coal declines in the 2020s as it is phased out of electric generation. Refined petroleum product (RPP) use gradually declines due to energy efficiency improvements and increasing use of renewable fuels and electricity. Natural gas use increases in the early part of the projection, driven by increasing demands in electricity generation, and upstream crude oil and natural gas production. Natural gas use falls in the latter parts of the projection, as renewables play a bigger role in electricity generation, and energy needs to produce fossil fuels decrease.

In contrast, fossil fuel consumption is relatively unchanged throughout the projection period in the Reference Scenario. This is due to steady improvements in energy efficiency offsetting population growth and increasing industrial output, particularly in the oil sands.

At the same time, demand for renewable energy sources such as hydroelectricity, wind, solar, and biofuels increases by 45% from 2019 to 2050 in the Evolving Scenario. Nuclear demand increases by 2%. Combined with declining fossil fuel use, the share of these low and non-emitting sources increases from 23% of the energy mix in 2019, to 38% by 2050.

Figure ES.3:
Primary Energy Use by Type, Evolving and Reference Scenarios

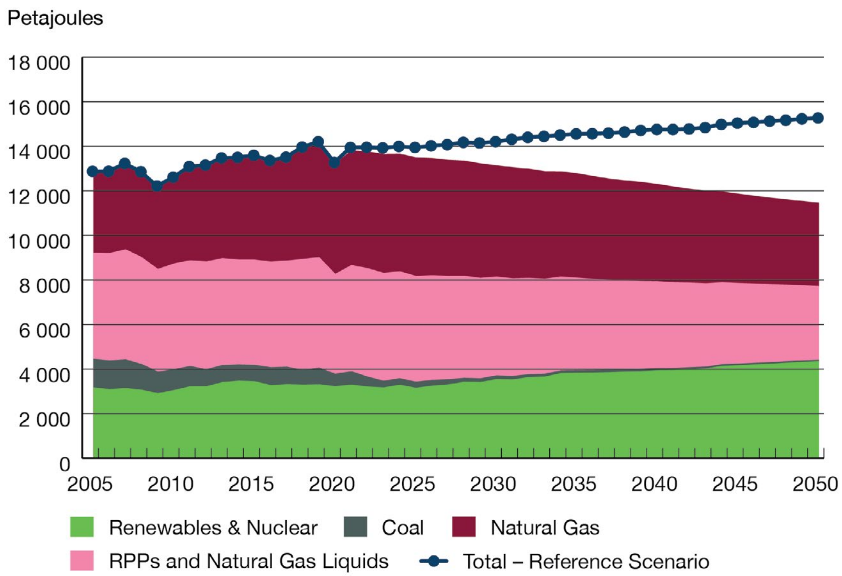
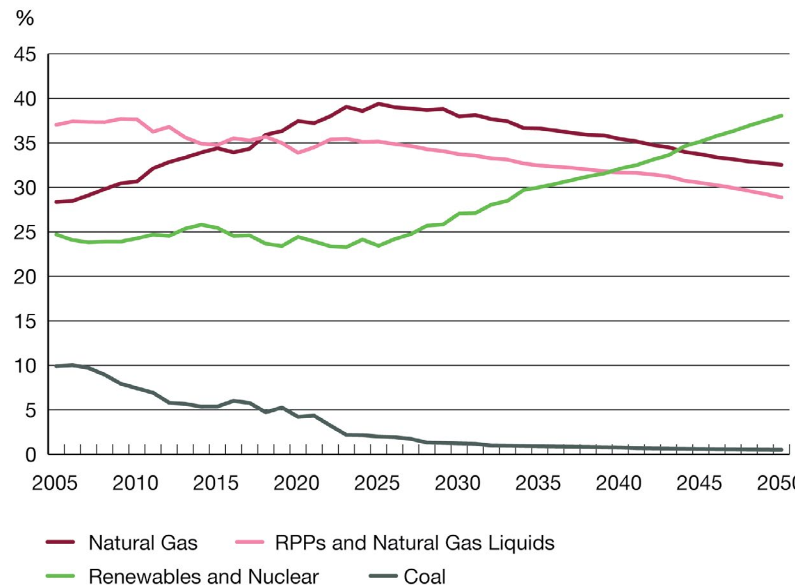


Figure ES.4:
Share of Energy Use by Type, Evolving Scenario



3. Electricity becomes increasingly competitive with fossil fuels in many parts of the energy system, including for passenger vehicles. Electricity's share of end-use demand increased from approximately 16% currently to over 27% in 2050 in the Evolving Scenario, when half of all passenger vehicle sales are electric vehicles. Renewable sources will also account for a larger share of electricity generation.

Many energy modeling studies[2] indicate that increased electrification will likely be a key part of energy system transitions. In the Evolving Scenario, assumed declining battery costs and increasingly stringent climate policies result in steady increases in electricity use in all sectors of the economy. Electricity use increases by an average of 1% per year from 2019 to 2050. Its share of end-use demand increases from approximately 16% currently to over 27% in 2050.

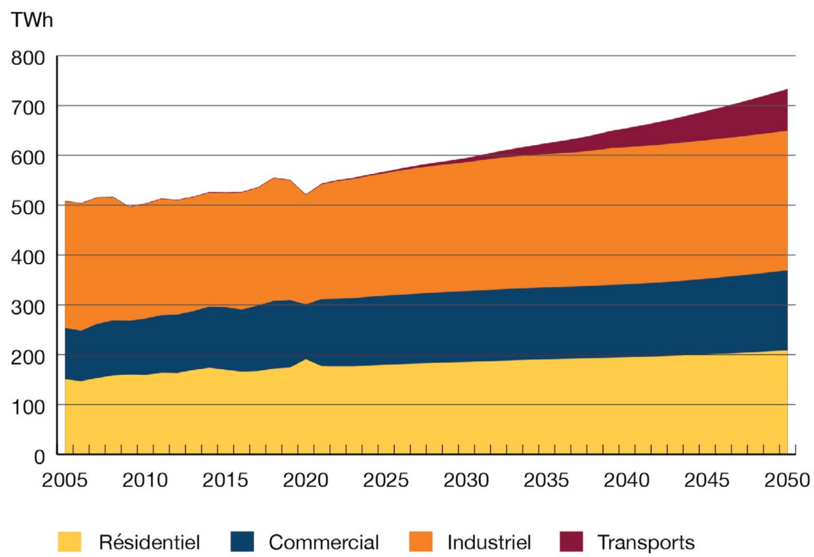
Notably, electricity gains a strong share of the transportation sector, where gasoline and diesel currently dominate. As they become more cost competitive, passenger electric vehicles (EVs) make considerable inroads over the projection period. By 2050 in the Evolving Scenario, EVs account for half of all new passenger vehicle purchases. In the longer term, the Evolving Scenario also includes some adoption of EVs and hydrogen fuel cells in the freight sector.

To meet these rising demands, Canada relies more on renewable generation. Wind, solar, and hydro electricity generation grow in the projections. In the Evolving Scenario, 90% of electricity generation comes from renewable and nuclear generation in 2050. This compares to 81% today.

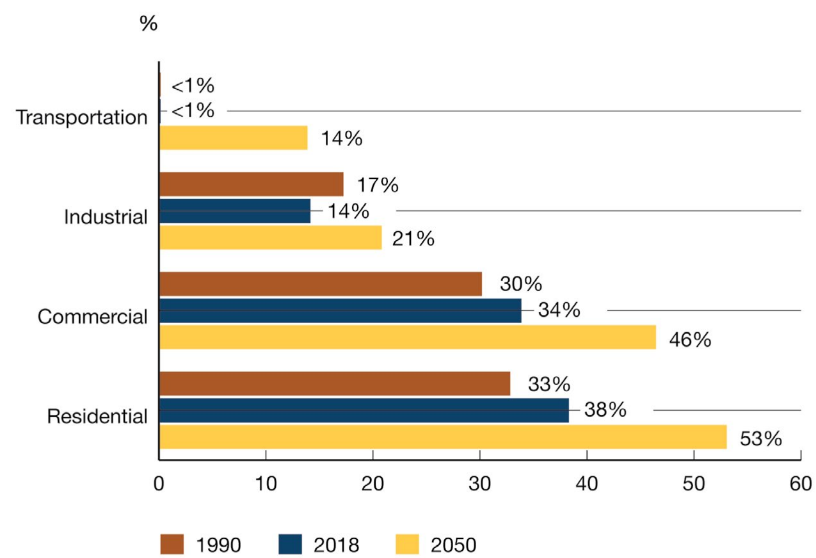
Electricity's share of end-use demand grows more slowly in the Reference Scenario. It reaches 20% in 2050, when 20% of passenger vehicles sold are EVs. Renewable generation also grows in the Reference Scenario, although at a slower pace. In 2050, natural gas plays a larger role in the electricity mix, and renewable and nuclear generation account for 81% of generation.

Figure ES.5:
Electricity Demand by Sector, Evolving Scenario

a) Total Electricity Demand by Sector



b) Share of Electricity In the Total Demand For Each Sector



4. Under the assumptions of the Evolving Scenario, Canadian crude oil production increases steadily until peaking in 2039 at 5.8 million barrels per day (MMb/d). Driven by growing exports of liquefied natural gas (LNG), Canadian natural gas production increases and peaks at 18.4 billion cubic feet per day (Bcf/d) by 2040. Both crude oil and natural gas production decline slowly over the last decade of the projection period.

Crude oil production in the Evolving Scenario grows from 4.9 MMb/d in 2019 to 5.8 MMb/d in 2039. In the last decade of the projection, production begins to decline, reaching 5.3 MMb/d by 2050. Growth is largely due to expansions of existing in situ oil sands projects. The price assumptions in EF2020 underpin this growth. The Evolving Scenario assumes that the Brent crude oil price increases from 2019 US$37/bbl in 2020 and plateaus at the 2019 US$55/bbl level from 2026 to 2038, before declining slowly to 2019 US$50/bbl by 2050.

Natural gas production increases in the Evolving Scenario from 15.7 Bcf/d in 2019 to 18.4 Bcf/d in 2040. This growth is driven by increasing LNG exports, which we assume increase to 4.9 Bcf/d by 2039. Most of this production growth comes from the Montney tight gas resource, especially in British Columbia (B.C.). After 2040, natural gas production slowly declines to 16.8 Bcf/d by 2050.

The Reference Scenario shows higher future production for both crude oil and natural gas. Drivers of this higher production include significantly higher assumed crude oil prices, greater volumes of assumed LNG exports, moderately higher natural gas prices, and a lack of additional domestic climate policies beyond those currently in place.

Figure ES.6:
Crude Oil Production by Type, Evolving and Reference Scenarios

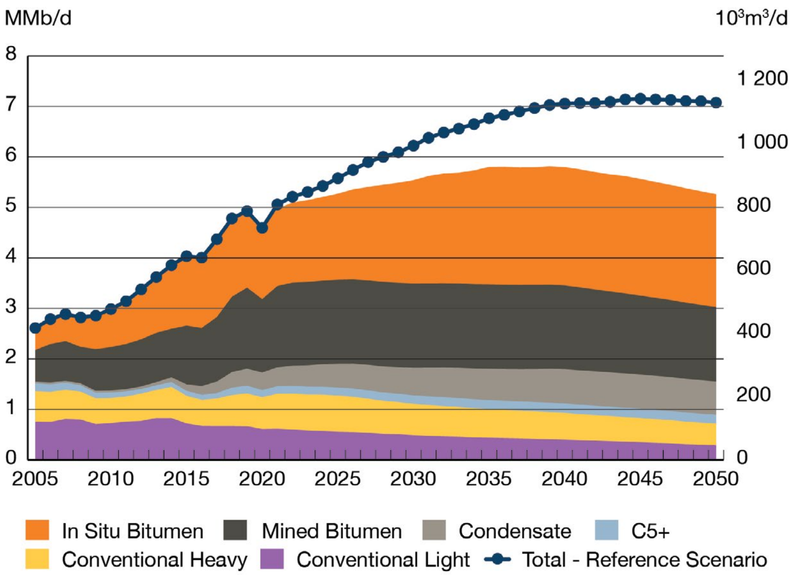
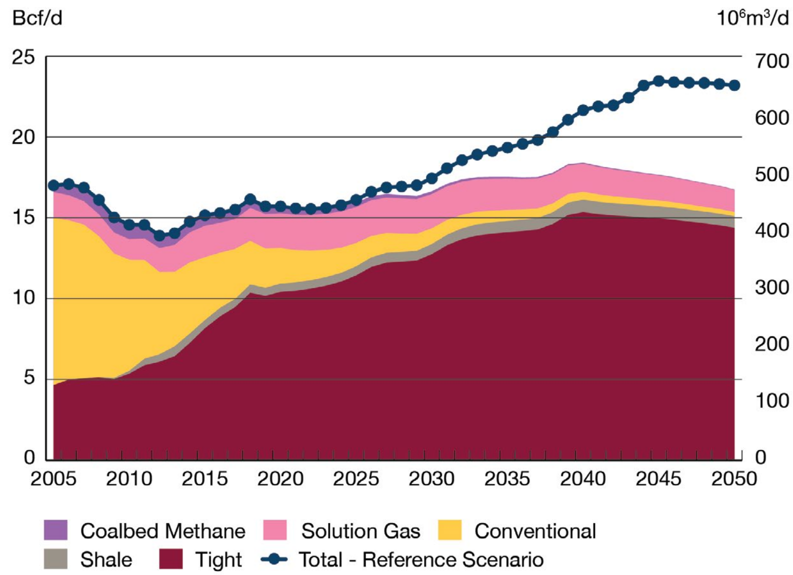


Figure ES.7:
Natural Gas Production by Type, Evolving and Reference Scenarios

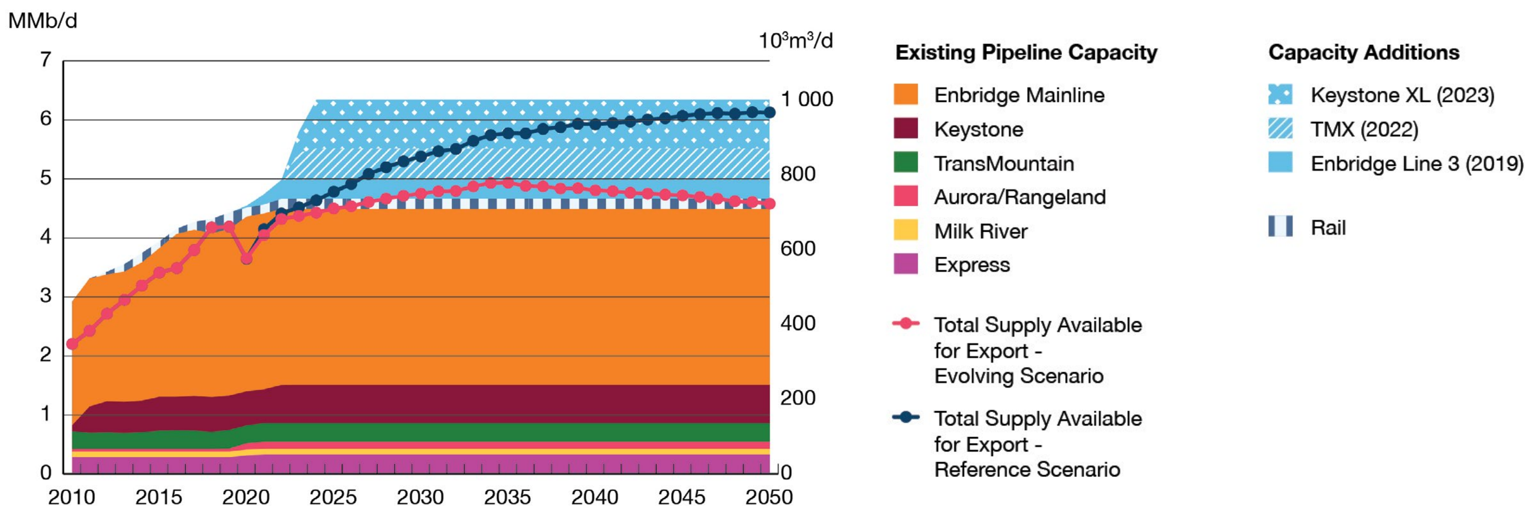


5. Major crude oil pipeline projects under construction will be able to accommodate all future production growth in both the Evolving and Reference Scenarios.

A key issue for Canada's energy system is the availability of crude oil export pipeline and rail capacity. This has implications for Canadian oil pricing and production trends. We assume that additional pipeline capacity is added according to announced completion dates of the Keystone XL pipeline, Line 3 Replacement Project, and the Trans Mountain Expansion. This assumption is not an endorsement of, or prediction about, any particular project. The "Scenarios and Assumptions" section provides further details on the infrastructure assumptions in EF2020.

With these announced pipeline projects assumed to proceed as proposed, crude available for export from western Canada remains below total pipeline capacity over the next 30 years in both scenarios.

Figure ES.8:
Crude Oil Pipeline Capacity vs. Total Supply Available for Export, Evolving and Reference Scenarios



Note: While the Evolving Scenario does project that, in some years, crude oil available for export is significantly lower than total pipeline capacity, this should not be interpreted as the Energy Futures Report concluding that any pipeline should or should not be built. The report does not assess the many factors that go into whether a pipeline is needed, including the value of access to new markets and the role of spare pipeline capacity in responding to temporary or lasting changes in markets.

6. While fossil fuel consumption declines in the Evolving Scenario, it still makes up over 60% of Canada's fuel mix in 2050. Achieving net-zero GHG emissions by 2050 will require an accelerated pace of transition away from fossil fuels.

EF2020 shows a range of outcomes in Canadian fossil fuel consumption trends, which will drive Canada's GHG emissions. In the Reference Scenario, there is limited growth in Canada's domestic fossil fuel use. In the Evolving Scenario, fossil fuel use declines steadily to 2050. At the same time, fossil fuels are still a large part of the Evolving Scenario energy mix in 2050.

Clearly, a low carbon economy will require an even greater shift in Canada's energy system. EF2020 includes a "Towards Net-Zero" section, which explores the unique challenges and opportunities in pursuing deep decarbonization. It discusses what net-zero could mean in Canada, and focuses on three segments of the Canadian energy system for more detailed analysis: personal passenger transportation, oil sands production, and remote and northern communities. What the exact 2050 balance might be between removing and emitting GHGs into the atmosphere is not yet clear. What *is* clear is Canada's likelihood of achieving our ambitious net-zero target increases as our energy system emissions fall. Figure ES.9 provides highlights from this analysis and further details are available in the "Towards Net-Zero" section.

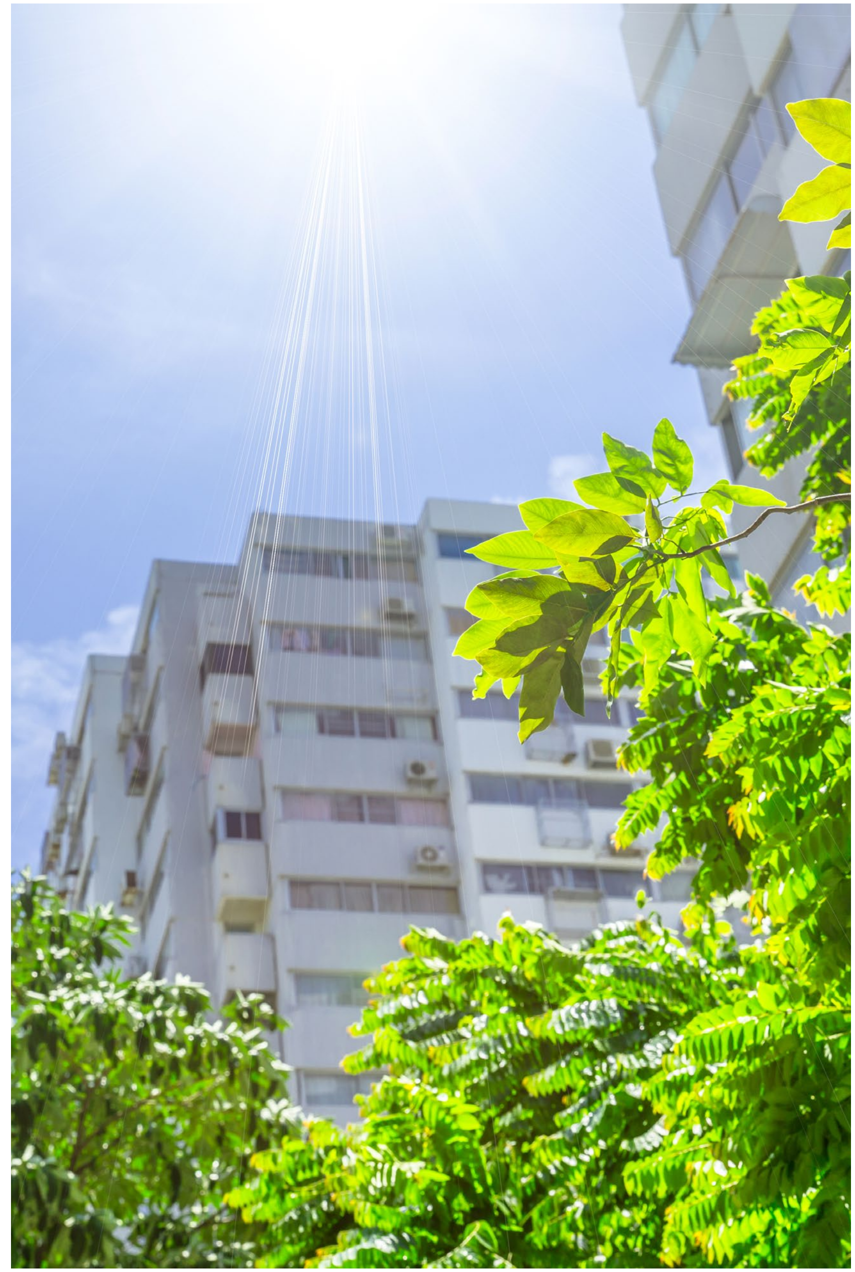


Figure ES.9:
Towards Net-Zero Overview

Analysis Highlights

Continued low carbon technology development will be essential to achieving 2050 goals. In a net-zero energy system, the equipment and processes used to provide energy will look much different than today.

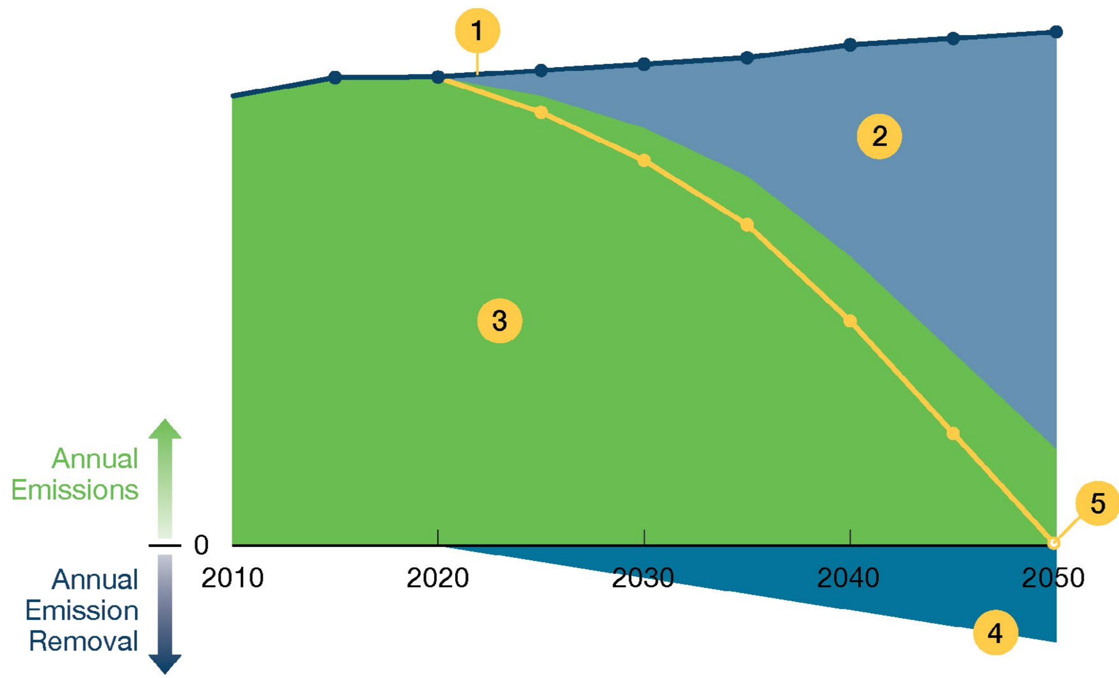
Policies will be a key driver of change. Government policies will play a key role in providing incentives for these necessary technology developments and adoptions to occur.

The energy system is highly integrated. The evolution of each segment of the energy system will depend on its specific circumstances, as well as broader domestic and international trends.

What is Net-Zero?

"Net-zero" GHG emissions, or "carbon neutrality", refers to the balance of emitting and removing human-caused GHGs from the atmosphere. Reaching net-zero emissions does not necessarily require eliminating all emissions everywhere. Instead, residual emissions can be balanced by enhancing biological sinks and negative emission technologies.

Conceptual Illustration of a Net-Zero Transition



1. **Business-As-Usual Emissions Trend.** Represents a hypothetical GHG emissions trajectory where future GHG reductions are not pursued.
2. **Mitigation.** Represents GHG emissions reductions relative to the business-as-usual trajectory.
3. **Remaining Emissions.** GHG emissions remaining after mitigation.
4. **Emission Removals.** GHGs removed via negative emission technologies or enhanced biological sinks.
5. **Net Emissions.** The balance of remaining emissions and emission removals.

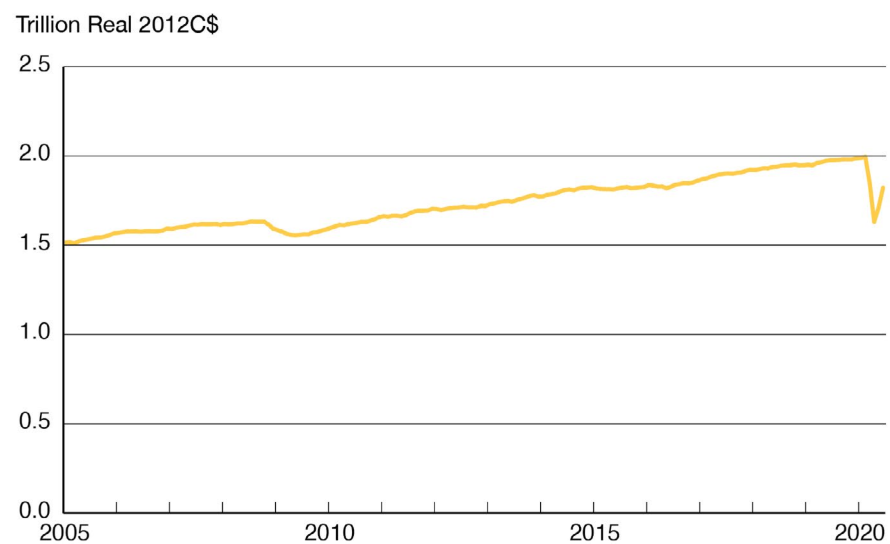
Energy Supply and Demand in a Pandemic: Effects of COVID-19

The COVID-19 coronavirus was first identified in December 2019 and by March 2020, the virus had spread around the world, including Canada. To protect the health of their citizens, governments tried to limit the virus's spread, including by encouraging social distancing, imposing travel restrictions, and closing businesses to reduce the gathering of crowds.

The impact on Canada has been significant. As shown in Figure C.1, Canada's gross domestic product (GDP) shrunk in March and April 2020 by 19% to a level not seen since 2010. For the whole of 2020, Canada's economy could shrink the most since the Great Depression of the late 1920s and 1930s.

Actions to reduce the spread of COVID-19, and the associated economic impacts, have had a significant impact on the Canadian energy system. The following section discusses the short-term market impacts of COVID-19 followed by the long-term uncertainties for the Canadian energy system resulting from the pandemic.

Figure C.1:
Monthly Canadian GDP



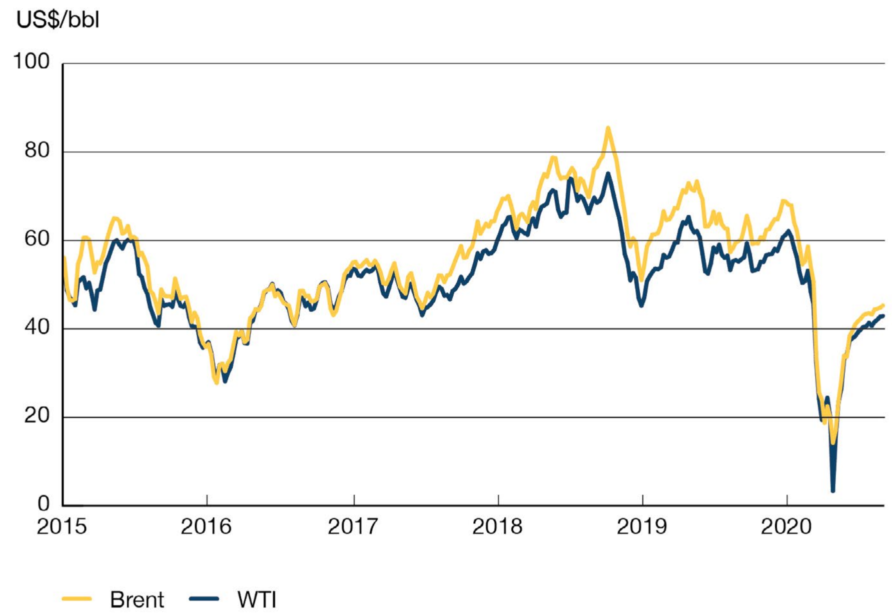
Short-term Energy Market Impacts

Restrictions and actions related to COVID-19 significantly reduced activities like air travel and commuting. This reduced demand for RPPs like gasoline, diesel, and jet fuel. As a result, global demand for crude oil dropped by almost 30 MMb/d by May 2020 (approximately 30% of total demand). Reduced demand for RPPs, and hence crude oil, combined with Russia and Saudi Arabia increasing the world's oil supply, caused oil prices to decline rapidly starting in February 2020.

As shown in Figure C.2, prices have since increased but remain below levels seen at the beginning of 2020. West Texas Intermediate (WTI), a global benchmark of sweet, light crude oil, priced in Cushing, Oklahoma, even traded at negative daily prices in late April 2020. Total global oil production was cut by nearly 14 MMb/d by June 2020. Western Canadian producers cut production by almost 1 MMb/d by mid-May 2020, and the United States (U.S.) cut over 2 MMb/d by mid-June 2020. The Organization of Petroleum Exporting Countries (OPEC) and Russia were largely responsible for the remaining reductions. Cuts have since eased and some production has come back online with rising prices.

In Canada, consumer prices for gasoline and diesel reached their lowest level since 2008. By March, demand for crude oil had fallen by over 35% from the start of 2020. In response, the Come-by-Chance refinery in Newfoundland and Labrador was temporarily shut down and other Canadian refineries reduced output. Canadian oil and gas producers, pipeline companies, and service companies cut their 2020 capital budgets by over $10 billion. The number of active drilling rigs in Canada fell to levels not seen for over 50 years. In Newfoundland and Labrador's offshore, work on the West White Rose project and maintenance on the Terra Nova project were suspended.

Figure C.2:
Global Benchmark Crude Oil Prices, Weekly Average



Prior to March 2020, Canada's major oil pipeline systems had been running at, or near, capacity for a number of years. This forced some crude oil exports onto rail, which peaked at over 400 Mb/d in February 2020. In the following months, crude-by-rail exports fell to levels not seen since February 2017 while pipelines began to run below full capacity. Since then, as some production has come back online, flows on pipelines have increased. As demand approaches pre-COVID levels, most market observers expect that pipelines will be full and crude by rail will once again be required to allow increasing Canadian crude oil production to reach markets.

The impact of the pandemic on natural gas use and production, particularly in Canada, was less acute than for crude oil. Natural gas prices in much of North America have been relatively low in 2020. However, western Canadian prices have actually been higher in 2020 compared to the past several years. Natural gas prices in western Canada rose significantly in the fall of 2019, prior to the COVID-19 pandemic. These high prices sustained Canadian natural gas production through the first half of 2020 at levels similar to 2019. Consumption of natural gas in Canada fell in early 2020, but not as significantly as RPP consumption.

The impacts on electricity demand and supply trends have also been significant, and vary by province. Recent research[3] suggests that electricity demand fell 5% in Alberta, B.C., and New Brunswick in the early months of the pandemic, while Ontario's electricity demand fell around 10%.[4] Generation in Ontario remained relatively stable, and lower demand led to increased net exports. In Alberta, lower demand caused a significant reduction in natural gas-fired power generation.

The pandemic has impacted electricity developments under construction as well. Nalcor suspended construction of the Muskrat Falls dam in Newfoundland and Labrador in March 2020. The project will now not be online until mid-2021 at the earliest. Suncor suspended the construction of the Forty Mile Wind Project in Alberta in May 2020, which at 400 MW, will be the largest wind farm in Canada.

Uncertainties for Long-term Energy Projections

We developed the scenarios, assumptions, and projections in EF2020 in the midst of these events over the course of 2020. The COVID-19 pandemic has clearly added an additional layer of uncertainty to any future projection or scenario. In the near term, key questions include the path of future infection rates, the timing and effectiveness of treatments and vaccines, and the evolution of policy measures in response to the pandemic. In the longer term, there are many questions on how this experience will shape future social, work, and travel trends.

Energy Futures is a long-term energy outlook. While COVID-19 introduces additional uncertainty to the projections in this report, EF2020 assumes that the acute effects of the pandemic slowly dissipate over the next two to three years.

The longer term implications of COVID-19 are one of many key uncertainties for future energy trends, and Canada's energy system. EF2020 considers two scenarios, described in detail in the following section. In the Reference Scenario, while lingering impacts of the macroeconomic shock of 2020 remain, the energy system essentially returns to pre-pandemic normal by mid-decade. In the Evolving Scenario, the near-to-mid-term recovery is interwoven with the ongoing energy transition. Reduced travel, influenced by continued working at home, as well as increased effectiveness and reliance on digital communication, continues to put downward pressure on oil demand and prices during the recovery period. These trends eventually intersect with the key drivers of the Evolving Scenario: continued advancements in low carbon energy technologies and expansion in climate policy.

Scenarios and Assumptions

Scenario Overview

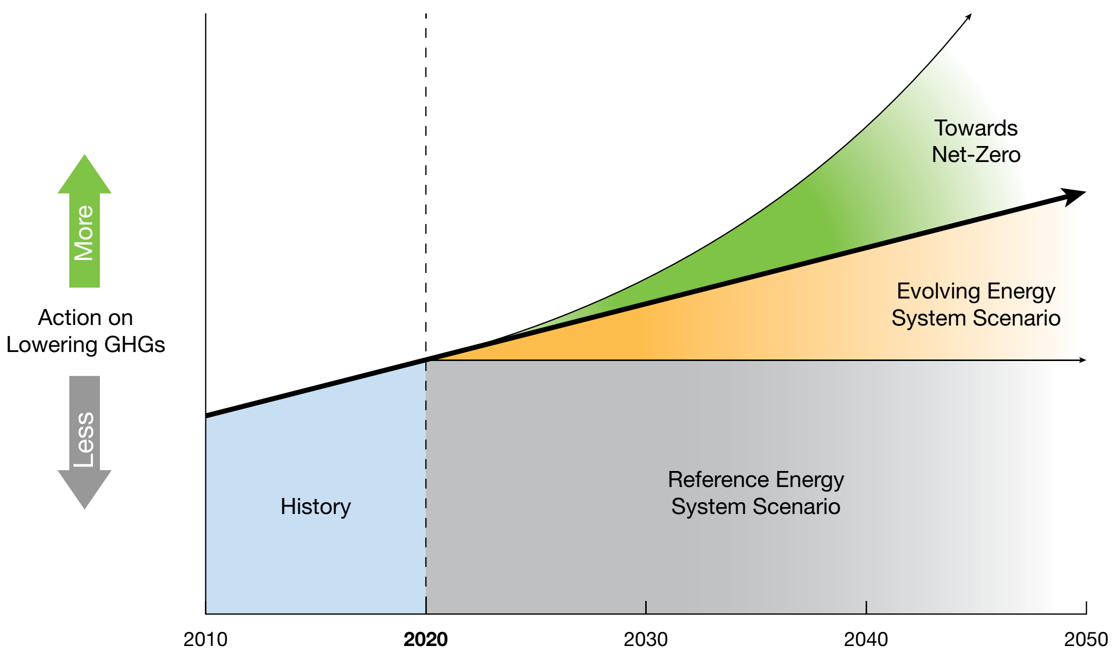
EF2020 includes two core scenarios that explore potential outcomes for the Canadian energy system over the next 30 years. These scenarios are the Evolving Energy System Scenario (Evolving Scenario) and the Reference Energy System Scenario (Reference Scenario). These scenarios provide energy supply and demand projections that differ based the level of future action[5] to reduce GHG emissions. The difference in the premise between these two scenarios impacts their specific assumptions – such as crude oil prices and renewable energy costs – which drive the supply and demand projections. EF2020 also includes a discussion of even greater climate action, in the "Towards Net-Zero" section. The "Towards Net-Zero" section does not provide a projection of the future, but rather a discussion of some of the key issues in transitioning towards a net-zero energy system.

The primary scenario in EF2020 is the Evolving Scenario. The core premise of the scenario is that action to reduce the GHG intensity of our energy system continues to increase at a pace similar to recent history, in both Canada and the world. This evolution implies less global demand for fossil fuels, and greater adoption of low carbon technologies. In contrast, the Reference Scenario assumes limited additional action to reduce GHGs beyond those policies in place today, implying higher demand for fossil fuels and less adoption of low carbon technologies. Consistent with these implications, in the Evolving Scenario we assume lower international prices for fossil fuels and a higher pace of technological change over the projection period, compared to the Reference Scenario.

EF2020 focuses primarily on the Evolving Scenario in order to provide a detailed exploration of the ongoing energy transition towards less carbon-intensive energy sources and technologies. Historically, there have been some important changes over long time periods in Canadian and global energy systems. Exploring a scenario where the energy system is assumed to evolve considerably is useful for a 30 year outlook to 2050. Allowing for continued change is a key feature of the Evolving Scenario. The Reference Scenario is a useful benchmark in illustrating a scenario with less assumed change.

Figure A.1 illustrates the key differences between the Evolving and References scenarios, and the Towards Net-Zero discussion. The vertical axis is a notional representation of the degree of action in GHG emission reduction. The horizontal axis is time, with the projection period starting in 2020.

Figure A.1:
Conceptual Illustration of EF2020 Scenarios and a Net-Zero Future



Towards Net-Zero
The pace of action on addressing climate change increases from current levels.

Evolving Energy System Scenario
Continues the historical trend of increasing action on climate change throughout the projection. Policies and agreements are strengthened after they sunset. Low carbon technologies continue to be developed.

Reference Energy System Scenario
Climate change actions limited to only the measures that are currently in place. Technological development is modest, generally limited to those with existing momentum and/or market share.

History
Gradually increasing action on climate change, including policies, regulations, and development of low carbon resources and technologies.

The upward sloping line from 2010 to 2020 in Figure A.1 represents the increasing level of action by governments, businesses, and citizens to reduce GHG emissions. This reflects that the breadth and stringency of federal, provincial, and municipal government climate policies have increased over this period. Likewise, a myriad of technologies which play a role in reducing GHG emissions, have steadily increased, improved, and become less expensive over the past decade.

Over the projection period (2020-2050), the pace of action diverges in the Evolving and Reference Scenarios. Unlike the Evolving Scenario, the Reference Scenario continues current levels of action forward into the projection period. This implies that only policies in place at the time of analysis are included. This results in only modest improvements in already established technologies that produce and consume energy, and stronger global demand – and higher international prices – for fossil fuels. As a result, the Reference Scenario provides a baseline for discussing what the Canadian energy system might look like if there is limited future progress on reducing GHG emissions. Previous iterations of *Canada's Energy Future*, going back to the 2007 Report, included a Reference Case. The framework underlying the Reference Scenario in EF2020 is conceptually similar to the Reference Case.

The Evolving Scenario provides a projection that reflects steady, continued progress towards reducing the GHG intensity of the energy system. It is not a pathway to a specific GHG emission reduction target. The assumptions in this scenario aim to provide an outlook where progress continues at roughly the same pace as in recent history. The Evolving Scenario includes a set of hypothetical future domestic climate policies to reflect greater ambition relative to the Reference Scenario. We describe the policies later in this section and in Appendix A. The Evolving Scenario also assumes a greater rate of technological progress relative to the Reference Scenario, with lower costs and greater efficiency of emerging technologies. Finally, we reflect weaker global demand for fossil fuels through lower assumed international prices for crude oil and natural gas compared to the Reference Scenario.

It is difficult to predict the policies that governments will put in place in the future. The future domestic policies included in the Evolving Scenario are entirely hypothetical and are not a recommendation, prediction, or evaluation of future policies that governments may choose to enact.

Together, the Evolving and Reference Scenarios provide a range of potential outcomes for Canada's energy system over the next 30 years. As discussed in the "Results" section, neither scenario depicts the deep reductions in fossil fuel consumption that would be needed to achieve net-zero GHG emissions by 2050. Such a result would require an acceleration of policy and technology drivers relative to the pace in recent history. To explore what such an energy future might look like, EF2020 includes three segment-specific discussions. These discussions explore what net-zero emissions by 2050 could look like for three specific segments of the Canadian energy system. The "Towards Net-Zero" section describes the assumptions, trends, and uncertainties of these areas.

Evolving and Reference Scenario Assumptions

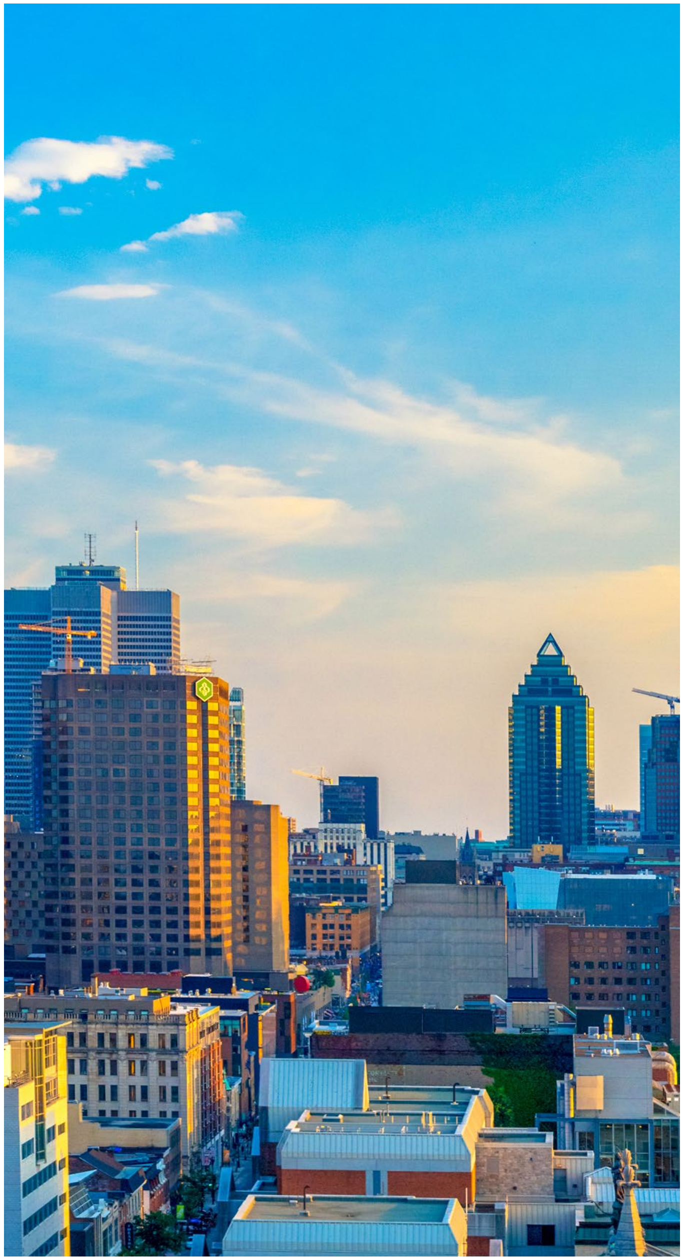
The EF2020 scenarios make a variety of assumptions about future trends that are necessary in making long-term projections. These include assumptions about domestic climate policies, rate of technological change, crude oil and natural gas markets (both domestic and global), major energy infrastructure, and future costs of new electricity generation capacity. Additional detail on the specific assumptions for each scenario follows.

The *Energy Futures* Scenarios in the Canadian Energy Information Landscape

EF2020 scenarios provide a broad perspective on the future of Canada's energy system.

This analysis complements other important work in the area of understanding possible future energy trends. Environment and Climate Change Canada's (ECCC) GHG emission projections provide an accounting of the impact of current, and planned, policy initiatives on Canada's emission outlook.

Various academic and institutional publications provide pathways to achieving stated climate objectives. Examples include the Trottier Energy Futures Project and the Deep Decarbonization Pathways Project. Many studies, from industry groups, researchers, academics, and institutions focus on specific aspects of Canada's energy system. Further, several initiatives, such as the Stanford Energy Modeling Forum and the Canadian Energy Modeling Initiative, bring energy modelers together to examine a diverse range of future energy issues.



EF2020 is a Baseline for Discussion

It is important to note that the projections presented in EF2020 are a baseline for discussing Canada's energy future today and do not represent the CER's predictions of what will take place in the future. EF2020 projections are based on assumptions which allow for analysis of possible outcomes. **Any assumptions made about current or future energy infrastructure, market developments, or climate policies, are hypothetical and have no bearing on any regulatory proceeding that is, or will be, before the CER.**

Over the projection period, it is likely that developments beyond normal expectations, such as geopolitical events or technological breakthroughs, will occur. Also, new information will become available and trends, policies, and technologies will continue to evolve. This report is not an official, or definitive, impact analysis of any specific policy initiative, nor does it aim to show how specific goals, such as Canada's climate targets, will be achieved.

Domestic Climate Policies

Evolving: We assume a hypothetical suite of future policies, reflecting greater ambition relative to the Reference Scenario.

Reference: We assume policies in place as of the summer of 2020 will continue. We also include various simplifying assumptions to reflect carbon pricing systems.

Technological Change

Evolving: We assume lower costs, and greater efficiency of technologies aiming to reduce the GHG intensity of the energy system. This includes established technologies, such as wind and solar power, as well as the inclusion of some emerging technologies with limited commercial adoption today.

Reference: We assume modest improvements in established technologies, and no adoption of emerging technologies.

Infrastructure and Markets

In both scenarios, we base crude oil infrastructure assumptions on three announced projects, all with Federal approvals, and their completion dates in the short term. This analysis should not be taken as an endorsement of, or prediction about, any particular project. Rather, these assumptions are necessary for the analysis. For natural gas, both scenarios assume that natural gas infrastructure will be sufficient to prevent sustained large differentials between prices in western Canada and Henry Hub. Both scenarios assume gradually increasing levels of LNG exports. LNG exports are higher in the Reference Scenario compared to the Evolving Scenario. Given production and consumption projections, we assume markets for energy exports exist at the assumed prices.

Energy Prices

We base crude oil and natural gas price assumptions on a consensus view of other forecasting agencies, as well as CER analysis. Prices are lower in the Evolving Scenario compared to the Reference Scenario. This accounts for lower global demand for fossil fuels in a scenario with greater action to reduce GHG emissions and a greater pace of technological change.

Goals and Targets

We do not explicitly model climate and other related goals and targets in either scenario.

COVID-19 Recovery

Evolving: We assume the main impacts of the COVID-19 pandemic are felt in 2020, and there is gradual economic recovery in the next two to three years. Reduced travel, influenced by continued working at home, as well as increased effectiveness and reliance on digital communication, continues to put downward pressure on oil demand and prices during the recovery period. These trends eventually intersect with the key drivers of the Evolving Scenario: continued advancements in low carbon energy technologies and expansion of climate policy.

Reference: We assume there will be gradual economic recovery in the near term, and that economic growth and energy markets return to pre-pandemic business-as-usual by 2025.

Domestic Climate Policy

The Evolving Scenario begins with domestic climate policies currently in place. It then builds on the current policy framework with a hypothetical suite of future policy developments. These policies are chosen to reflect increasing ambition to reduce GHG emissions, and generally align with the broad trends of historical progress. Alternatively, the Reference Scenario only includes policies that are currently in place. This section outlines specific policies included in detail.

Current policies:

The Reference Scenario includes only current policies. In the Evolving Scenario, current policies provide a baseline that is built upon over the projection.

In order to determine whether to include a policy in the analysis, the following criteria were applied:

- The policy was publically announced prior to 1 August 2020.
- Sufficient details exist to model the policy.[6]
- Goals and targets, including Canada's international climate targets, are not explicitly modelled. Rather, policies that are announced, and in place, to address those targets are included in the modelling and analysis.

Table A.1: **Overview of Domestic Policy Assumptions**

Key Current Policy Assumptions	Key Future Policy Assumptions
Current policies are the base for policy assumptions in the Evolving Scenario. The Reference Scenario only includes current policies.	Future policy assumptions are hypothetical increases in policy stringency. They are only included in the **Evolving Scenario**.
Carbon Pricing Current provincial and territorial systems, as well as the Federal Carbon Pricing Backstop.	**Rising cost of Carbon Emissions** → Carbon prices continue to rise beyond 2022, to $125 in 2019 real terms by 2050. → Credits for large emitters are gradually reduced over the projection period.
Coal Phase Out Traditional coal-fired generation is phased out of electricity generation by 2030. **Energy Efficiency** Currently in place regulations including appliance standards, building codes, and vehicle standards.	**Reduced Emission Intensity of End-Uses** → **Energy Efficiency Regulations:** Gradually stronger energy efficiency regulations across the economy, including net-zero ready building codes, improving appliance standards, and increasing light-duty vehicle efficiency standards. → **Low Carbon/Clean Fuel Standard:** Average emission intensities of fuels are gradually reduced over the projection period through increased use of renewables, end-use switching, and upstream emission reductions. → **ZEV Mandates:** Requirements for ZEV's in new sales are gradually introduced and/or increased over the outlook period.
Electric Vehicles Provincial policies and initiatives including those in B.C. and Quebec, as well as Federal rebates and infrastructure program. **Renewable Energy** Current requirements for renewable electricity, and blending of ethanol, biodiesel and renewable natural gas.	**Support for Clean Energy Technology and Infrastructure** Policy continues to support new technology development as well as key infrastructure developments including electric transmission, carbon capture and storage, and electric vehicle charging infrastructure.

Future policies:

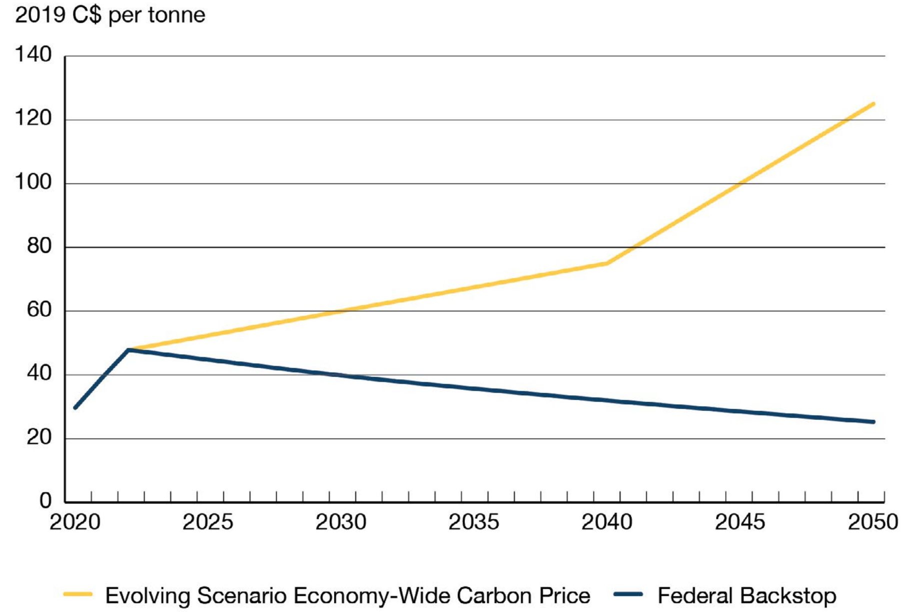
The Evolving Scenario adds a hypothetical suite of future policy developments to current policies. These policy assumptions take into account several considerations:

- Announced policies that are currently in the development stage (such as those included in Environment and Climate Change Canada's (ECCC) "With Additional Measures" GHG scenarios) are included to the extent possible. Generally their inclusion requires simplifying assumptions, as final regulations are not available.
- Some policies that are being increasingly enacted by various jurisdictions are broadened to others later in the projection period. For example, over the past several years, zero emission vehicle (ZEV) mandate regulations have been implemented in Quebec and B.C., as well as several U.S. states. The Evolving Scenario assumes hypothetical minimum ZEV mandate implementation across all Canadian provinces.
- Some hypothetical policies are included that supplement existing policy frameworks. For example, as described in Table A.1, we include a hypothetical carbon price that increases steadily over time in the Evolving Scenario in addition to the Federal Backstop carbon price.

Table A.1 describes specific policy initiatives. Figure A.2 compares the federal backstop carbon price to the increasing cost of carbon pollution in the Evolving Scenario. Additional policy detail is available in Appendix A.

Figure A.2:

Current Federal Backstop Carbon Pricing Schedule[7] and Evolving Scenario Economy-wide Carbon Pricing



Technology

Technological changes can have large impacts on energy systems. There is a strong link between policies and the pace of technological development – policy frameworks are key drivers of technological innovation and greater use of GHG reducing technologies. Over the past decade, technological advancements have unlocked unconventional fossil fuel resources and dramatically reduced the cost of technologies like wind, solar, and batteries. The Evolving Scenario assumes substantial technological progress, including adoption of many promising technologies currently in the early stages of commercialization, in the latter half of the projection period. Alternatively, the Reference Scenario assumes only moderate technological progress, including incremental efficiency improvements and cost reductions for well-established technologies.

Emerging Technologies Included in the Evolving Scenario

The Evolving Scenario allows for penetration of new technologies over the 30 year projection period. This list below includes several assumptions about the adoption of technologies that currently have limited adoption, but that could make significant impacts in the future. The pace of technological development, as well as how it interacts with policy, market, and social dynamics is a key uncertainty. Adoption of these and other emerging technologies could be faster or slower than the Evolving Scenario assumes:

- **Utility scale battery storage:** Approximately 3 GW by 2050.
- **Solvent-assisted oil sands extraction:** New projects and expansions post-2025 utilize solvent-assisted methods.
- **Digitisation and sector coupling:** Increased EVs and electrification in buildings.
- **Low carbon hydrogen use for freight and industrial applications:** Gradually adopted in the latter half of the projection period, varying by sector and province. Hydrogen powered freight meets 2% of trucking needs by 2040 and 12% by 2050, largely for heavy duty trucking.
- **Freight electrification:** Electric trucks provide 3% of freight trucking needs by 2040 and 14% by 2050, largely in light and mid-duty trucking.
- **Carbon capture use and storage:** An additional 15 megatonne (MT) per year sequestered by 2040, 30 MT per year by 2050, beyond existing projects.
- **Small modular reactors:** Addition of some small pilot projects from 2035-2040, gradually increasing in the 2040s to installed capacity of 500 MW by 2050.

Crude Oil and Natural Gas Markets and Infrastructure

International crude oil and natural gas prices are a key driver of the Canadian energy system and are determined by supply and demand factors beyond Canada's borders. Canadian crude oil and natural gas benchmark prices (such as Western Canada Select (WCS) for heavy crude oil and [Nova Inventory Transfer (NIT)] for natural gas) are driven by international trends, but are also driven by local factors, such as local crude quality and export pipeline capacity constraints.[8]

The COVID-19 pandemic is a key driver of current energy market dynamics. This is particularly true for crude oil. Figure A.3 shows the EF2020 crude oil assumptions for Brent, the primary global benchmark price for crude oil, for both the Evolving and Reference Scenarios. Prices decreased drastically early in 2020 because of lower demand for transportation fuels in response to the COVID-19 pandemic. In both scenarios, we assume prices begin to gradually increase over the next several years. In the Evolving Scenario, the increase is limited as behavioral and technological changes associated with the pandemic (less international travel and increased remote work) continue to depress global crude oil demand. These dynamics maintain a competitive global crude oil market, which keeps prices near recent average levels. In the longer term, increased global action on climate change, which reduces demand for crude oil, puts downward pressure on prices relative to the Reference Scenario. In the Evolving Scenario, the Brent price peaks at 2019 US$55 before declining to $50 by the end of the projection period. In the Reference Scenario, crude oil prices rise to 2019 US$75/bbl for the majority of the projection period. In both scenarios, WTI, a key North American crude benchmark, is 2019 US$4.00 lower than Brent in the long term.

Table A.2: **Announced Crude Oil Capacity Additions**

	Enbridge Line 3	Keystone XL	Trans Mountain Expansion
Announced in-service date	2019	2023	2022
Expected date at full capacity	2021	2023	2023
Full capacity (Mb/d)	370	830	540

Both EF2020 scenarios assume that the Canadian heavy benchmark price is discounted to WTI at a level consistent with the historical average. The WTI-WCS differential is 2019 US$12.50 for most of the projection. Both the Evolving and Reference Scenarios assume that additional pipeline capacity will become available in western Canada in the early 2020s, based on announced online dates for Enbridge's Line 3 Replacement Project, the Trans Mountain Expansion (TMX), and Keystone XL.

The assumed capacities and in-service dates of additions to existing systems are as announced by the operators of those pipelines. Likewise, the capacity and timing of the three pipelines included in Table A.2 are as per the announcements of the operators.[9]

Figure A.3:
Brent Crude Oil Price Assumptions to 2050, Evolving and Reference Scenarios

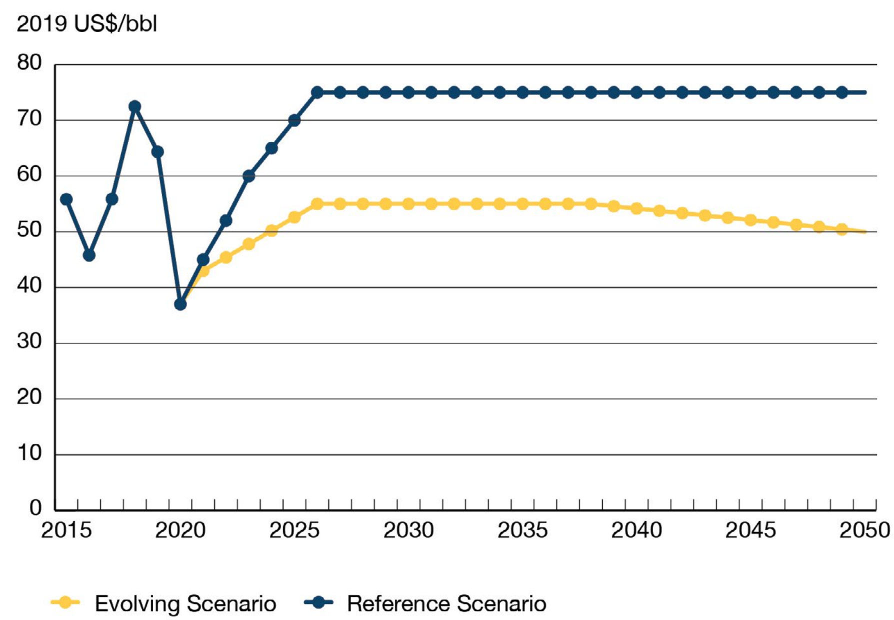
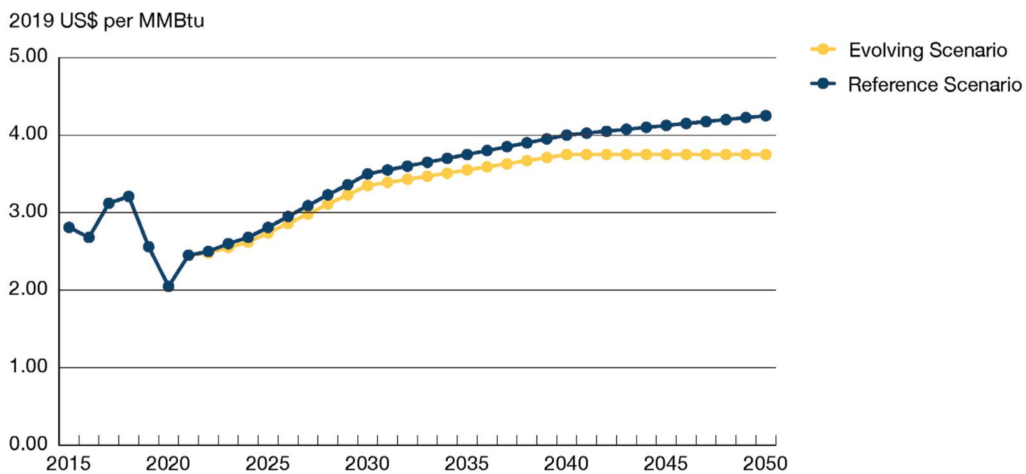


Figure A.4 shows the EF2020 natural gas price assumptions for the Evolving and Reference scenarios. Henry Hub, a key North American benchmark price, declines in 2020 in response to the COVID-19 pandemic, although to a lesser extent than oil. Western Canada Sedimentary Basin (WCSB) gas prices began to rebound late in 2019 and remain higher than recent lows, despite a well-supplied market. An assumed rising long-term price in both scenarios balances the market as demands for North American natural gas increase. Over the projection period, the Henry Hub price is assumed to increase gradually, reaching 2019 US$3.75 by 2040 in the Evolving Scenario. In the Reference Scenario, natural gas prices are assumed to rise faster, reaching 2019 US$4.25 by 2050, consistent with greater North American demand growth and LNG exports than in the Evolving Scenario.

Figure A.4:
Henry Hub Natural Gas Price Assumptions to 2050, Evolving and Reference Scenarios



Factors Currently Affecting Oil Markets:

- Global crude oil supply and demand.
- Pace and extent of COVID-19 recovery.
- Incremental pipeline and rail capacity in western Canada.
- Government regulations.
- Increased environmental, social, and governance (ESG) considerations.

A Global Evolving Energy System

In EF2020, we focus on Canada's energy system. However, global dynamics critically influence how technology and energy market trends evolve over the projection period. The assumptions discussed in this section provide a link to this global context, particularly benchmark price and technology cost assumptions. The Evolving Scenario considers the impact of continuing the historical trend of increasing global action on climate change.

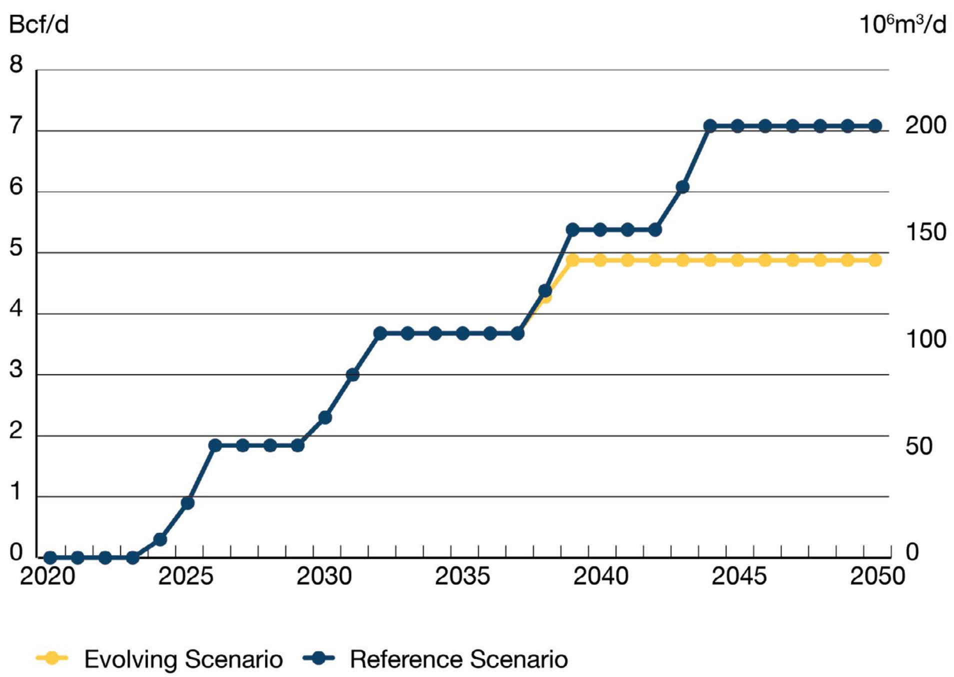
Accordingly, on the basis that global policy and technology developments will constrain demand for fossil fuels, we assume lower benchmark prices for crude oil and natural gas in the Evolving Scenario. Similarly, on the basis of greater global adoption of emerging technologies, such as EVs, battery storage, and renewable electricity, we assume continued cost declines and efficiency gains for those technologies.

EF2020 assumes a narrowing differential between western Canadian and U.S. natural gas prices in the short term. This is consistent with the recent increased NIT prices. Several projects have recently come online, and additional pipeline expansions are planned for the Nova Gas Transmission Ltd. (NGTL) System, as well as Enbridge's BC Pipeline. Over the long term, the Henry Hub-NIT differential remains around 2019 US$0.90/million British thermal units (MMBtu).

EF2020 assumes LNG export volumes from Canada as shown in Figure A.5. These volumes include Phase 1 of the LNG Canada project, which has a final investment decision and is currently under construction. They also include an assumption of additional volumes that are not specific to a particular project. The Reference Scenario assumes greater LNG exports than in the Evolving Scenario beginning in 2039. Future LNG development is uncertain and could be significantly different than these assumptions. For both scenarios, we assume that 75% of LNG feedstock will come from natural gas production dedicated to supplying LNG facilities.

Figure A.5:

Canadian LNG Export Volume Assumptions to 2050, Evolving and Reference Scenarios



Factors Currently Affecting Natural Gas Markets:

- Increased North American production.
- U.S. LNG exports.
- WCSB and export pipeline capacity.
- Oil sands demand for natural gas and condensate.
- Potential Canadian LNG and liquefied petroleum gas (LPG) exports.
- Increased ESG considerations.

Electricity

The analysis in EF2020 reflects current utility and system operator expectations of future electricity developments in their respective regions, especially for major planned projects. We also make assumptions on the cost to add new electricity generating capacity in the future. Table A.2 shows assumptions for natural gas, solar, and wind costs, including their capacity factors. Current schedules and plans from utilities, companies, and system operators are the primary basis for the timing and magnitude of other forms of generation added over the projection period (such as hydroelectric and nuclear refurbishments).

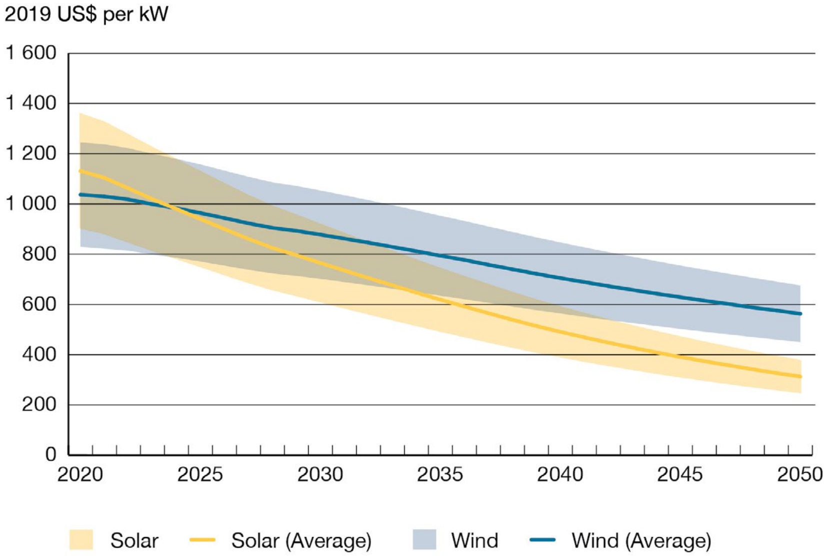
As discussed earlier in this section, costs for wind, solar, and other emerging technologies are lower in the Evolving Scenario than the Reference Scenario. This assumes a stronger global shift towards these low carbon technologies, and that advancements and efficiencies continue to lower their costs and improve their performance.

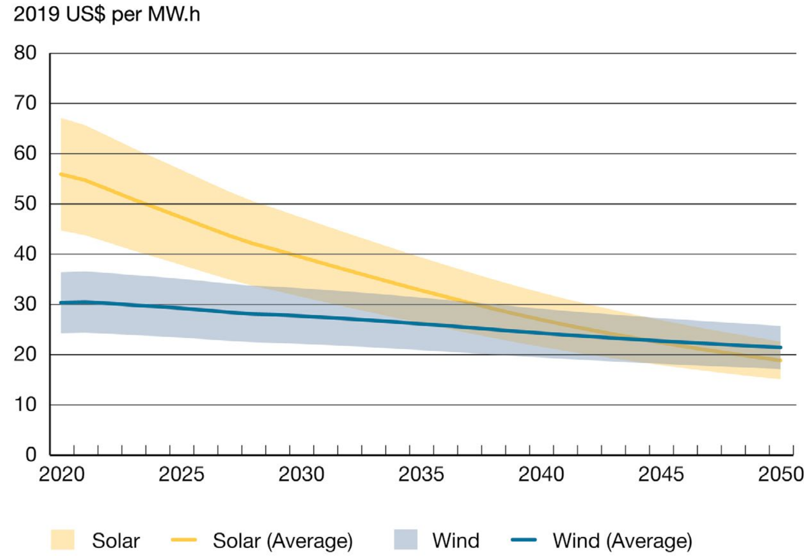
Figure A.6 shows assumed average levelized costs of onshore wind and utility scale solar for the Evolving and Reference scenarios. The levelized cost includes all project costs over its lifetime (operating, fuel, financing, capital costs etc.) along with assumptions about capacity factor and project life. The ranges around the wind and solar figures highlight the variability, and importance of these other factors, in determining the ultimate cost of the resources.

Table A.3: **Electricity Cost Assumptions for Natural Gas, Onshore Wind, and Utility Scale Solar to 2050, Evolving and Reference Scenarios**

	Capital Cost (2019 US$/ kilowatt (kW))	Fixed Operating and Maintenance Costs (2019 US$/kW)	Variable Operating and Maintenance Costs (2019 US$/ megawatt hour (MW.h))	Capacity Factor (%)[10]
Gas (Combined Cycle)	1 100-1 450	16	4	70
Gas Peaking	800-1 100	14	4	20
Wind (2020)	1 036	20-45	0	35-50
Solar (2020)	1 131	16-20	0	10-20
EVOLVING SCENARIO				
Wind (2030)	877	20-45	0	35-50
Wind (2040)	705	20-45	0	35-50
Wind (2050)	562	20-45	0	35-50
Solar (2030)	765	16-20	0	10-20
Solar (2040)	491	16-20	0	10-20
Solar (2050)	313	16-20	0	10-20
REFERENCE SCENARIO				
Wind (2030)	1 020	20-45	0	35-50
Wind (2040)	998	20-45	0	35-50
Wind (2050)	936	20-45	0	35-50
Solar (2030)	887	16-20	0	10-20
Solar (2040)	650	16-20	0	10-20
Solar (2050)	470	16-20	0	10-20

Figure A.6:
Wind and Solar Capital Costs and Levelized Cost[11] Assumptions to 2050, Evolving Scenario





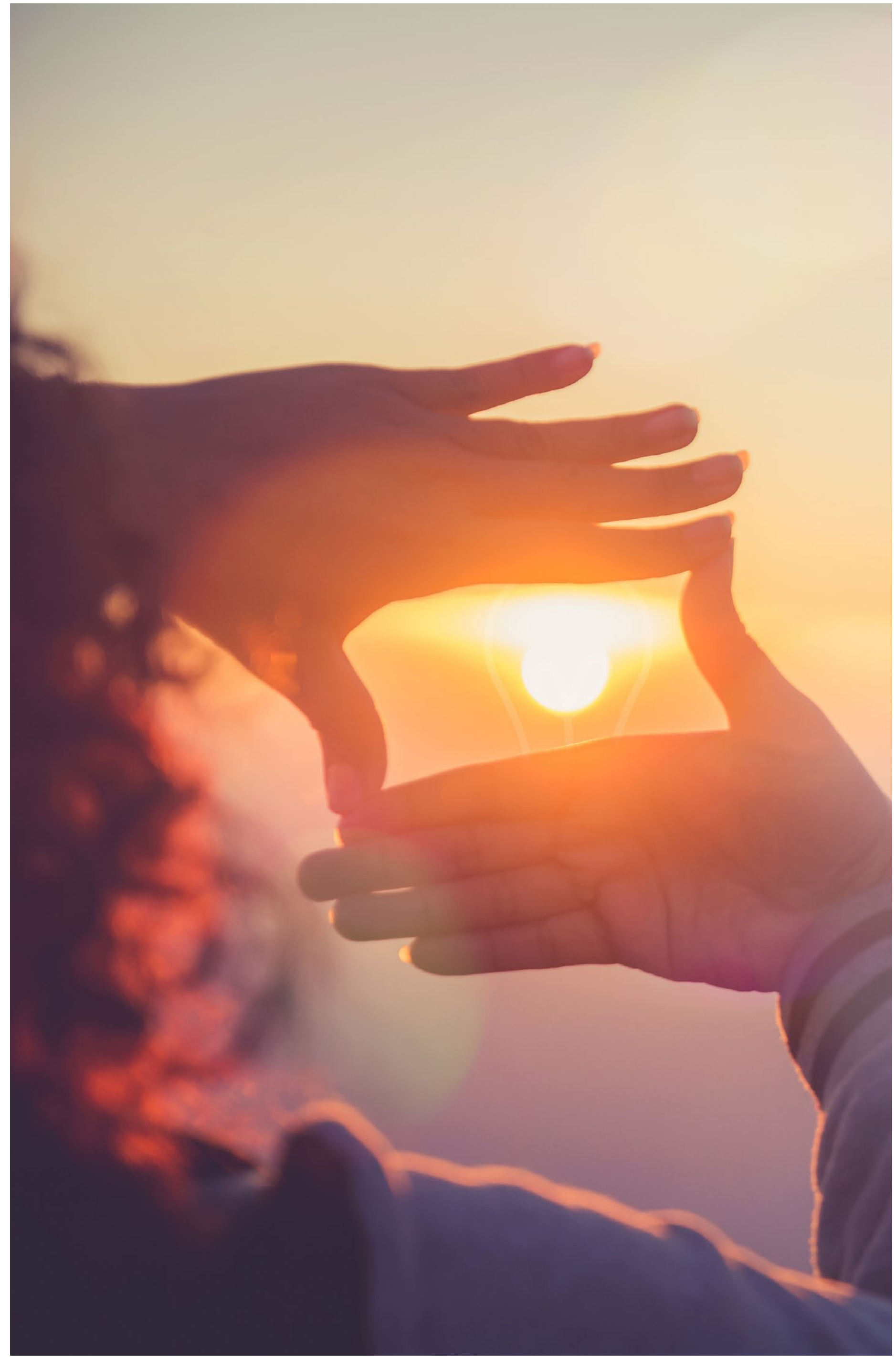
Factors Currently Affecting Electricity Markets:

- Moderate electricity demand growth in Canada and U.S.
- Pace and nature of COVID-19 recovery and impact on electricity demand.
- Electricity pricing in export markets.
- Federal and regional climate policies such as coal retirement and carbon pricing systems.
- Decline in cost for non-hydro renewables, particularly for solar and wind technologies.
- Aging infrastructure and reliance on diesel in remote communities.

Results

This section presents results of the EF2020 projections. The primary focus is the Evolving Scenario. These projections are not a prediction, but instead present possible future outcomes based on the assumptions described in the previous section. There are many factors and uncertainties that will influence future trends. Key uncertainties are included for each section.

For a description of the various ways to access the data supporting this discussion, see the "Access and Explore Energy Futures Data" section.



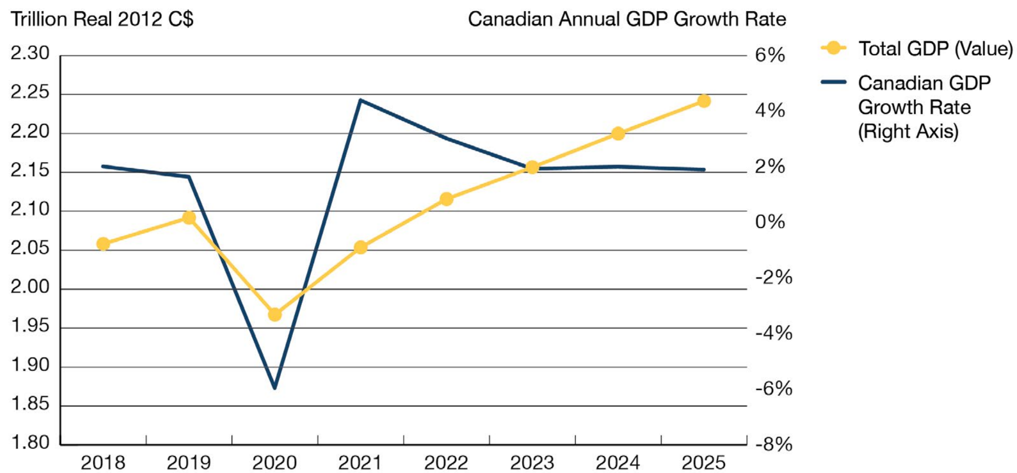
Macroeconomics

The economy is a key driver of the energy system. Economic growth, industrial output, inflation, exchange rates, and population growth all influence energy supply and demand trends.

In the near term, we assume that the impacts of COVID-19 are strongest in 2020, with gradual recovery beginning in 2021. As shown in Figure R.1, total GDP declines 6.0% in 2020,[12] grows by 4.4% in 2021, and recovers to pre-pandemic levels in 2022.

The long-term projections for key economic variables are in Table R.1. Real economic growth averages 1.4% per year over the projection period in the Evolving Scenario. Economic growth over the projection is generally slower than the 1990-2018 historical period for a variety of reasons, including an aging population and slower global economic growth.

Figure R.1:
GDP Decreases Sharply in 2020 and Rebounds



KEY UNCERTAINTIES:
Macroeconomics

COVID-19 pandemic recovery: Recovery from COVID-19 is a key uncertainty for global, North American, and Canadian macroeconomic growth.

International demand for Canadian goods: International demand for Canadian goods impacts export-oriented industries. Faster or slower economic growth in the U.S., Canada's largest trading partner, would affect Canada's economic growth and energy demand projections.

Global economic growth: Global economic growth affects many factors that are important for Canada's economy, including commodity prices, and demand for Canadian energy and non-energy exports.

Large infrastructure projects: Projects in the mining, oil, natural gas, and electricity sectors affect the macroeconomic projections in a number of provinces. The pace of these developments is uncertain and could lead to higher or lower economic growth, and impact energy trends.

Table R.1: **Economic Indicators, History, Evolving and Reference Scenarios**

Average annual % growth unless otherwise noted.

Economic Indicators	1990-2018	Evolving Scenario (2019-2050)	Reference Scenario (2019-2050)
Real gross domestic product	2.7%	1.41%	1.56%
Population	1.0%	0.8%	0.8%
Inflation	1.7%	1.9%	2.0%
Exchange rate (C$/US$), average	0.81	0.77	0.79
Residential floor space	2.1%	1.5%	1.5%
Commercial floor space	1.8%	1.6%	1.7%

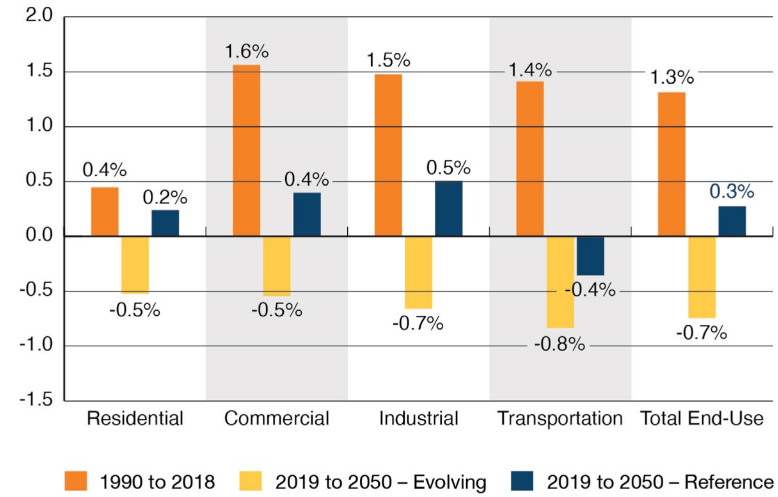
Energy Demand

This section focuses on end-use, or secondary energy demand, when looking at energy use by sector of the economy. It focuses on primary energy demand when looking at economy-wide energy use. End-use demand includes electricity, while the fuel used in generating electricity is accounted for in primary demand. Historical data is sourced primarily from Statistics Canada's Report on Energy Supply and Demand in Canada. That data is supplemented with additional details from ECCC, Natural Resources Canada, and various provincial data sources.

In the near term, energy use follows macroeconomic trends and declines 5.6% in 2020, and then recovers in the next two years. Following the recovery, the Evolving Scenario projects Canadian energy use to decline until 2050. Figures R.2 and R.3 break energy use down by sector, showing declines in all sectors. The largest declines are in the industrial (including upstream oil and gas) and transportation sectors. These declines are due to factors such as improved energy efficiency, gradual electrification of the transportation sector,[13] and various policies like carbon pricing. Economic growth and near-term increases in crude oil and natural gas production (discussed later in this section) provide some upward pressure on energy use. However, economic growth is slower than historical trends, and crude oil and natural gas production eventually declines. In the Reference Scenario, lack of additional climate policy action beyond current policies, higher crude oil and natural gas production, and less electrification leads to moderate demand growth in the projection, although at levels lower than recent history.

Energy use trends vary by sector, and within the sectors they vary by energy type. See Figure R.4. These trends result from several drivers, including macroeconomics, energy production trends, energy efficiency improvements, policies, technology advancements, and market developments. The transportation sector undergoes a notable shift. RPPs such as gasoline, diesel, and jet fuel have historically dominated the transportation sector, and this begins to change in the Evolving Scenario. Improved fuel economy, as well as electrification, cause transportation energy use to decline over the projection. For passenger transportation, electric vehicles grow gradually from a small share of personal vehicles to an important part of the transportation mix. Driven by falling costs, as well as steadily increasing policy support, ZEVs, including battery electric and plug-in hybrid electric, represent one out of every two passenger vehicles purchased by 2050. Electric freight, particularly light-to-mid-duty, and hydrogen-powered freight (mid-to-heavy duty), and increasingly electrified public transportation (electric bussing) grow steadily in the 2030s and 2040s.

Figure R.2:
End-use Demand Declines in All Sectors in the Evolving Scenario

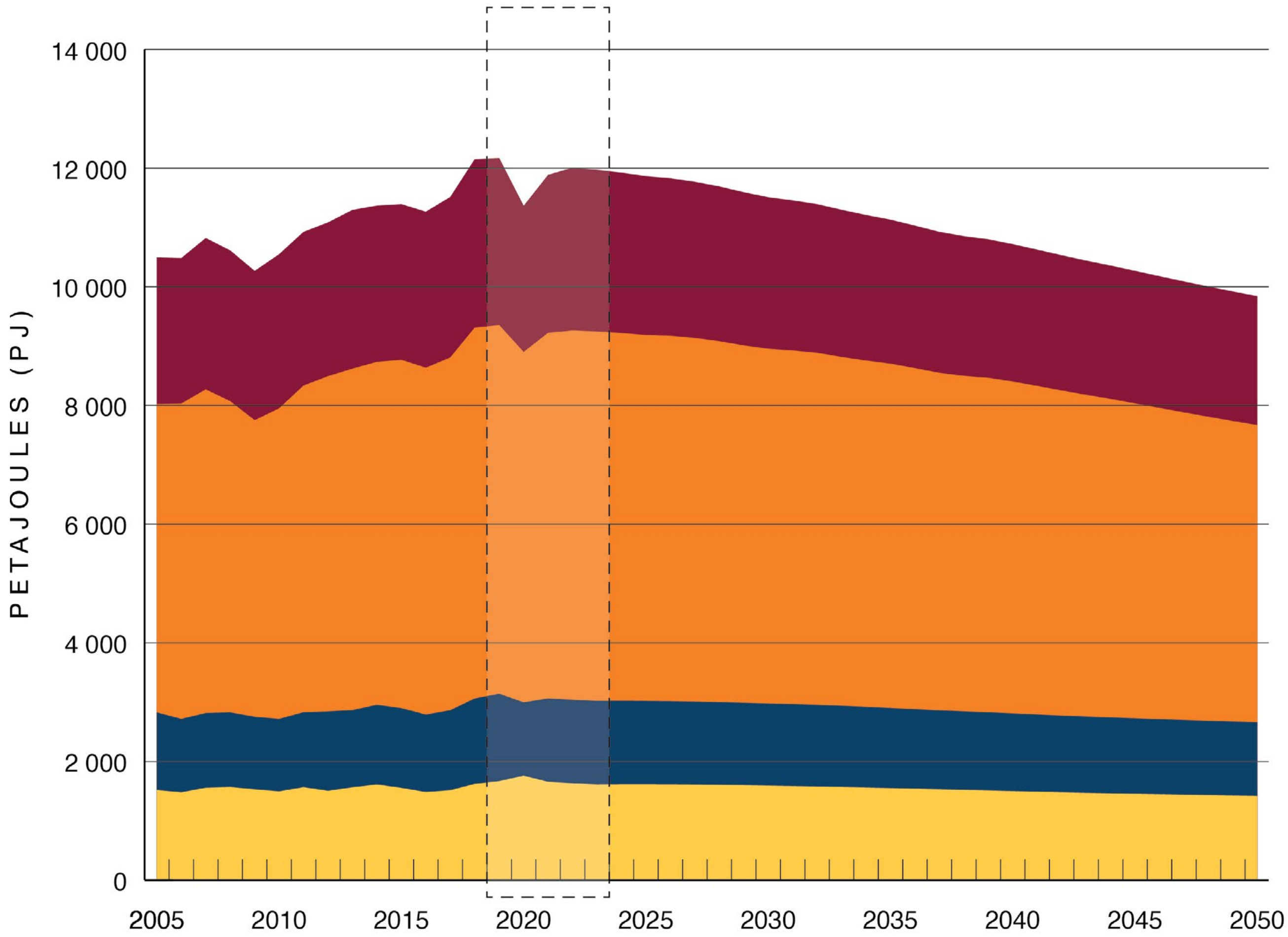


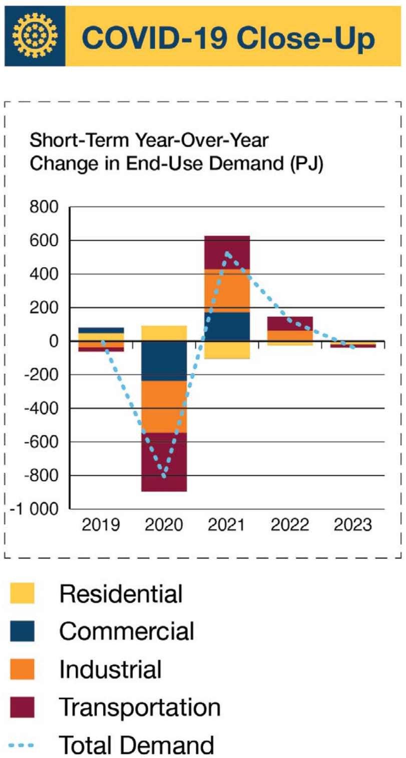
KEY TRENDS:
Energy Demand

- Energy use declines in the Evolving Scenario, and grows slowly in the Reference Scenario.
- Historical growth rates are higher than both scenarios.
- The mix of energy sources that Canadians use continues to change. Use of natural gas and renewables increases; coal and RPP use declines.
- Energy use grows slower than population and GDP, implying a decline in energy use per person and per dollar of economic activity.

Figure R.3:

End-Use Energy Consumption Peaks in 2019 and Declines over the Long Term in the Evolving Scenario





In this analysis, primary demand is the total amount of energy used in Canada. Primary demand is calculated by adding the energy used to generate electricity to total end-use demand, and then subtracting the end-use demand for electricity.

Figure R.5 illustrates the projection of primary demand by fuel for the Evolving Scenario, compared with total primary demand in the Reference Scenario. In the Evolving Scenario, total demand gradually falls, driven by declining fossil fuel use. Coal demand declines considerably due to declining coal-fired power generation. Oil demand falls along with improving energy efficiency and electrification of the transportation sector. Demand for non-energy oil products, such as asphalt, lubricants, and feedstocks are relatively stable, which supports overall demand of oil products. Natural gas demand sees significant growth in the near term, driven by increasing crude oil and natural gas production (both large users of natural gas) as well as its increasing role in power generation.

Driven by increased electrification at the end-use level, overall electricity demand rises steadily in the Evolving Scenario. This leads to stable demand for nuclear power and growth in renewable power as major hydro projects are completed, and wind and solar costs continue to fall. Renewables become an increasingly important part of the energy mix. Increased blending of renewable fuels in liquid fuels and natural gas also support increasing renewable demand.

Energy use grows much slower than both the economy and Canada's population, implying energy intensity–measured in energy use per capita or per $ of real GDP–declines. This is summarized in Figure R.6. From 2019 to 2050, real GDP increases over 60% and population increases over 30% in the Evolving Scenario. Primary energy use declines 18%. These different trends imply that energy use per $ of real GDP declines nearly 50% from 2019 to 2050, while energy use per person declines nearly 37%.

Figure R.4:
End-Use Energy Demand Trends Vary by Sector and By Fuel

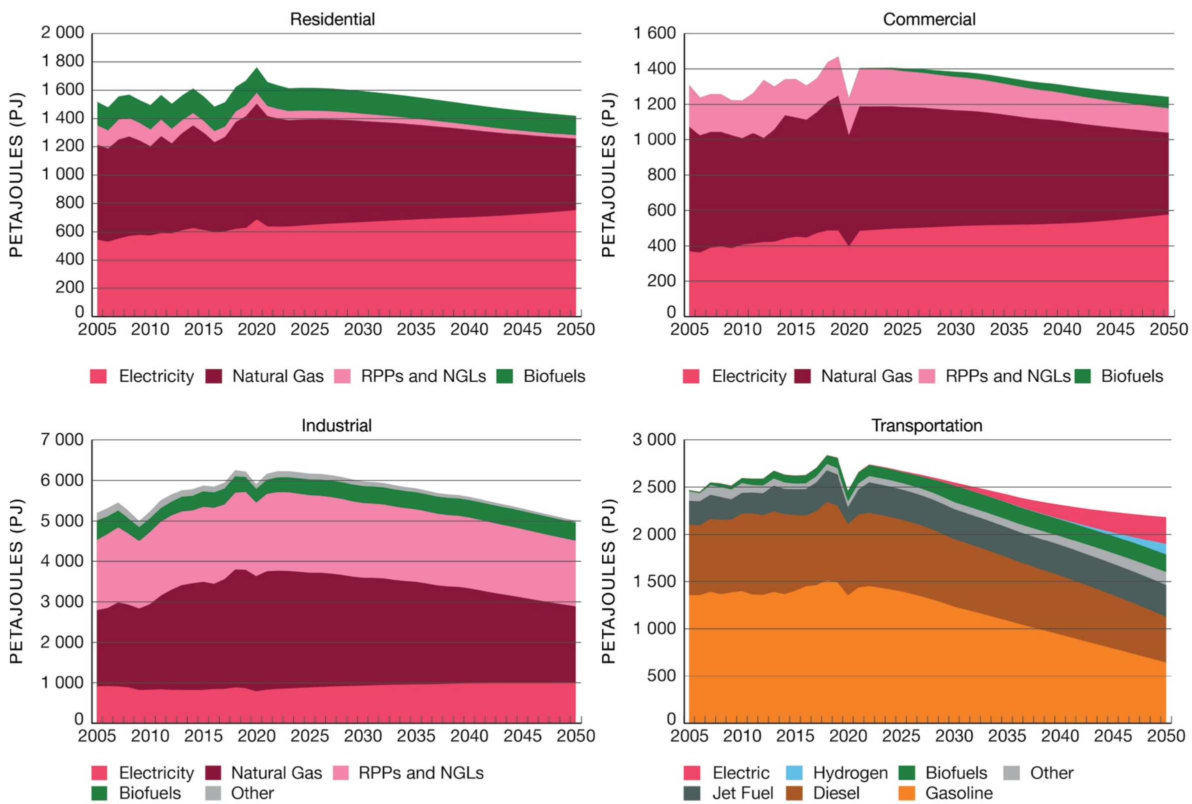


Figure R.5:
Primary Demand Gradually Declines and Renewables Account For a Larger Share in the Evolving Scenario

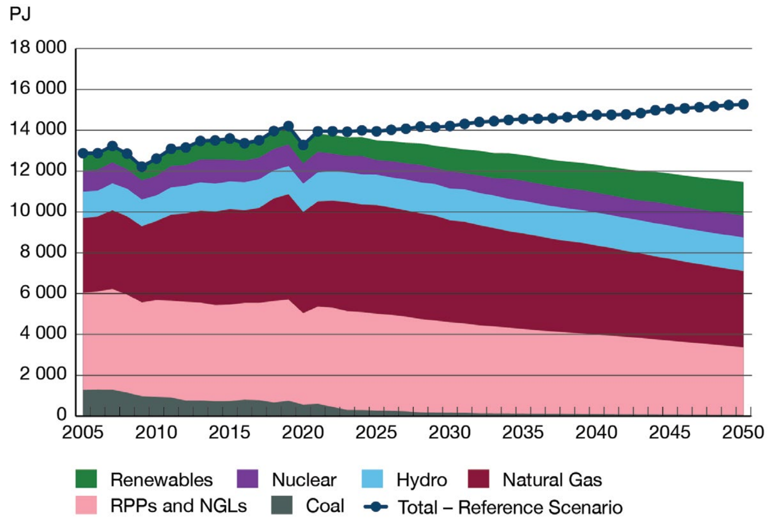
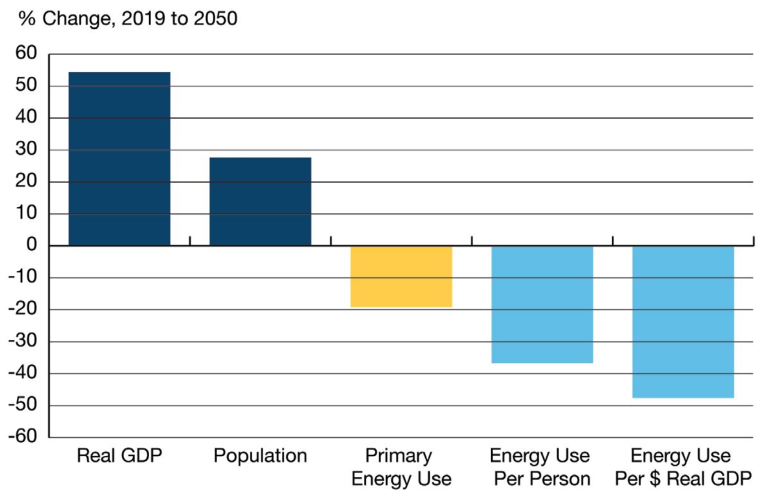


Figure R.6:
The Economy Grows Faster than Energy Use, and Energy Intensity Declines in the Evolving Scenario



KEY UNCERTAINTIES:
Energy Demand

Technological influences: The impacts of technology on the energy system can be substantial and difficult to predict. The Evolving Scenario continues the momentum for increased use of established technologies, and allows for the adoption of new technologies. The pace and type of new technological adoption may differ significantly from those assumed in the Evolving Scenario.

Oil and natural gas industry transformations: In the past decade, the oil and natural gas industry has undergone rapid transformations in both the types of resources extracted and the technologies used to extract them. Depending on the future development of these resources and technologies, the energy used in this sector may be higher or lower than this projection.

Alternative fuels and new end-uses: The Evolving Scenario shows a shift towards electricity, supported by increasing use of renewables. It also features moderate adoption of hydrogen and renewable natural gas. Faster electrification of the economy, or growth in alternative fuels, could lead to different trends compared to those shown here.

Crude Oil

Crude oil is produced in Canada for domestic refining as well as for exports. In 2019, Canadian crude oil production averaged 4.9 million barrels per day (MMb/d) (784 thousand cubic metres per day (10^3m^3/d)). Recent growth has been dominated by new oil sands facilities coming online. Production is mostly in Alberta, with additional volumes in Saskatchewan and offshore Newfoundland and Labrador.[14]

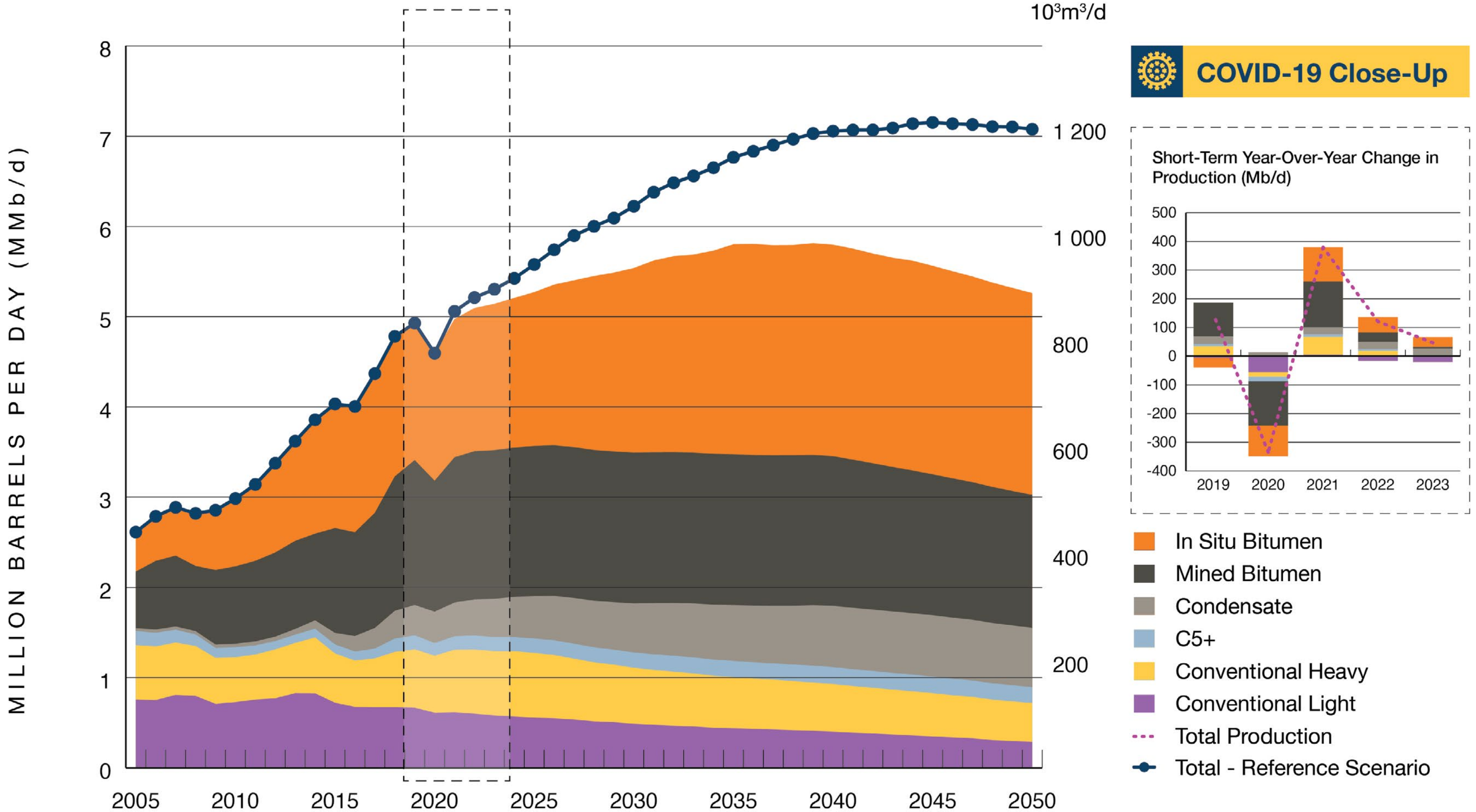
Figure R.7 shows the outlook for Canadian crude oil production by type in the Evolving Scenario, compared to total Reference Scenario production. Canadian crude oil production in the Evolving Scenario peaks at 5.8 MMb/d in 2039 and declines to 5.3 MMb/d (836 10^3m^3/d) in 2050, an increase of 7% from 2019. For comparison, production peaks at 7.2 MMb/d (1 137 10^3m^3/d) in 2045 in the Reference Scenario, driven by higher crude oil price assumptions and a lack of future domestic and global climate policy action.

KEY TRENDS:
Crude Oil Production

- Production grows through much of the projection period, peaking in 2039 at just over 5.8 MMb/d. Assumptions of increased takeaway capacity from western Canada and prices underpin this growth. Longer term, lower assumed crude oil prices lead to declines in production.
- From 2019 to 2040, crude oil production increases 20%. Between 2040 and 2050 production decreases by 8%.
- In situ bitumen production grows 37% over the projection period.
- Mined bitumen production peaks in 2026 at 1.7 MMb/d, declining thereafter to 1.5 MMb/d by 2050.

Figure R.7:

Total Crude Oil Production Peaks in 2039 and then Declines through 2050 in the Evolving Scenario



Production growth in the oil sands continues in the near term, led by new phases of existing in situ projects. It peaks in 2039 and declines slightly through 2050 in the Evolving Scenario, as shown in Figure R.8. These additions are profitable given Evolving Scenario price levels and technology improvements that increase productivity.

Conventional, tight, and shale production is classified as light or heavy, depending on the API gravity of the oil. In 2019, 49% of western Canadian conventional production was heavy, 51% was light. Near-term production in these categories is stable primarily due to increases in tight light oil production in Alberta along with growing heavy oil production in Saskatchewan. Tight oil growth is based on producers' preference to target wells which have higher initial production rates and a quicker return on investment. Growth in Saskatchewan's heavy oil production is due to the low cost and low decline rates of heavy oil reservoirs in that province. See Figure R.9.

Currently, the majority of condensate production comes from Alberta. Growth in condensate production in the projection period occurs in Alberta and B.C., as producers focus on liquids-rich natural gas plays like the Montney Formation and the Duvernay. See Figure R.10. Condensate is used in a number of industrial processes, most notably as a diluent for bitumen and heavy oil.

Newfoundland offshore production in the Evolving Scenario gradually declines as shown in Figure R.11. We assume no new discoveries in the Evolving Scenario. Additional discoveries and developments could change these trends.

Figure R.8:

Oil Sands Production Growth Peaks in 2039 and then Declines Slightly throughout the Projection Period in the Evolving Scenario

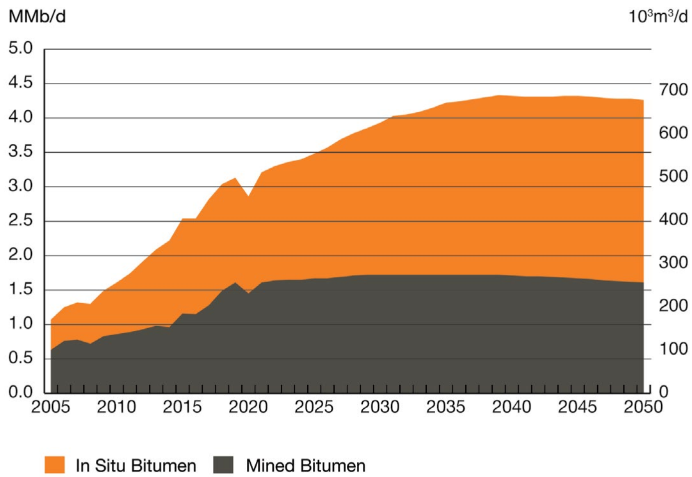


Figure R.9:

Conventional Oil Production Decreases Steadily over the Projection in the Evolving Scenario after a Brief COVID-19 Recovery Increase in 2021

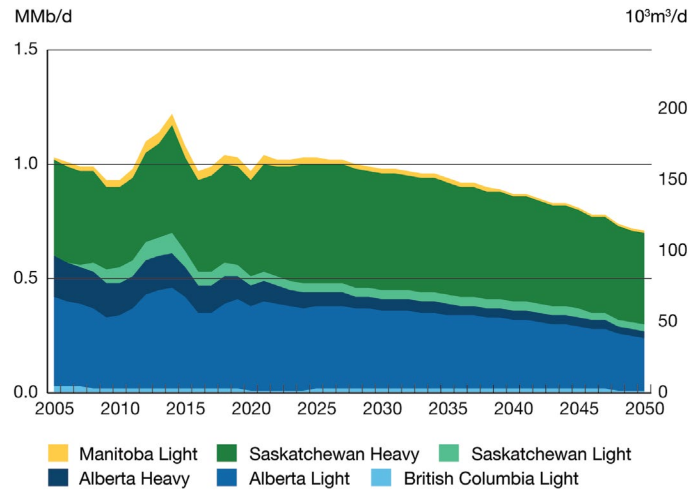


Figure R.10:

Condensate Production Driven by Increasing Diluent Demand in the Evolving Scenario

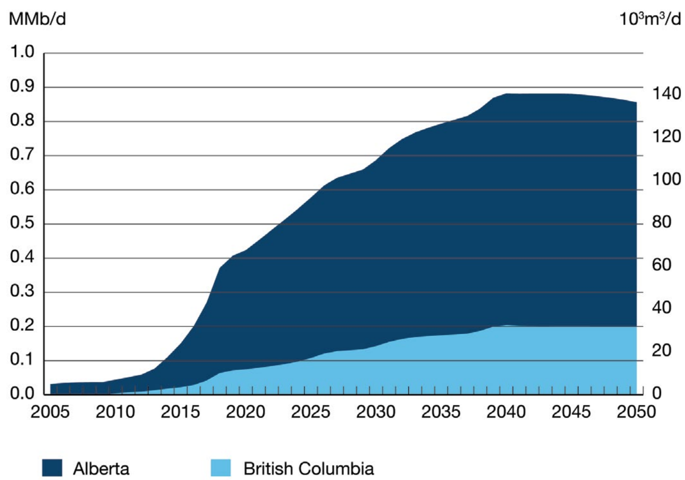
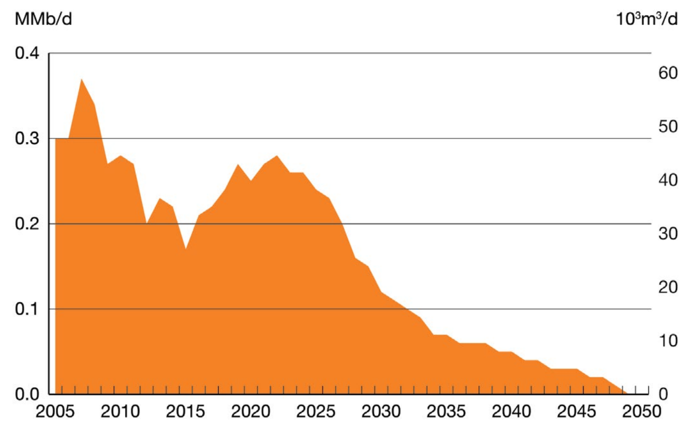


Figure R.11:

Newfoundland Offshore Oil Production Increases in the Near Term and then Steadily Declines to 2050 in the Evolving Scenario

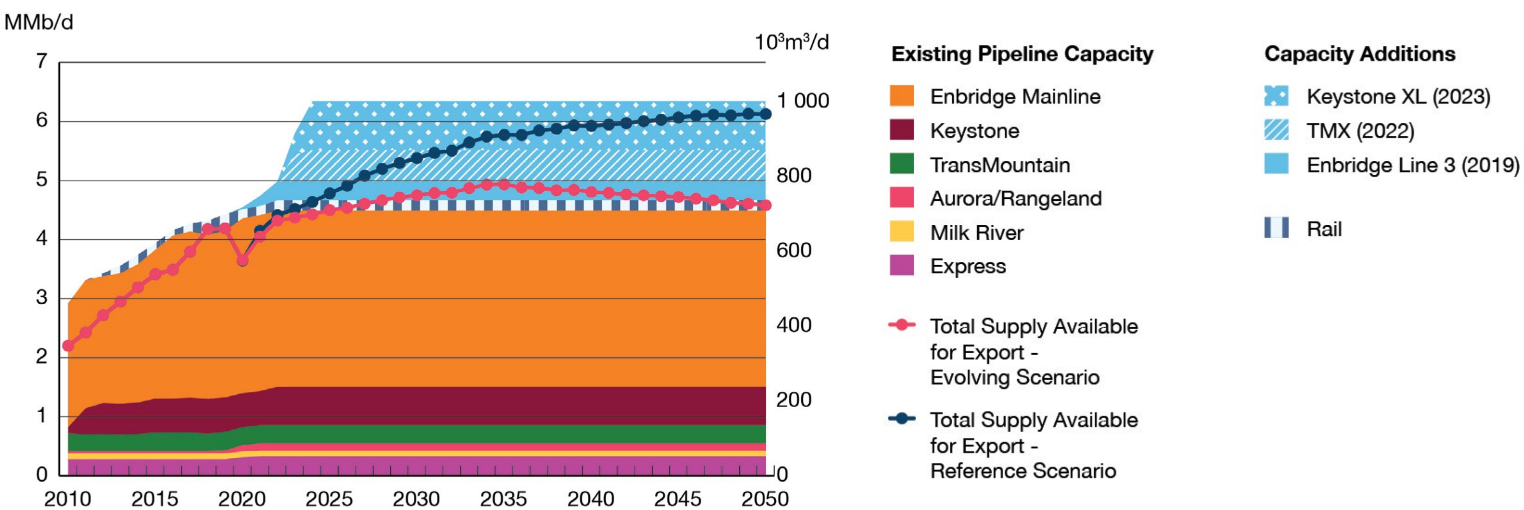


A recent trend in Canadian oil markets[15] has been production growth in the WCSB outpacing increases in pipeline capacity. Figure R.12 provides a detailed look at available supply from the WCSB and takeaway capacity in the Evolving Scenario. The available capacity of a pipeline is the volume of crude oil it can safely transport while considering the type of crude being transported, planned and unplanned outages, downstream constraints and pressure restrictions; among other factors.[16]

Crude-by-rail volumes are included as companies may choose to export crude oil by rail due to a number of reasons. These include existing contractual commitments, ownership of the required infrastructure, and arrangements with specific refineries.

Figure R.12:

Crude Oil Pipeline Capacity vs. Total Supply Available for Export in the Evolving and Reference Scenarios



Note: While the Evolving Scenario does project that, in some years, crude oil available for export is significantly lower than total pipeline capacity, this should not be interpreted as the Energy Futures Report concluding that any pipeline should or should not be built. The report does not assess the many factors that go into whether a pipeline is needed, including the value of access to new markets and the role of spare pipeline capacity in responding to temporary or lasting changes in markets.

The assumed capacities and in-service dates of additions to existing systems are as announced by the operators of those pipelines. Likewise, the capacity and timing of the three pipelines included in Table R.2 are as per the announcements of the operators.

Table R.2: **Announced Crude Oil Capacity Additions**

	Enbridge Line 3	Keystone XL	Trans Mountain Expansion
Announced in-service date	2019	2023	2022
Expected date at full capacity	2021	2023	2023
Full capacity (Mb/d)	370	830	540

Dive Into Crude Oil Production

Data and analysis on crude oil production and other commodities is available by region, type, and scenario. Visit our visualization tool, *Exploring Canada's Energy Future*. A dedicated summary of oil production is also available in our Fact Sheets: *Oil Sands Production*, and *Conventional, Tight, and Shale Oil Production*.

New Technology in Oil Sands Production

In the Evolving Scenario, we assume that technological improvement in extraction and upgrading methods of existing projects continues on the same pace as recent history. This improvement leads to significantly improved per-barrel emissions.

Much of the growth in oil sands production is in the form of expansions to existing facilities. By the end of the projection, facility expansions make up 15% of all oil sands production, or just over 600 Mb/d. Growth also comes from new facilities. No new oil sands mining or upgrading facilities come online over the projection period. However, new in situ facilities make up 8% or 340 Mb/d of total oil sands production from 2019 to 2050. We assume new or expanded facilities, which begin production after 2025, use the following technologies[1] to lower their emissions intensity:

Steam and pure solvents: The injection of heated solvents (typically a mixture of natural gas liquids (NGLs)) into the reservoir to replace the steam generation units currently in use, lowering emissions. This process also leaves some of the less desirable components within bitumen (asphaltenes) in the reservoir.

In-pit extraction: A technique, currently being developed by Canadian Natural Resources Limited at its Horizon Oil Sands mine, which involves separating oil sands ore into its component parts within the extraction pit of the operation. This method requires comparatively less heavy equipment and electric power, resulting in less emissions per barrel.

Each of these processes also has the potential to reduce the per barrel cost to produce bitumen, helping to offset the higher environmental compliance costs and lower commodity prices assumed in this scenario. Pure solvents have the potential to reduce per barrel costs by up to $3.40, while in-pit extraction could lower costs by $2.00 per barrel.

Each of the processes described above has the potential to increase the productivity of projects compared to conventional in situ projects. The estimates vary, with some showing no significant productivity uplift and others, like MEG Energy's eMVAPEX, showing an uplift of up to 76%. For the purposes of our projections, we have chosen to not model a production uplift associated with the technologies.

[1] There are many potential technologies to reduce the emissions intensity of oil sands production. See the "Towards Net-Zero" section on oil sands production for further details.

KEY UNCERTAINTIES:
Crude Oil Production

Future crude oil demand: COVID-19 continues to add uncertainty to both short and long-term projections. The extent to which global economies return to energy consumption levels more typical of the previous five year average, and the timing of that return, is a major uncertainty for future crude oil demand. Future global climate action and its impact on global crude oil demand and prices is another important uncertainty.

Technological development in the oil sands: The need to reduce GHG emissions and costs are two significant factors in the future development of oil sands facilities. Technologies are currently being developed to address both of these factors although their potential adoption is uncertain. As in previous editions of *Energy Futures*, EF2020 assumes that companies continue to work towards lowering both the cost, and GHG emissions, of their operations.

Western Canadian takeaway capacity: EF2020 assumes that over the projection period additional takeaway capacity is available to transport increasing production. This additional capacity is in the form of new pipeline infrastructure. In addition, technological advances that either increase the amount of oil that can flow on existing infrastructure, or decrease the amount of diluent required to transport bitumen, could play a larger role in the future.

ESG considerations: The investment community is shifting its attention towards firms that align with their values on ESG performance criteria.[17] Organizations that embed ESG frameworks into their fundamental values can strengthen their resilience to economic and environmental pressures.[18] The extent and nature to which ESG considerations alter future upstream investment trends could affect future production trends.

Natural Gas

In Canada, natural gas is produced for domestic use and exports. In 2019, Canadian marketable natural gas production averaged 15.7 Bcf/d or 445 million cubic metres per day ($10^6m^3/d$).

Natural gas production in Alberta has been relatively flat over the last few years, while B.C. production has been steadily increasing since 2010. This increase has been driven by a variety of factors including:

- Drilling to evaluate natural gas resources expected to supply LNG exports off of Canada's west coast.
- NGLs in the Montney tight gas play driving drilling and production despite lower natural gas prices.

In the Evolving Scenario, natural gas production from new wells is just enough to keep pace with the declining production from existing wells in the near term. As a result, total production is level until 2025. In the longer term, rising prices and the onset of LNG exports support higher capital expenditure and production growth. This leads to more natural gas wells and production in the WCSB, with total Canadian production peaking in 2040 at 18.4 Bcf/d (521.4 $10^6m^3/d$). After 2040, we assume no new additional LNG exports, and prices are too low to support adequate drilling to keep up with existing well declines. This results in production continuously decreasing to 16.8 Bcf/d (474.4 $10^6m^3/d$) by 2050, as shown in Figure R.13. Without additional production to feed LNG exports, production would continuously decline over the projection period to 13.0 Bcf/d (369 $10^6m^3/d$) in 2050.

In the Reference Scenario, higher gas prices and higher LNG export assumptions lead to continued increasing natural gas production in the longer term, reaching 23.5 Bcf/d (665.0 $10^6m^3/d$) by 2045 and then levelling off. Reference Scenario projections are driven by higher prices, a lack of future domestic and global climate action, and higher assumed LNG exports.

Figure R.13:
Total Natural Gas Production Peaks in 2040 in the Evolving Scenario and Increases in the Long Term in the Reference Scenario

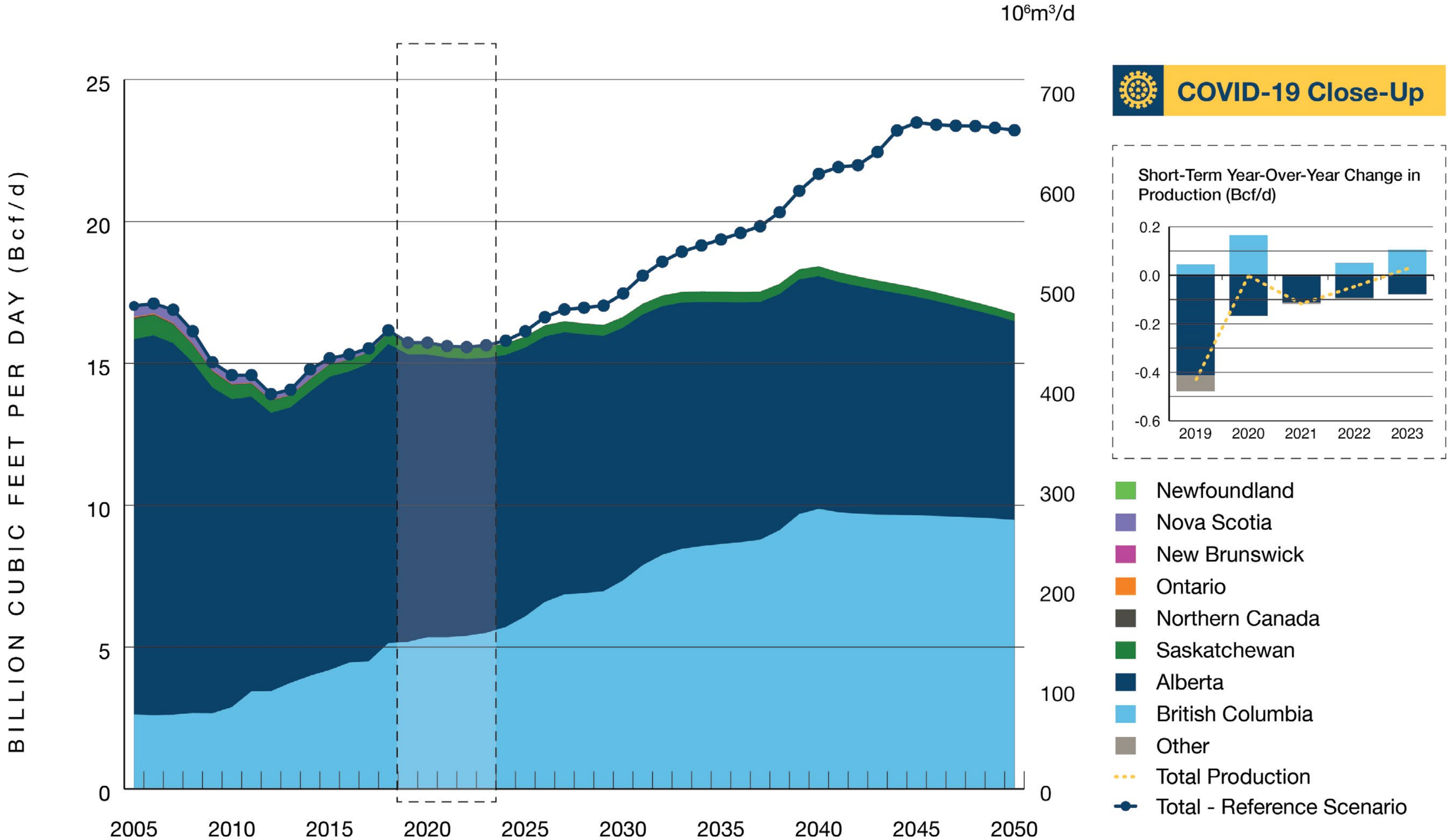


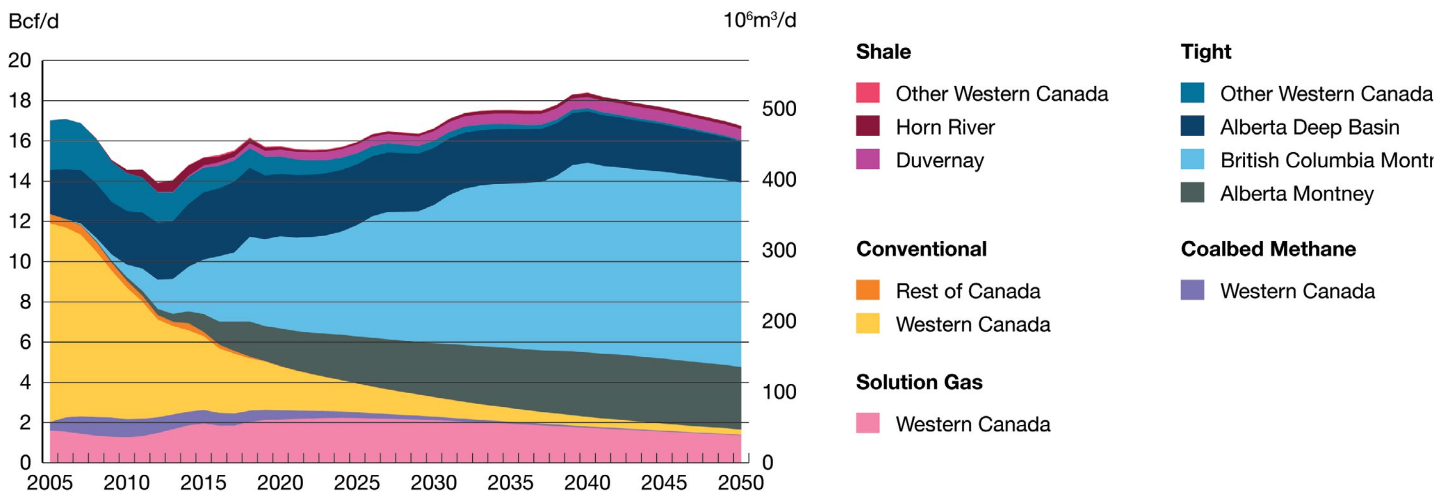
Figure R.14 shows production of natural gas by type in the Evolving Scenario. Production growth is led by tight natural gas produced from the Montney Formation, both in Alberta and B.C. Tight natural gas production from the Montney Formation has grown significantly over the past five years. Alberta Deep Basin tight natural gas production declines moderately. There is some small growth in shale gas from the Duvernay and Horn River shales, and solution gas declines slightly. Conventional gas and coal bed methane production declines significantly over the projection period.

Natural gas exports have increased over the last several years, mostly to the western U.S. Imports of natural gas have been relatively steady over the last decade, ranging from 2-3 Bcf/d (56-85 $10^6m^3/d$). Imports could potentially rise as pipeline capacity increases from the Appalachian Basin in northeastern U.S. to Dawn, Ontario.

Projected net pipeline exports, which is calculated as Canadian natural gas production less Canadian demand,[19] is shown in Figure R.15 for the Evolving Scenario. It also shows Canadian demand, production and assumed LNG exports. In the early 2020's, increasing Canadian natural gas demand and stable production lead to shrinking net exports.[20] As domestic demand declines and production ramps up after 2025, net exports start to increase. LNG exports make up the majority of net export increases. The remaining net exports are pipeline exports to the U.S., some of which could also end up as additional LNG exports from U.S. terminals.

Figure R.14:

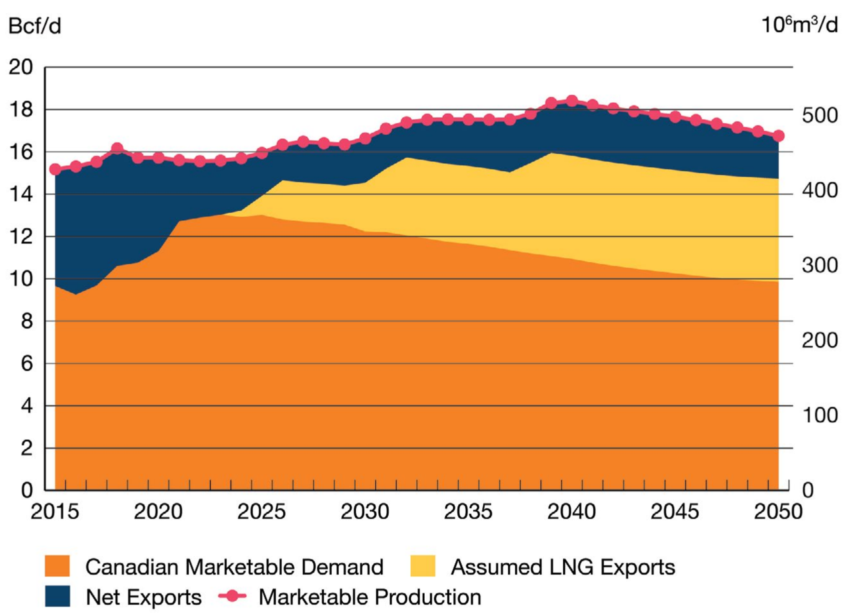
Natural Gas Production by Type Remains Steady, while the Montney Formation Continues to Increase, in the Evolving Scenario



KEY TRENDS:
Natural Gas Production

- Natural gas production levels off in the near term due to modest prices.
- Assumptions on LNG export projects, infrastructure developments, and long-term prices are the drivers for production increasing to 2040, and then declining.
- The majority of the production growth comes from Montney Formation in the form of tight gas.

Figure R.15:
Natural Gas Supply and Demand Balance sees the Increasing Importance of LNG Exports as Domestic Demand Declines in the Long Term in the Evolving Scenario



KEY UNCERTAINTIES:
Natural Gas Production

Future natural gas prices: Prices could be higher or lower, which would lead to different production results under both EF2020 scenarios.

Canadian natural gas price discounts: This analysis assumes that over the long term, all energy production will find markets and infrastructure will be built as needed. Several capacity expansions are planned in the WCSB to debottleneck pipelines and increase exports. Increased differentials for Canadian natural gas relative to Henry Hub could reduce gas production in the longer term.

LNG exports: It is possible that global market conditions and the costs of constructing a new LNG export capacity may change in the future, influencing future volumes of LNG exports from Canada in both EF2020 scenarios.

ESG considerations: The investment community is shifting its attention towards firms that align with their values on ESG performance criteria.[21] Organizations that embed ESG frameworks into their fundamental values can strengthen their resilience to economic and environmental pressures.[22] The extent and nature to which ESG considerations alter future upstream investment trends could affect future production trends.

Natural Gas Liquids

NGLs are produced along with natural gas. Natural gas production is the main source of NGL production in Canada. Demand for certain NGLs adds value to natural gas production and has been a driver of its increase. Raw natural gas at a wellhead is comprised primarily of methane, but often contains NGLs ethane, propane, butanes, condensate and other pentanes. In 2019, 1 193 Mb/d (190 10^3m^3/d) of NGLs were produced in Canada.

Figure R.16 shows that NGL production grows 40% over the projection period in the Evolving Scenario. Growth is dominated by condensate, which doubles to 2050. Condensate demand has, and will continue to, influence natural gas drilling to focus on NGL-rich plays. Condensate, along with butanes, are added to bitumen as a diluent to enable it to flow in pipelines and be loaded on to rail cars.

Propane and butanes production follows natural gas production, and increases over the projection period in the Evolving Scenario. Demand for these NGLs increases in the medium term as petrochemical use in Alberta and propane and butanes exports rise.

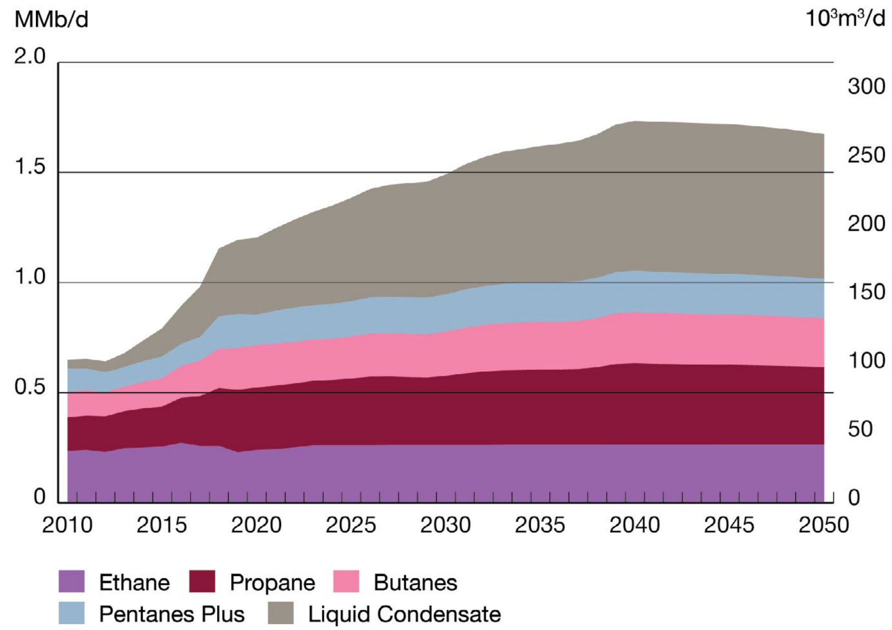
Additional Detail on Crude Oil, Natural Gas, and NGL Projections

For additional data on crude oil, natural gas and NGL production, see the EF2020 Data Appendices. These data sets include additional geographical and monthly detail on production and drilling trends.

Further information about these and other EF2020 data sets can be found in the "Access and Explore Energy Futures Data" section.

The majority of ethane is extracted at large natural gas processing facilities located on major natural gas pipelines in Alberta and B.C. In 2019, ethane made up 19% of NGL production. Ethane production increases slowly over the Evolving Scenario projection to 2050, as its recovery from the natural gas stream is essentially constrained by the capacity of the petrochemical facilities in Alberta. Ethane produced in excess of this capacity is reinjected back into the natural gas pipeline system to be consumed by end users as natural gas.

Figure R.16:
Condensate Leads Natural Gas Liquids Production Growth in the Evolving Scenario



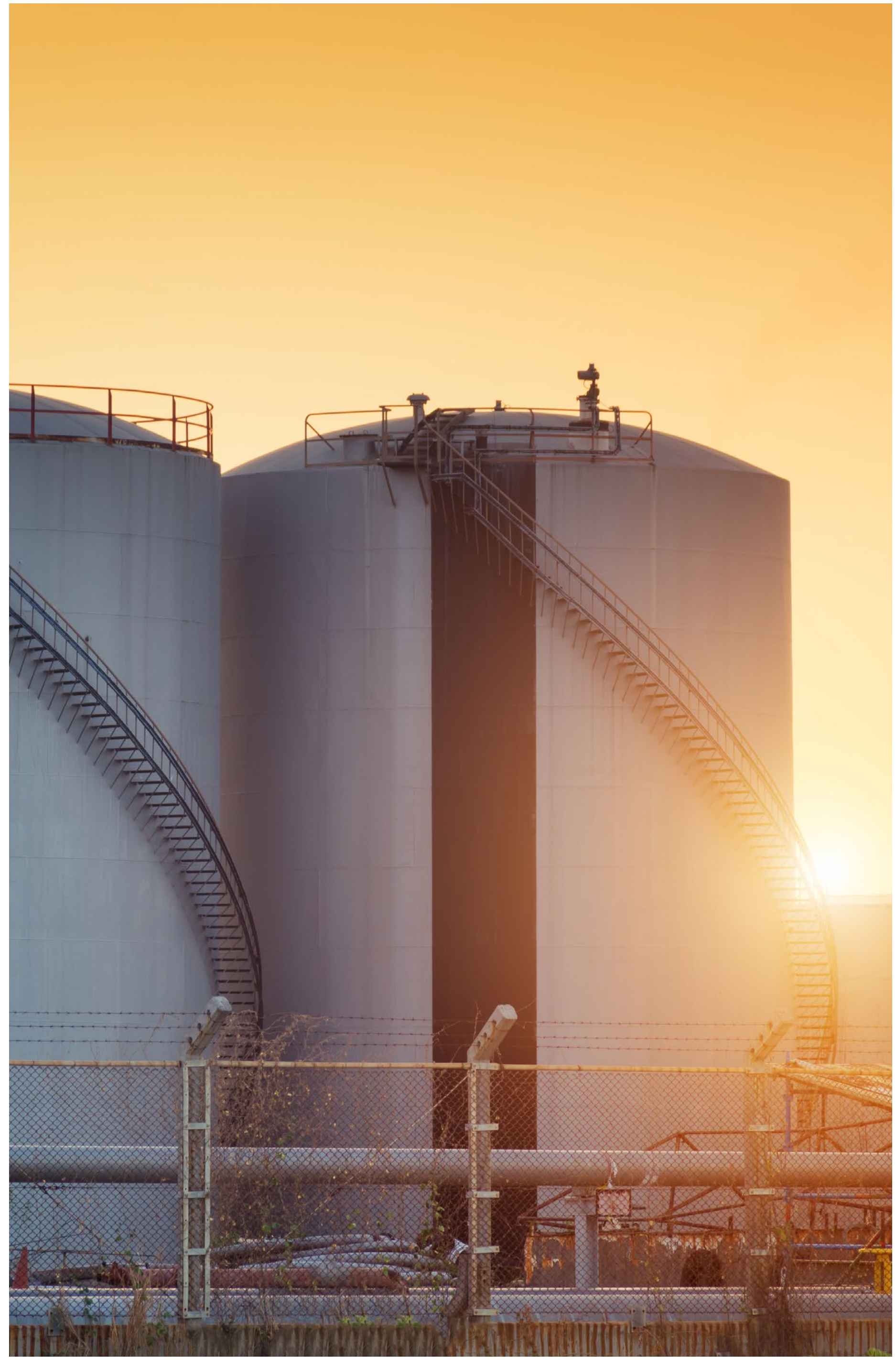
KEY UNCERTAINTIES:
Natural Gas Liquids

Natural gas: NGLs are a by-product of natural gas production, and as such, any uncertainty discussed in the Natural Gas section applies for NGL projections.

Oil sands: The rate of oil sands and other heavy oil production growth, and the amount of blending, will affect the demand for condensate and butanes required for diluent. Likewise, the use of solvents to reduce steam requirements in the oil sands could impact demand and prices for propane and butanes and influence the degree to which they are targeted by future natural gas drilling.

Petrochemical development: There is potential for ethane and propane recovery to increase further if there is an increase in petrochemical capacity requiring either as feedstock. This could result from government programs, such as royalty credit incentives for petrochemical facilities in Alberta's Petrochemicals Diversification Program.

Global LPG export market: Several large-scale facilities have been approved by provincial and federal regulators to export LPG from B.C.'s coast. Propane exports from one facility began in May 2019 and butanes also became part of the LPG mix in April 2020. Over the outlook period, propane will likely be the majority of exported LPG. The amount and composition of the LPG stream exported at these terminals could impact domestic NGL prices and the attractiveness of drilling for NGL-rich natural gas.



Electricity

In the Evolving Scenario, electricity demand grows steadily at the end use level, as shown in Figure R.17. This is driven by growth in all sectors, in particular the transportation sector where electrification provides an alternative in a sector long dominated by RPP use. Currently, electricity makes up approximately 16% of Canada's end-use energy demand. In the Evolving Scenario, electricity demand increases at an average annual rate of 1% over the projection period, which raises electricity's share of end-use demand to 27% by 2050. See Figure R.18. Electricity demand grows approximately 35% over the projection period, despite overall energy use decrease, as previously discussed in the energy demand section.

Figure R.17:
Electricity Demand Grows Steadily in the Evolving Scenario

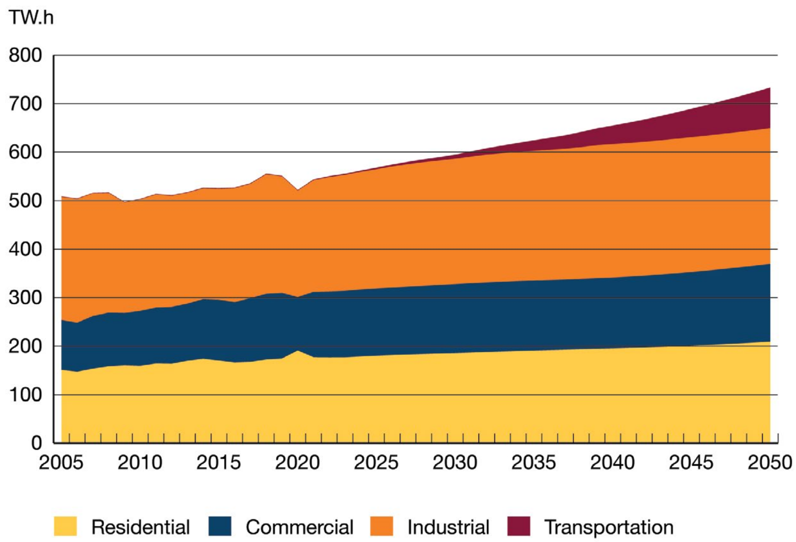


Figure R.18:
Share of Electricity in End-use Demand by Sector and Total in the Evolving Scenario

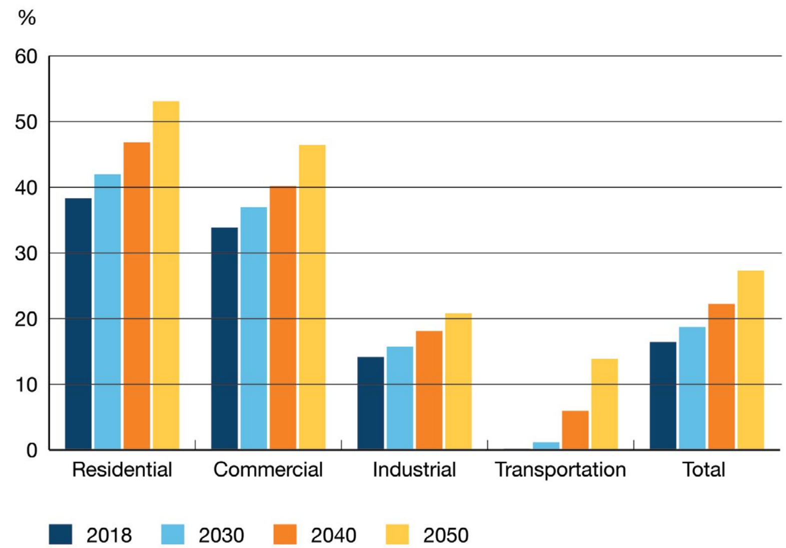
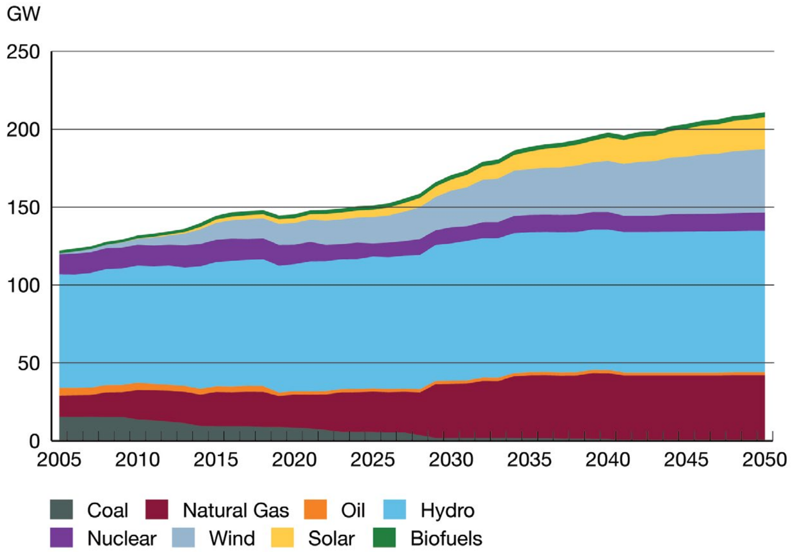


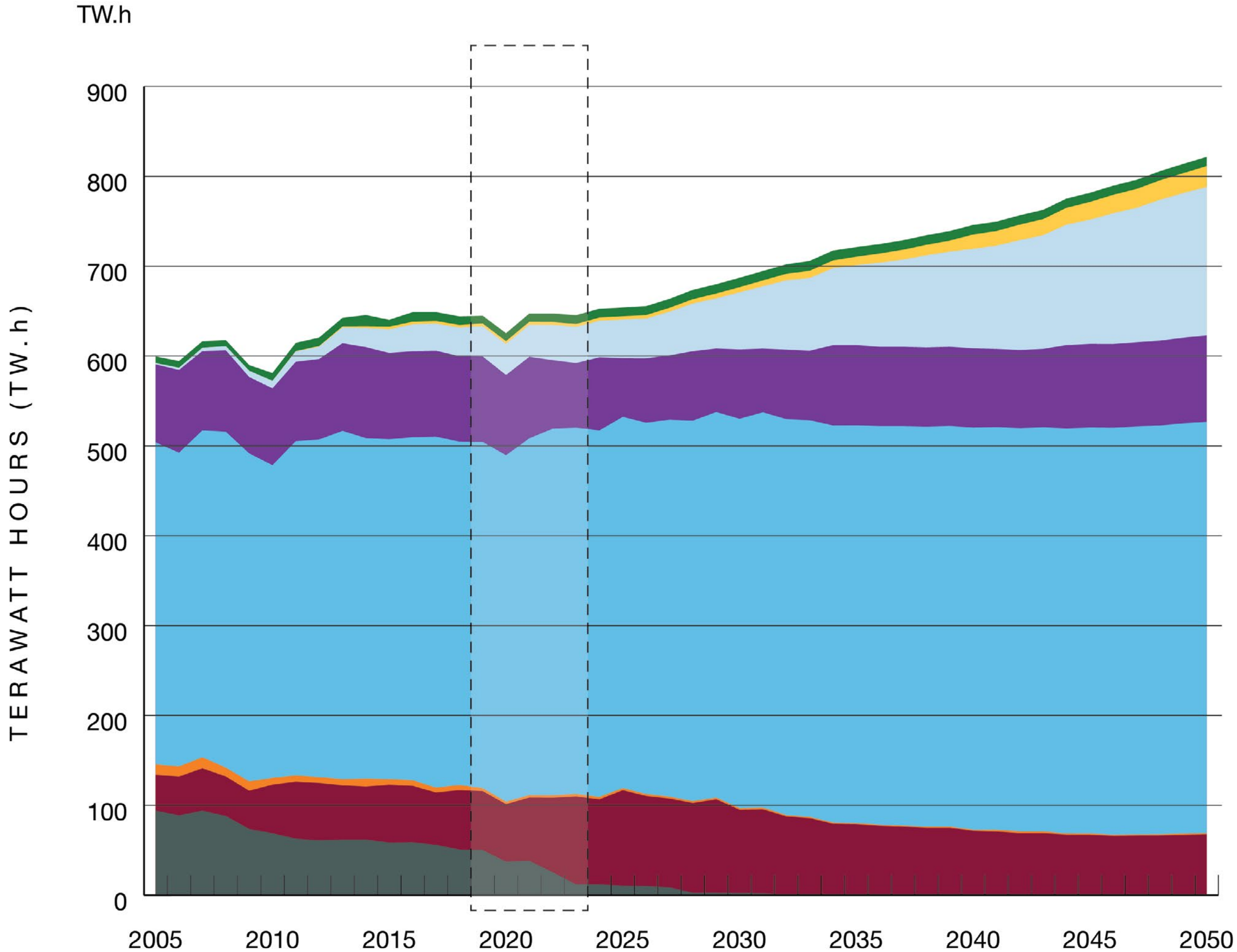
Figure R.19:
Electricity Installed Capacity Grows Significantly in the Evolving Scenario

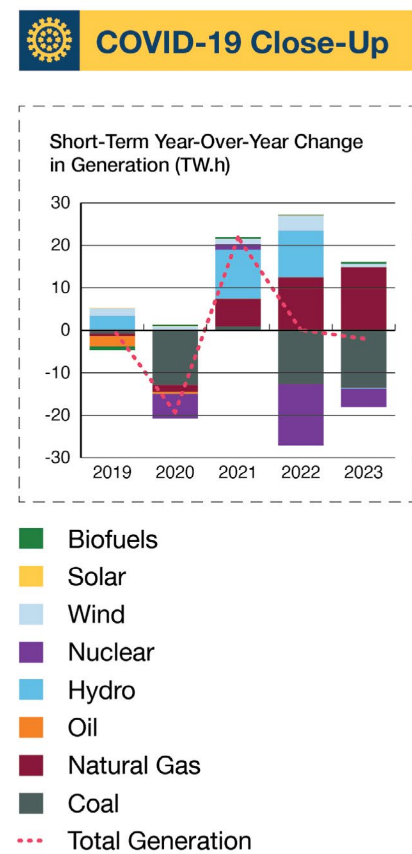


Electricity demand influences the growth, and mix, of fuels and technologies used to generate electricity. Canada has considerable renewable resource potential including hydro, wind, biomass, and solar. Over the past decade, there have been significant changes in Canadian electricity capacity and generation trends, and it continues to evolve in the EF2020 projections. Figure R.19 shows total Canadian installed capacity by fuel type, and Figure R.20 shows electric generation by fuel type.

In the earlier part of the projection, renewables and natural gas replace phased-out coal generation. In the longer term, falling costs lead to large growth in non-hydro renewables such as wind and solar. The share of renewable and nuclear generation increases from 81% currently to 90% in 2050.[23]

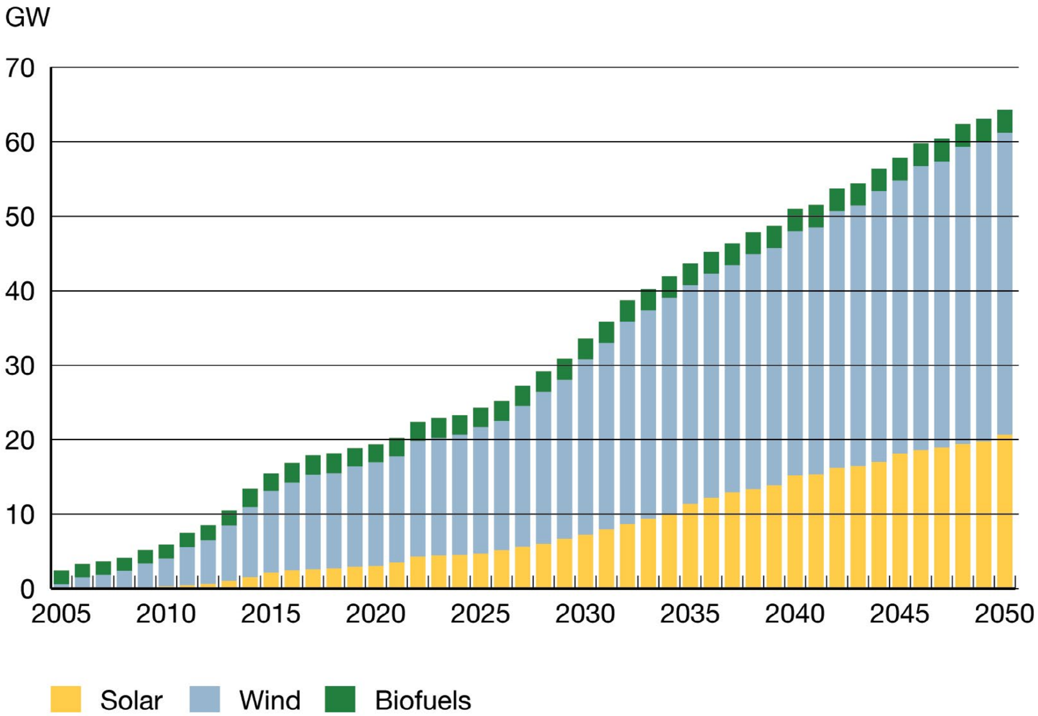
Figure R.20:
Electric Generation Trends by Primary Fuel Type in the Evolving Scenario





The increase in non-hydro renewables is driven by falling costs, technological improvements, as well as improved integration of variable renewable energy (VRE) sources such as wind and solar. Figure R.21 shows that by 2050, total non-hydro renewable capacity in the Evolving Scenario is over triple 2018 levels. Total wind capacity rises to 40 GW and total solar capacity rises to 20 GW.

Figure R.21:
Increasing Capacity of Non-Hydro Renewables in the Evolving Scenario



The integration of increasing levels of variable resources such as wind and solar is supported in a number of ways in the Evolving Scenario. Other forms of energy, such as hydropower and natural gas, help back up non-hydro renewables. In the Evolving Scenario, interconnection between many provinces increases, including between Manitoba-Saskatchewan, and Alberta-B.C. This increased ability to exchange power helps regions integrate larger amounts of variable energy. Finally, the Evolving Scenario includes around 3 GW of utility-scale battery storage. This is based on the falling costs of storage, as well as the falling costs of renewables, especially solar. Storage is especially critical for large additions of solar.

As the proportion of VRE increases, variations in generation from hour-to-hour and minute-to-minute become increasingly important in balancing electricity production and use. Figure R.22 illustrates simulated generation, for 24 hour periods in winter and summer, for the 2030 and 2050 electricity mix in the Evolving Scenario. The provinces are generally grouped by region. Manitoba, B.C., and Quebec are grouped together given they have similar hydro-dominated mixes.

As wind and solar generation vary throughout these simulated days, other generation sources fill in to meet requirements. For regions that have low shares of non-hydro renewables, the generation mix remains fairly constant. The mix and generation levels vary seasonally, with considerably more solar generation in the summer months.

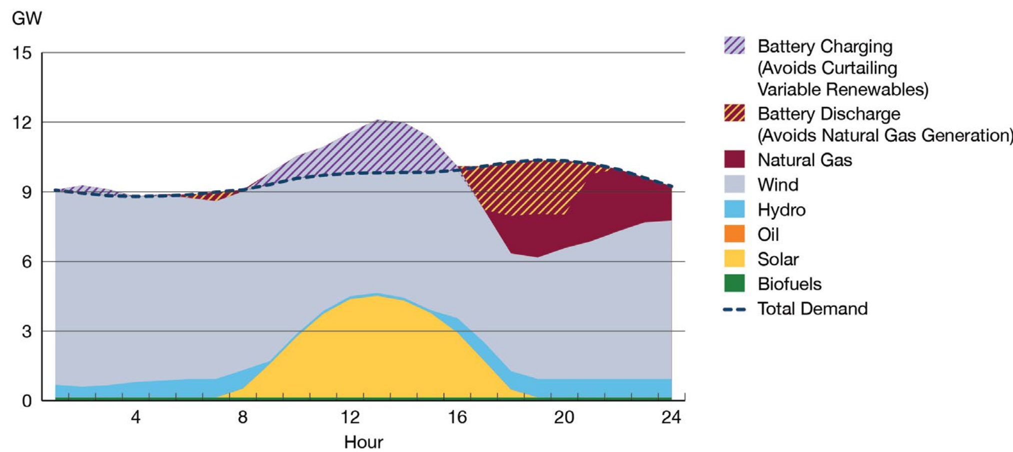
The hourly generation projections presented here are simulations and represent one particular sample from many different outcomes. They are not a definitive statement on what will happen in the future, but rather an illustration of one potential outcome. Electricity demand, solar irradiation, and wind speed can vary greatly hour-to-hour and day-to-day, resulting in many different possible electricity demand and renewable generation outcomes.

Utility Scale Battery Storage

The Evolving Scenario includes a gradual uptake of utility scale battery storage, reaching nearly 3 GW of national capacity by 2050. This is driven by a variety of factors, including falling costs of batteries and variable renewable energy, and continued climate action.

An important potential use for storage is in the integration of more variable renewable energy. The figure below provides a simulated example of how this could work. It is based on the Evolving Scenario capacity mix for Alberta in 2050, for a day with high levels of wind generation. In this example, large amounts of mid-day solar energy, and significant wind generation, lead to excess generation. Without storage, this renewable generation would be unused (curtailed), but when storage is available it can be used to charge the batteries (shown in purple/grey pattern). Later in the day, when solar generation declines, the energy that was stored earlier in the batteries can be discharged to offset natural gas generation, which would otherwise be needed to meet load requirements (shown in yellow/maroon pattern).

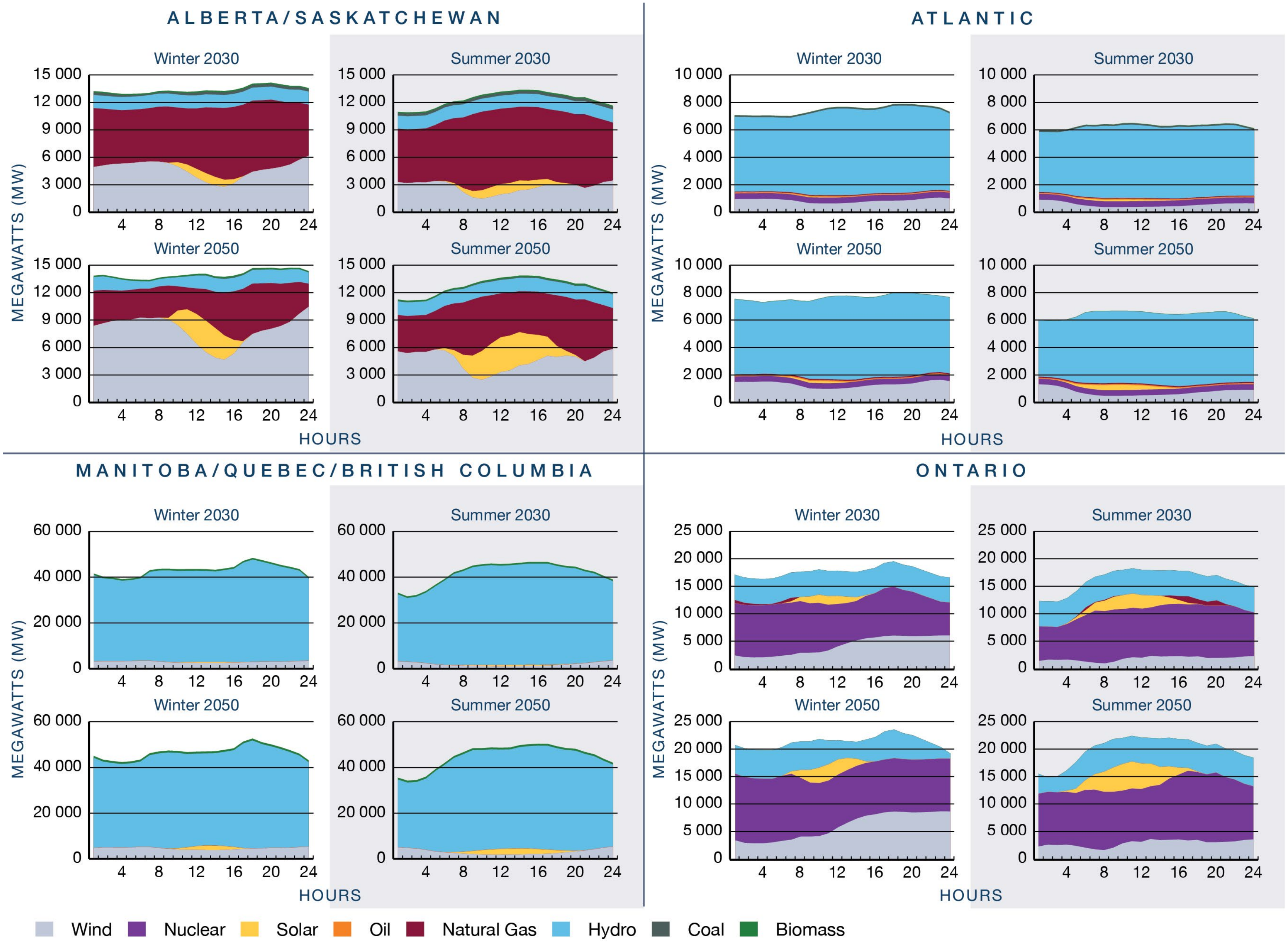
Simulated Example of Storage Allowing for More Renewable Integration in Alberta, 2050(1)



In addition to integrating renewables, storage has many other potential applications. This includes voltage regulation and grid operations, allowing for economic arbitrage (charging when power is low cost to sell when prices are higher), and contributing to system efficiencies (for example, charging with more efficient, but less flexible combined cycle natural gas generation, and discharging to reduce the need for more flexible, but less efficient, simple cycle natural gas generation).

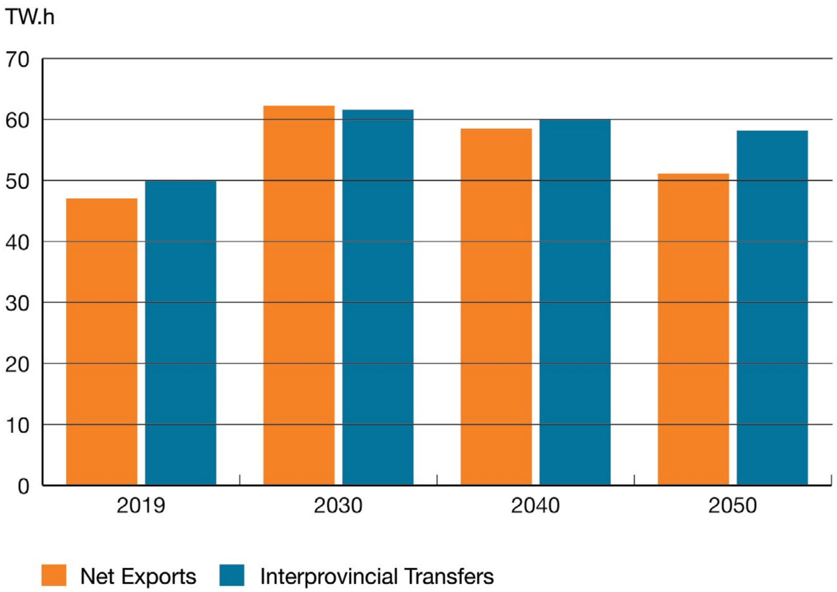
(1) Excludes own use generation, such as industrial cogeneration.

Figure R.22:
Simulated Hourly Electricity Profiles, 2030 and 2050



Canada is a net exporter of electricity to the U.S., and large amounts of electricity are also traded between provinces, mainly in eastern Canada. By connecting the electricity grids of different regions, grid operators can take advantage of regional differences in electricity mixes, available variable renewable energy, and periods of peak electricity demand. Figure R.23 shows projected net exports out of Canada, as well as aggregate interprovincial trade volumes. Trade remains relatively small when compared to total generation.[24]

Figure R.23:
Net Exports of Electricity and Interprovincial Trade Trend Higher than 2019 in the Evolving Scenario



KEY TRENDS:
Electricity Generation

- Technologies enabling Canada's transition to a low carbon economy make inroads across the energy system, particularly in electricity generation.
- Natural gas and renewable generation is added, and most nuclear will be refurbished.
- Coal will be largely phased out.
- The share of renewable and nuclear generation increases from 81% currently, to 90% in 2050.

KEY UNCERTAINTIES:
Electricity Generation

Future capital cost declines of generating facilities: The capital costs associated with different generating technologies is an important factor in determining what type of facilities are built. This is especially true with rapidly changing technologies such as wind, solar, and battery storage.

Electricity demand growth: This is important in determining future electricity supply. As a result, the uncertainties identified in the energy demand section are uncertainties that also apply to the electricity supply projections.

Export market developments: Climate policies, fuel prices, electrification and power sector decarbonization in export markets could impact future projects and transmission intertie developments.

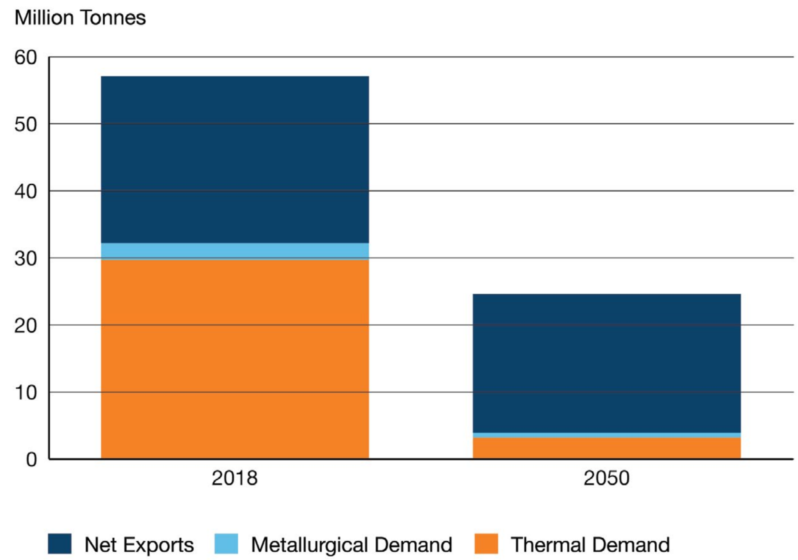
Coal

There are two main types of coal produced in Canada: thermal and metallurgical. Canadian thermal coal production is linked to the use of coal in the electricity sector, particularly in Alberta, Saskatchewan, and Nova Scotia. Metallurgical coal is primarily used for steel manufacturing domestically and internationally. Much of Canada's metallurgical coal production is exported and future production trends are linked to global metallurgical coal demand and prices.

Figure R.24 shows Canadian production and consumption of coal in Canada in 2018. Thermal coal accounted for 88% of total Canadian coal consumption in 2018. In the Evolving Scenario, demand for thermal coal declines by 89% over the projection period, falling from 30 million tonnes in 2018 to just over 3 million tonnes in 2050. This declining trend is driven primarily by retirements of coal-fired generation capacity resulting from regulations to phase out traditional coal-fired power plants by 2030, while some industrial sector demand remains.

Domestic demand for metallurgical coal used in steel manufacturing declines from 2.5 million tonnes in 2018 to roughly 0.7 million tonnes by 2050. In the Evolving Scenario, total metallurgical coal production in Canada decreases from about 29 million tonnes in 2018 to 22 million tonnes by 2050. Total production declines from about 55 million tonnes in 2018 to 24.5 million tonnes in 2050.

Figure R.24:
Canadian Coal Production and Disposition Trends Driven by Falling Thermal Demand in the Evolving Scenario



KEY UNCERTAINTIES:
Coal

Prices and global development: Future price movements for metallurgical coal in the global coal markets, and the rate of development in export markets are key uncertainties for Canadian coal production.

Climate policies: Canadian climate policies, and the climate policies of coal importing countries, could have a significant impact on both Canadian thermal and metallurgical coal production.

Greenhouse Gas Emissions

Currently, energy use and GHG emissions in Canada are closely related. ECCC's most recent official GHG projections are available through Canada's National Reports to the United Nations Framework Convention on Climate Change.[25]

The majority of GHGs emitted in Canada are a result of fossil fuel combustion. Fossil fuels provide the vast majority of energy used to heat homes and businesses, transport goods and people, and power industrial equipment. Energy related emissions accounted for 82% of Canadian GHG emissions in 2018.[26] The remaining emissions are from non-energy sources such as agricultural and industrial processes, and waste handling.

KEY TRENDS:

Fossil Fuel Use and GHG Emissions

- Overall fossil fuel use declines in the Evolving Scenario.
- Natural gas, oil, and coal each have a distinct future trend.
- The emission intensity of fossil fuel use falls, driven by the phase out of coal, and the long-term adoption of carbon capture and storage (CCS).

Does the Evolving Scenario Meet Canada's Climate Commitments?

The Evolving Scenario provides an energy supply and demand outlook for Canada under the general premise that the energy system continues to transition at its historical pace. This contrasts with the Reference Scenario, which projects the Canadian energy system as it looks today into the future. Recent ECCC projections show that Canada is making progress to reach near-term climate targets, particularly in its "With Additional Measures" scenario, and that more work needs to be done to achieve them. Since the Evolving Scenario includes a similar policy framework, readers can draw similar conclusions from our analysis of changing Canadian energy use trends in the Evolving Scenario. The Government of Canada has announced commitments to strengthen existing, and introduce new GHG-reducing measures, to exceed Canada's 2030 emissions reduction goal and begin working toward achieving net-zero emissions by 2050.

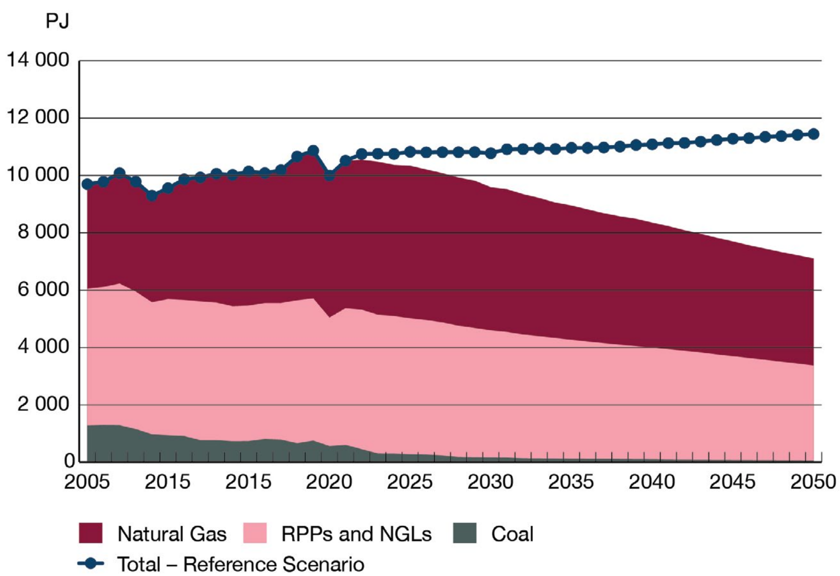
It is also clear that Canada's more ambitious goals, such as achieving net-zero by 2050, will require a faster transition than we have witnessed historically, and faster than is shown in the Evolving Scenario. Recognizing this fact, we have included the "Towards Net-Zero" section in EF2020.

EF2020 focuses on potential future outcomes for Canada's energy system. It should not be viewed as an assessment, or a pathway, for meeting Canada's climate commitments. ECCC produces the official analysis of Canada's current emissions outlook and performance against its climate commitments. The most recent analysis can be found in ECCC's *4th Biennial Report on Climate Change*.

Figure R.25 shows total domestic Canadian consumption of fossil fuels in the Evolving Scenario, by fuel type (and compared with the Reference Scenario total), as well as growth relative to 2005 levels for the fuel types. From 2019 to 2050, total fossil fuel use declines 35% in the Evolving Scenario, but growth varies significantly across the different fuel types. Natural gas continues to grow quickly in the early part of the projection period, following its increased role in power generation and its use in rising oil sands production. Use of RPPs gradually declines throughout the projection period. In the earlier years, this is driven by efficiency improvements and increased blending of biofuels, and in the long term is driven by increased electrification of the transportation sector. Coal significantly declines over the projection, driven by its phase out from electricity generation by 2030.

Figure R.25:

Total Demand for Fossil Fuels Consistently Declines in the Evolving Scenario and Gradually Rises in the Reference Scenario



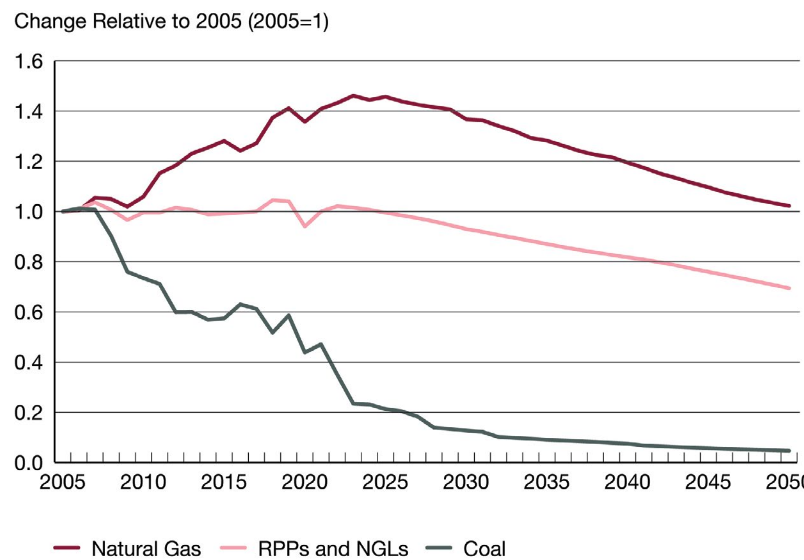


Figure R.26 shows the change in total domestic Canadian fossil fuel use per person and per dollar of real GDP by indexing these indicators to a base year (2005). Relative to 2005, both measures decline significantly. By 2050, fossil fuel use per person is about half of what it was in 2005, and fossil fuel use per dollar of real GDP declines over 60%.

Changing proportions of which fossil fuels are consumed leads to declining GHG emissions per unit of fossil fuel energy used in the Evolving Scenario, particularly with coal use declining to 2030. Deployment of carbon capture and storage (CCS) technology in industrial facilities also reduces the GHG intensity of fossil fuel use in the longer term. As shown in Figure R.27, in 2050 fossil fuel emission intensity is 19% lower than 2019, and 25% lower than 2005 in the Evolving Scenario. Accounting for reductions in non-combustion emissions, such as reducing methane emissions, as well as including emission credits purchased through international trading mechanisms (like Quebec's emission trading with California) could further decrease emission intensity.

Figure R.26:
Fossil Fuel Demand per Person and per $ Real GDP Falls Steadily in the Evolving Scenario

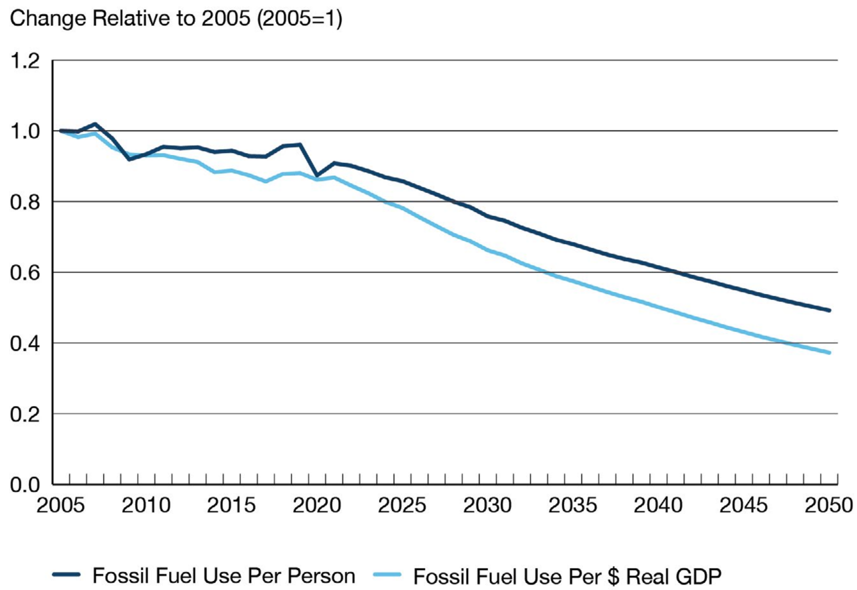
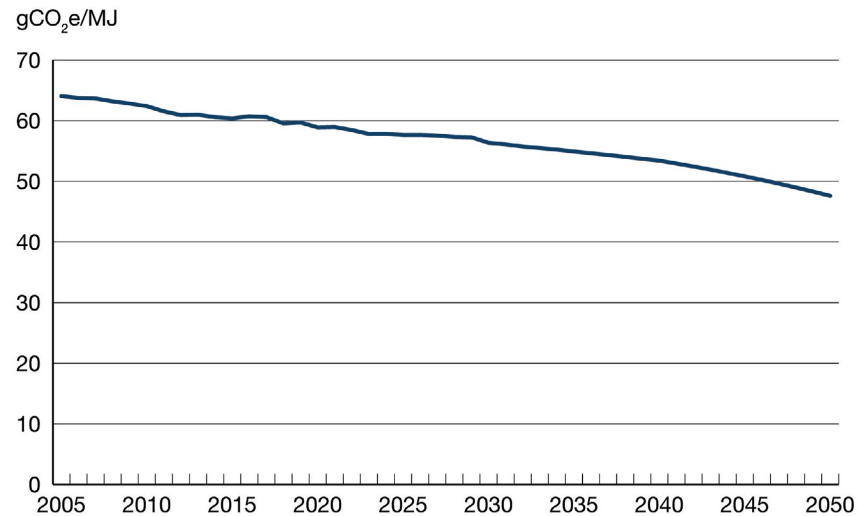


Figure R.27:
Fossil Fuel Emission Intensity Falls due to Higher Shares of Natural Gas, Less Coal, and Greater Adoption of CCS in the Evolving Scenario



Carbon Capture, Utilization and Storage

Canada has a number of commercial scale CCS projects. This includes the Boundary Dam power station that began operations in 2014, the Quest Project that captures CO_2 from Shell's Scotford upgrader in Alberta, and the Alberta Carbon Trunk Line, a 240 km pipeline that will transport CO_2 from an industrial area north of Edmonton to enhanced oil recovery projects in central Alberta. The pipeline has an annual capacity of nearly 15 MT to allow for future CCS projects.

CCS could be an important part of the global energy transition. It is a technology group of great interest, but also one where the momentum has been mixed. The International Energy Agency (IEA's) 2019 *Tracking Clean Energy Progress* categorizes CCS as "not on track". The IEA's recent *Energy Technology Perspectives 2020* report underscores CCS's importance as a key technology area to help the globe achieve deep decarbonization.

The Evolving Scenario assumes an increase in momentum for CCS in the latter half of the projection period. This is driven by an assumption of similar momentum globally, particularly as mid-century draws near, leading to overall technology development, learning, and cost reductions. In Canada, CCS deployment in the Evolving Scenario is supported by the assumed increases in carbon pricing shown in the "Scenarios and Assumptions" section. Costs of CCS are often measured in $ per tonne basis. Estimates are uncertain, and can vary significantly by the industry employing CCS. The Evolving Scenario assumes a gradual increase in carbon capture resulting in an additional 15 MT sequestered per year by 2040, rising to 30 MT by 2050.

KEY UNCERTAINTIES:
GHG Emissions

Technology development: Future adoption of low carbon technologies could alter these trends. Faster adoption of renewable energy, energy efficiency, battery storage, and other technologies could reduce fossil fuel use faster. Increased deployment of technologies such as CCS, could weaken the link between fossil fuel use and future emission trends, enabling greater levels of fossil fuel use to coexist with declining emission levels.

Future climate policies: The evolution of climate policies in Canada will be an important factor in fossil fuel consumption and GHG emission trends. Future developments in policies such as carbon pricing, energy and emission regulations, and support for emerging technologies could alter these projections.

Towards Net-Zero

Overview of Net-Zero

Canada has recently announced more ambitious climate commitments, including exceeding 2030 emission targets and achieving net-zero emissions by 2050. Internationally, momentum towards climate action continues to accelerate, reinforcing the global commitment made in the 2015 Paris Agreement to reach net-zero in the second half of the century.[27] Canada's plan to achieve net-zero emissions by 2050, still under development, will set legally-binding, five year emissions reduction milestones, based on the advice of experts and consultations with Canadians.[28]

The Evolving Scenario projections in the "Results" section show significant change across the energy system. These changes reflect the core premise of the scenario – climate action continues to develop as Canada keeps with global efforts to proceed towards energy transition. Even though the Evolving Scenario shows a very different energy system than today's, fossil fuels still make up a majority of Canada's energy mix by 2050, and are not fully decoupled from emissions via technologies such as carbon capture, utilization and storage (CCUS).

Given that the Evolving Scenario continues the recent pace of change in Canada's energy transition, the continued reliance on fossil fuels is an important insight. For Canada to meet its 2050 goals, the rate of energy transition will need to increase beyond levels shown in the Evolving Scenario. This section discusses the implications of going beyond the Evolving Scenario, and moving the energy system towards net-zero emissions. First we look at what net-zero means. Then, to gain insight into what a net-zero energy transition might mean for different parts of the economy, we focus on three diverse segments of Canada's energy system: personal passenger transportation, oil sands production, and remote and northern communities. For each segment, we explore its current status, considerations for the segment in the energy transition, and potential pathways and uncertainties in moving towards net-zero.

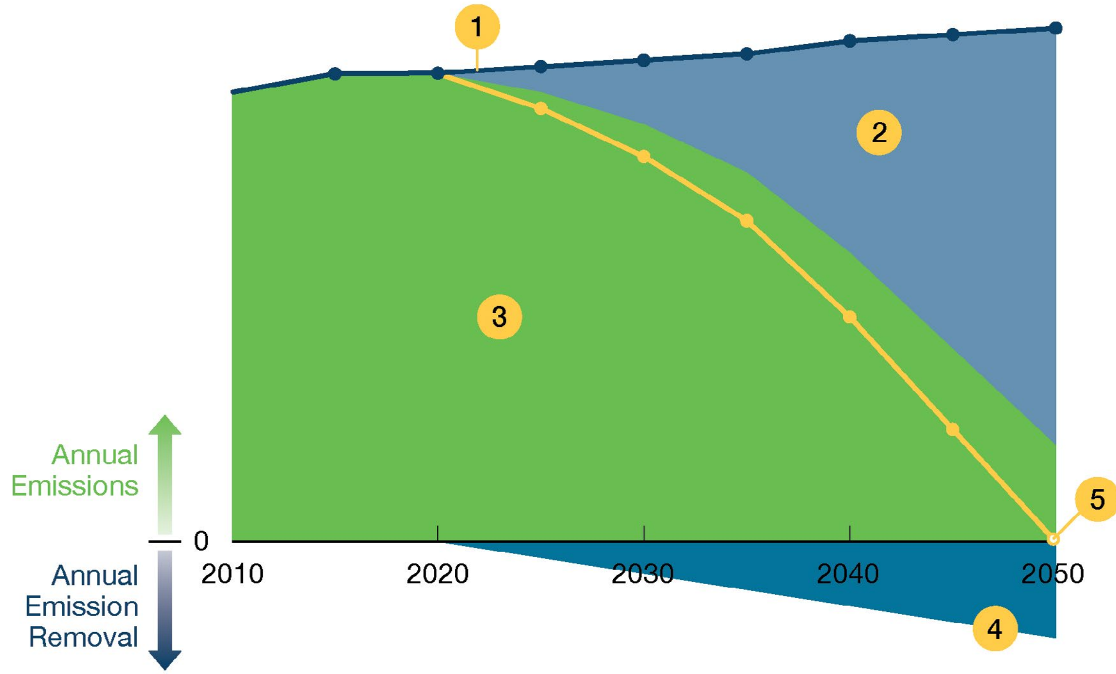
What is Net-Zero?

"Net-zero" GHG emissions, or "carbon neutrality", refers to the balance of human-caused GHG emissions and removals from the atmosphere. Reaching net-zero emissions does not necessarily require eliminating all emissions everywhere. Instead, residual emissions can be balanced by enhancing biological sinks and negative emission technologies. For more information, see the "Greenhouse Gas Removal" textbox.

Figure NZ.1 provides a hypothetical illustration of net GHG emissions over time, with net emissions of zero in 2050. In this illustration, the level of emission reductions relative to a post-2020 business-as-usual baseline ("mitigation") increases over time, as negative emission technologies are increasingly developed and commercialized, and biological sinks are enhanced.

Recent reports, including the Intergovernmental Panel on Climate Change's (IPCC's) special report, *Global Warming of 1.5°C*, indicate that achieving economy wide net-zero GHG emissions is likely required to stabilize global average surface temperatures at a level needed to avoid the worst impacts of climate change. This includes emissions from land use, agriculture, and industrial production, in addition to the energy system. International climate targets, such as limiting global temperature increase to well below 2°C, likely require an energy system with net-zero (or even net-negative) emissions later this century.[29] Net-zero emissions targets are a useful focal point for linking global temperature targets to their implications for Canada's energy system transformation.

Figure NZ.1:
Illustrative Example, the GHG Emission Balance Remaining after Mitigation and Emissions Removal



1. **Business-As-Usual Emissions Trend.** Represents a hypothetical GHG emissions trajectory where future GHG reductions are not pursued.
2. **Mitigation.** Represents GHG emissions reductions relative to the business-as-usual trajectory.
3. **Remaining Emissions.** GHG emissions remaining after mitigation.
4. **Emission Removals.** GHGs removed via negative emission technologies or enhanced biological sinks.
5. **Net Emissions.** The balance of remaining emissions and emission removals.

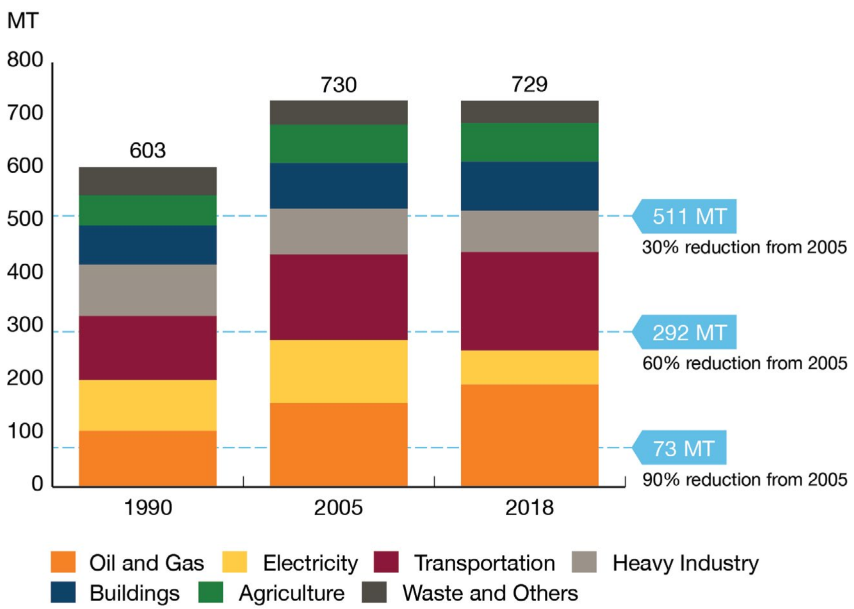
What Does It Involve?

What the exact 2050 balance might be between removing and emitting GHGs into the atmosphere is not yet clear.[30] The specific energy-using technologies, and their role within the economy is uncertain, as is their overall emissions profile. Recycling, and removing carbon from the atmosphere will be important activities. However, the extent to which biological sinks will be enhanced, and negative emissions technologies deployed is unclear, and currently challenged by high perceived risk and market uncertainties.[31]

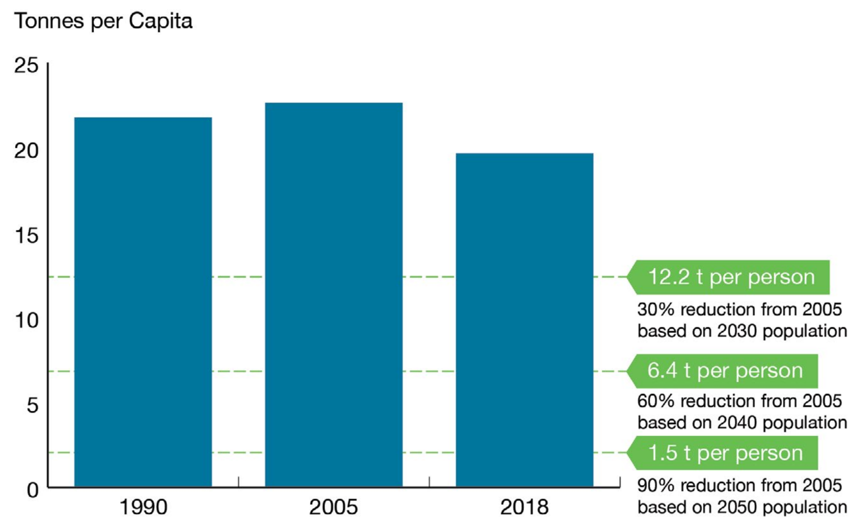
What *is* clear is that Canada's likelihood of achieving our ambitious net-zero target increases as our energy system emissions fall. Over 80% of Canada's GHG emissions are currently associated with the energy system. Given the diversity of Canada's current and historical energy and emissions profile, deep reductions in emissions will likely need to be achieved across Canada's energy system and economy to achieve net-zero emissions. Figure NZ.2 compares historical emission levels to hypothetical 30%, 60% and 90% reduction levels, illustrating the large difference between current levels and significant reductions that could be needed to reach net-zero, based on recent research.[32]

Figure NZ.2:
Historical Canadian GHG Emissions Compared to Implied 30%, 60%, and 90% Reductions, by Sector (a), and Per Capita (b)

a) Total Emissions by Sector



b) Emissions per Capita



To substantially decrease energy system emissions, several complementary dynamics will likely play a large role. Increasing the share of zero and low carbon energy sources, such as low carbon electricity, used across the entire economy will be key, as will the contributions from existing trends in energy efficiency.[33] Even with considerable improvements in energy conservation and efficiency, research suggests shifting away from burning fossil fuels for energy and replacing them with low carbon alternatives will be crucial to long-term deep decarbonization of the Canadian economy.[34]

Some energy uses, like passenger transportation, might be relatively straightforward to decarbonize economically by 2050. Other energy uses carry with them emissions that are unlikely to be fully eliminated, such as energy used for steel and cement production. It is the emissions that are likely to remain even after significant mitigation efforts that highlight the potential role to be played by GHG emissions removal.

Greenhouse Gas Removal

Negative emissions technologies and enhanced biological sinks involve removing CO_2 from both the emissions' source, and the atmosphere, and storing it in land, ocean, or geological reservoirs.[1] While hypothetically promising, most assessments agree that negative emissions technologies, in particular, are not a replacement for conventional mitigation and adaptation methods, due to the high costs, potential for risks, and uncertainties involved.[2] Significant uptake of negative emissions technologies could require increased demand of low carbon energy, like electricity and sustainable biomass, for their operation. This is an important consideration for a future net-zero energy system.

Notable GHG removal methods include:

- **Reforestation and afforestation:**[3] Carbon can be sequestered in biomass through restocking of existing forests and woodlands that have been depleted, or introducing trees to areas that have not previously been forested.
- **Soil carbon sequestration:**[4] Carbon can be removed from the atmosphere and stored in the soil carbon pool, primarily in the form of soil organic carbon. This can be accomplished through a variety of methods, including the restoration of degraded soils or widespread adoption of soil conservation practices in agriculture. For instance, reducing soil carbon loss can be achieved in certain circumstances by switching from tillage to no-till cropping.
- **Bio-energy with carbon capture and storage (BECCS):**[5] Carbon can be captured and stored by geological sequestration or land application, as energy is extracted from biomass through combustion, fermentation, or other conversion methods. Limiting factors for BECCS include the availability and sustainability of feedstock biomass, and the availability of storage capacity.
- **Direct air capture (DAC):** Carbon can be captured via thermochemical processes at atmospheric concentrations (as opposed to from point sources) to produce a concentrated stream of CO_2. It can then be sequestered (resulting in emission removals), or used to make carbon neutral synthetic fuels. DAC is energy-intensive, so its net effect on emissions largely depends on the carbon intensity of its fuel.

1 IPCC AR5 – Assessing Transformation Pathways.
2 IPCC AR5 – Assessing Transformation Pathways.
3 IPCC AR5 – Agriculture, Forestry and Other Land Use.
4 IPCC AR5 – Agriculture, Forestry and Other Land Use.
5 For a review of BECCS and DAC research, see section 6.9 of IPCC AR5 - Assessing Transformation Pathways.

Looking Ahead

It is clear that Canada will need a combination of low carbon fuel switching and energy efficiency going forward, but the precise mix is uncertain. Reaching net-zero targets will require considerable emissions reduction as well as GHG emissions removal.

The remainder of this section explores the implications of moving towards net-zero for three segments of Canada's energy system: personal passenger transportation, oil sands production, and remote and northern communities. These areas present a diverse range of challenges and opportunities in the shift towards a net-zero energy system. Exploring these three segments provides insights into what a net-zero energy transition might mean for different parts of the energy system.

Exploring these specific segments yields some key insights:

Continued low carbon technology development will be essential to achieving 2050 goals. Our analysis of all three segments discusses many potential technologies that could help reduce emissions to varying degrees. In a net-zero energy system, the equipment and processes used to provide energy will look much different than today. The rate at which the economics can improve for technologies such as zero emission vehicles, low carbon oil sands production processes, and reliable low carbon energy for remote communities is a key factor that will shape Canada's evolution towards its 2050 goals. Most of these technologies will involve a reduction in the use of fossil fuels, and/or an increase in low or non-emitting energy sources.

Policies will be a key driver of change. Government policies will play a key role in providing incentives for these necessary technology developments and adoptions to occur. Without policy signals that provide a requirement, or value for reducing and/or eliminating GHG emissions, the required changes are unlikely to be made. While policies will be a key driver of change, other factors could play important roles. These include consumer preferences, investor and ESG considerations, domestic and global energy market developments, and unique regional concerns. Effective policies will need to account for these considerations.

The evolution of each segment of the energy system will depend on its specific circumstances, as well as broader domestic and international trends. We have analysed three segments of Canada's energy system in relative isolation. However, each of these segments depend heavily on many other factors beyond their own energy consumption and production processes. In the case of oil sands production, global energy supply and demand trends that set market prices will be critical in its future. For personal passenger transportation, consumer tastes and preferences, as well as the development of a global market for ZEVs, will help determine the future vehicle mix and energy use. Remote and northern communities highlight many key social and environmental issues, such as local air quality, and energy reliability and affordability, as key considerations in the energy transition.

Highlights from Focus Areas

Personal Passenger Transportation

- Future transportation trends will be influenced by the interaction of technology costs, consumer preferences, and policies.
- Considering the dominant role of oil products in transportation today, the Evolving Scenario shows a very significant shift in personal transportation – with about half of new personal vehicles sold in 2050 being ZEVs. If ZEV costs fall faster, the penetration rates are even higher.

Oil Sands Production

- There are a variety of emerging technological solutions to reduce emissions in oil sands production.
- The broader market for crude oil, including demand for oil products and market price impacts, and the relative competitiveness of the oil sands, will be key factors in determining whether investments in these technological solutions are made.
- ESG considerations could have an increasing role in the deployment of emissions reduction technologies in the oil sands.

Remote and Northern Communities

- Remote and northern communities have unique energy systems, with a higher reliance on RPPs, such as diesel, compared to the rest of Canada.
- Many of the technology improvements in the broader energy system, such as improved efficiency and falling costs of renewable energy, could help these communities transform their energy systems. However, their specific needs and considerations will influence how these changes can be adopted.
- Remote and northern communities are diverse. High energy costs, limited transportation access, cold climates, local air quality, and maintaining reliability without being connected to North American electric or natural gas grids, are just some of the relevant issues in these communities. GHG reduction options will need to reflect this diversity and these issues.

Personal Passenger Transportation

Energy Profile of On-road Vehicle Passenger Transportation

The transportation sector is a major source of energy demand in Canada and is comprised of multiple subsectors. These include passenger, freight, marine, and air transportation. This section focuses on on-road vehicle passenger transportation.

In 2018, energy use in the transportation sector totaled 2 840 PJ, which accounts for almost 23% of all energy consumed in Canada. Of this amount, non-aviation passenger transportation accounted for 1 170 PJ, or 41% of all transportation energy use. Of this, 95% was from fossil fuels, almost all of which was gasoline. Given the large amount of fossil fuels consumed by the sector, reaching net-zero emission represents a major change.

In the EF2020 Evolving Scenario, passenger transportation undergoes a significant shift. The share of biofuels blended in gasoline and diesel increases, fuel economy improves, and in the long-term EVs take up a significant share of total vehicle sales. However, as shown in the previous chapter, while fossil fuels decline in the transportation sector, they still account for a significant share in 2050. This section explores the potential for even greater change in the transportation sector in the context of Canada achieving net-zero emissions by 2050. We focus specifically on personal vehicle transportation and the transition from conventional fossil fuel vehicles towards EVs.

Figure PT.1:
Share of Total Canadian SUV Sales are Increasing While Cars are Decreasing

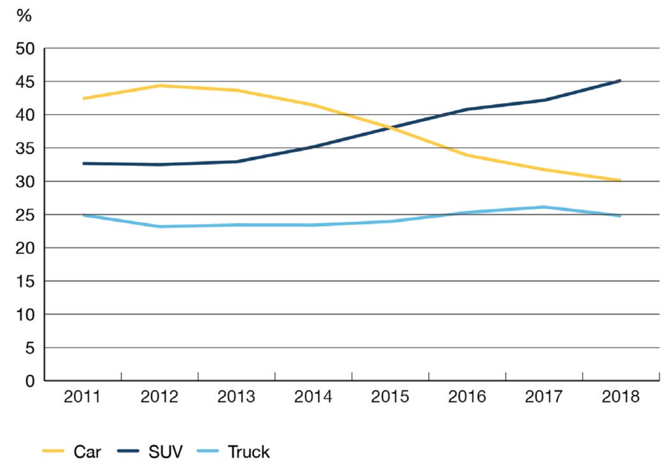
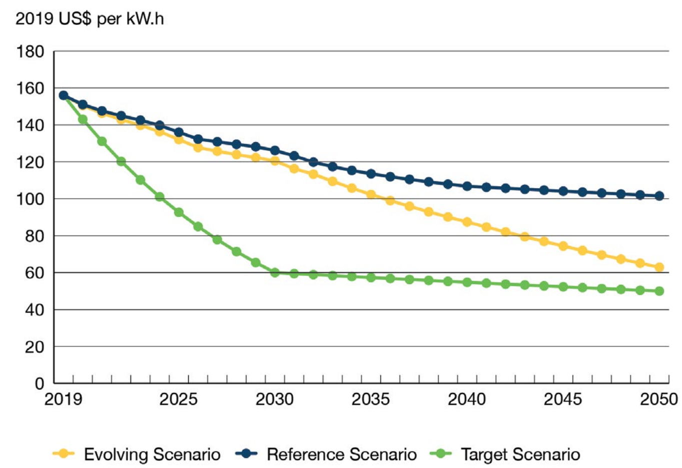


Figure PT.2:
Assumed Battery Costs Decline Faster in the Evolving Scenario vs the Reference Scenario



Considerations for the Energy Transition

Many factors have influenced, and will continue to influence, energy use trends related to personal passenger vehicle choices. Here are some of the key considerations:

Consumer preferences: Increasingly, Canadians are purchasing larger vehicles like sports utility vehicles (SUVs) and trucks. Figure PT.1 plots the market shares of cars, trucks, and SUVs. Since 2011, the market share of SUVs has grown rapidly, from about 58% in 2011 to 70% in 2018. At the same time, the share of cars has fallen from 42% to 30%. It should also be noted that this breakdown varies between provinces. For example in Saskatchewan SUV and truck sales made up 85% of new sales, while in Quebec the share was lower at 60%. The breakdown of vehicle types is an important variable when modelling the adoption of ZEVs. In 2018, almost 2.5% of all vehicle sales were ZEVs. However, within the ZEV category, sales were predominantly made up of cars, comprising 77% of ZEV sales in 2018. This disparity is due to the differences in the selection and costs of ZEV cars and SUVs. The market for ZEV cars is better established, relative to SUVs, and the market for ZEV trucks is non-existent to date.

Policies: Many policies can influence transportation energy trends.[35] These include vehicle fuel economy standards, biofuel blending requirements, low carbon and clean fuel standards, and ZEV mandates. The Canadian federal government provides subsidies for EV purchases and is investing in charging infrastructure. It also has a target of 100% of Canada's vehicle sales being ZEVs by 2040, which – like other targets – is not explicitly modeled in the Evolving or Reference Scenarios. Achieving that target is modeled here in a separate scenario, the 2040 Target Scenario.

Technology: EV battery costs are assumed to fall significantly in both the Evolving and Reference Scenarios (Figure PT.2). Continued cost reductions are uncertain and could be greater,[36] or less[37] than shown in the Evolving Scenario. The ultimate reduction in battery costs will be a key factor in making EVs a competitive option in the personal vehicle market. Another key factor is the type of ZEVs available. As mentioned above, the selection of ZEVs on the market is dominated by cars. However, the market for ZEV trucks and SUVs is expected to grow rapidly in the coming years with auto manufacturers bringing a wider selection of ZEVs to market. The development of ZEV vehicles range as well as charging speed and availability, are additional factors that could impact future adoption.

Alternatives to personal transportation: Alternatives to personal transportation could also play a key role in decarbonizing transportation. This includes public transportation, reduced travel through increased digital communication, and changing transportation infrastructures to those that are more conducive to other non-vehicle travel options, like walking or cycling.

Vehicle stock: The vehicle stock represents the total number of registered vehicles on the road. Over time as vehicles reach the end of their useful lives, they are removed from the stock, while new vehicles sold are added to the stock. ZEVs require less maintenance relative to internal combustion engine (ICE) vehicles and are expected to have longer lifespans. ZEVs are assumed to have an average lifespan of 17 years, relative to 12 years for ICE vehicles.[38] Since vehicles remain on the road for many years, even if the sales share of ZEVs were to reach 100%, it would still take some time for the stock of ICE vehicles on the road to retire.

Potential Pathways for Deep Decarbonization

To further explore deeper decarbonization of passenger transportation, we will complement the Evolving and Reference scenarios with an additional sector specific scenario: the 2040 Target Scenario. This scenario explores the vehicle sales and stock dynamics of meeting the government's 2040 target of 100% light-duty vehicle sales[39] being ZEVs. While many factors could influence increased ZEV uptake, we model the target scenario by assuming more aggressive battery cost declines. Analysis for the 2040 Target Scenario only extends to personal vehicle sales and stocks, as discussed in this section. We have not modeled this scenario for the energy system at large.

The results of the three scenarios are shown in Figure PT.3. The figures on the left compare the share of ZEV vs ICE vehicles in total Canadian sales. The figures on the right show how these sales figures translate into total vehicle stock. Each year, new sales are added to total vehicle stock, and vehicles that reach the end of their operational life are retired.

Differing battery cost assumptions drive very different outcomes for sales and stock of ZEV vehicles. There is a significant disparity between the Reference Scenario, which assumes only moderate battery cost reductions and no new policies, the Evolving Scenario, and the 2040 Target Scenario. As costs of ZEVs fall in the Evolving and 2040 Target Scenarios, ZEV adoption increases. While other factors, such as policies, could affect ZEV adoption, the relative cost of ZEVs and ICE vehicles will play an important role in the transformation of passenger transportation in Canada. The "Key Uncertainties: Passenger Transportation" section covers additional uncertainties.

KEY UNCERTAINTIES:
Personal Passenger Transportation

Technology costs and development: A key factor in the cost of ZEVs is the cost of producing battery packs. The assumed battery production costs are shown in Figure PT.2. Realized production costs may be much higher, or lower, in the future, which could lead to very different rates of adoption of ZEVs. The potential for autonomous/connected vehicles could also impact future vehicle ownership, travel, and energy use trends.

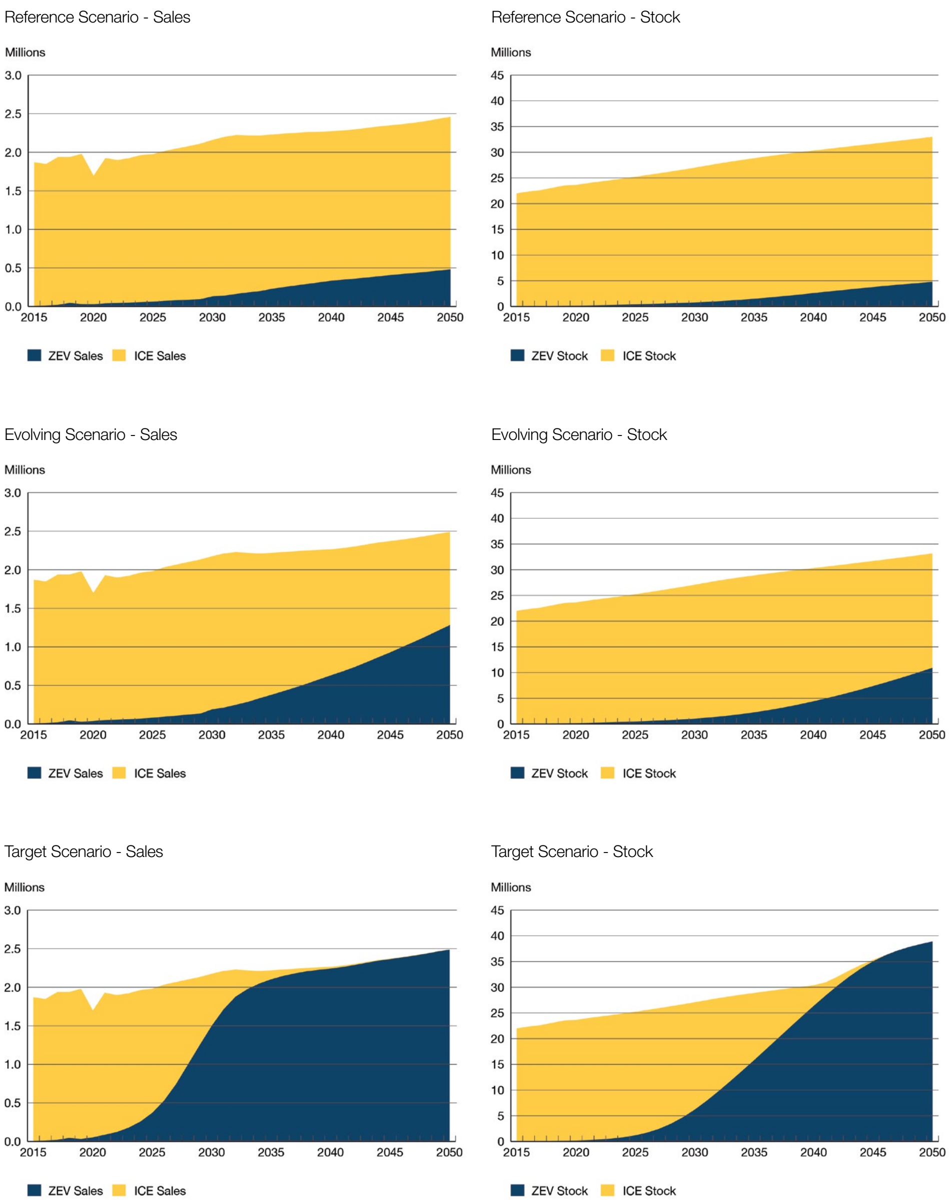
Energy costs: The cost of energy, both for gasoline and electricity, will influence the attractiveness of ZEVs relative to ICE vehicles. Future relative costs of gasoline and electricity could be different from the projected costs used in EF2020. For example, growing electrification of transportation globally could put downward pressure on crude oil prices, which in turn could make ICE vehicles more competitive.

Consumer preferences: There are many factors beyond the cost of vehicles that drive consumer purchasing decisions. There are intangible factors that affect the purchase decision-making process. For example, in the case of ZEVs, unfamiliarity with new technology may make consumers hesitant to purchase them, even if they have a lower cost of driving. The trend towards purchasing fewer cars and more SUVs is another example. These preferences could also lead to outcomes much different from those discussed here.

Alternatives to personal transportation: Zero emissions public transportation, powered by electricity or hydrogen, could play an increasing role in a decarbonized transportation sector. Likewise, reduced demand for personal vehicles via increased walking, cycling, or digital communication could influence the number of ZEVs required. Ride sharing technologies using electric vehicles is another factor which adds uncertainty to the decarbonization of the transport sector.

Figure PT.3:

Sales and Stock Trends by Scenario, ZEV vs ICE Personal Vehicles



Modeling ZEV Adoption in Various Scenarios

In all scenarios, the market share of each vehicle type is a function of the levelized cost[1] of driving (LCOD) of that respective vehicle type. The LCOD is a metric which represents a full cost accounting of vehicle ownership on a per kilometer basis. It is a function of many different costs related to owning and operating a vehicle, including purchase price, fuel cost, maintenance, fuel efficiency, kilometers driven and discount rate. The relative differences in the LCOD of different vehicle types drive the differences in market shares over the projection period.

While the LCOD varies by province, the Evolving Scenario ZEV LCOD is approximately 10% lower in 2050 compared to the Reference Scenario, while the 2040 Target Scenario LCOD is 26% lower than the Reference Scenario. These differences are mainly driven by the assumed battery costs shown in Figure PT.2. As the LCOD of ZEV improves relative to ICE vehicles, the ZEV market share increases. In the Evolving Scenario, the LCOD of ZEVs begin to reach parity with ICE vehicles in the mid-2030s, leading to the rapid adoption of ZEVs. In addition to sales, the vehicle stock is also projected forward, and is shown in Figure PT.3. Note that the ZEV share of the total vehicle stock is much lower than the ZEV share of sales. This highlights the fact that it takes time for the vehicle stock to turnover.[2]

The 2040 Target Scenario takes the same modelling approach as the other scenarios. However, in order to meet the 2040 government target, it assumes more aggressive battery cost declines, as shown in Figure PT.2. Earlier and faster reductions in battery costs are the driver of accelerated ZEV adoption in this scenario. If battery costs do not decline as aggressively, it is still possible for other policy levers to be used to drive ZEV adoption. For example, higher carbon prices[3] and policies such as the proposed federal Clean Fuel Standard could be used to improve the economics of ZEVs and incent their adoption.

1 For more information on LCOD see the CER's Market Snapshot "Levelized cost of driving EVs and conventional vehicles" and NREL's *Electrification Futures Study: End-Use Electric Technology Cost and Performance Projections through 2050.*

2 This analysis assumes a vehicle lifespan of 12 years for ICE vehicles and 17 years for ZEVs.

3 Apart from the differences in battery costs, both the Evolving and Target Scenarios use the same assumptions for all other variables (carbon price, fuel prices, provincial policies etc.).

Oil Sands Production

Energy Profile of Oil Sands Production

In 2019, Canada was the fourth largest producer of oil in the world, responsible for over 5% of global output. It holds the third largest proven reserves at 169 billion barrels. The oil sands were responsible for 63% of total Canadian production in 2019, over 3 MMb/d, and comprises 96% of its reserves.

There are three different types of oil sands production. Each production and processing method requires different energy sources, resulting in varying amounts of GHG emissions.

Mining and upgrading: Oil sands mining relies on diesel to fuel heavy machinery and equipment that extracts oil sands ore and transports it to processing facilities. Oil sands mines also have cogeneration facilities to produce the energy (heat) required for the mining, bitumen extraction and upgrading processes, and the electricity used to run the operation. The cogeneration units use natural gas or petroleum coke – a by-product of upgrading bitumen into synthetic crude oil (SCO). Similarly, the process through which bitumen is extracted from the mined oil sands ore, as well as upgrading, requires natural gas or petroleum coke to produce steam for heat and to generate the hydrogen needed to upgrade heavier oil into lighter SCO.

Standalone mining: In 2013, the first standalone mine, Imperial Oil's Kearl mine, commenced operation, followed by Suncor's Fort Hills mine in 2017. The process for this new type of mine creates a diluted bitumen[40] that is sent to market without being upgraded. Many of the same emissions sources as in other types of mining are in play here but without any emissions associated with upgrading.

In situ: In situ projects rely on a constant supply of stream to maintain steam-assisted gravity drainage (SAGD) and cyclic steam stimulation production operations. Industrial boilers combust natural gas to create this steam from water, which then heats underground reservoirs and mobilizes bitumen for extraction, similar to how conventional oil is pumped to the surface.

Key characteristics of oil sands production that differentiate it from many other forms of oil production:

Long-lived with low decline rates: Conventional oil production, and in particular shale oil, can have annual decline rates of over 50% in the first year. This means that wells need to be drilled to keep production levels constant, and even more to wells to grow production. In comparison, the oil sands have a near-zero decline rate with only modest reinvestment. A typical oil sands operation can likely operate for 40-50 years in the case of mines, and 20-40 years in the case of in situ operations. The lives of these assets can be extended beyond these timelines if economic conditions are favourable.

Capital intensive: Though costs in the oil sands have declined considerably over the last decade, these operations are still capital intensive and require large upfront investment. In general, higher commodity prices are required to incent a company to build new oil sands production capacity, while expansions to existing facilities can be economic at lower prices. For instance, much of the growth projected for the oil sands in the Evolving Scenario will come from expansions to existing in situ facilities. These operations require a WTI price of roughly US$45/bbl to be profitable. Other types of oil sands operations require comparatively higher commodity prices with oil sands mining and upgrading being the highest at over US$75/bbl.

Export oriented: Though a portion of the crude oil produced in Canada is refined domestically, most of it is destined for export markets. Figure R.12 in the Results section illustrates the supply available for export in the Evolving and Reference scenarios.

Considerations for the Energy Transition

Emissions Intensity of Production

In 2005, the oil sands accounted for approximately 5% of Canada's GHG emissions. By 2018, it increased to approximately 11%. Absolute oil sands emissions increased by 51% from 2011 to 2018. Most of Canada's growth in oil production was from the increase in in situ oil sands projects over that period. When measured on a per barrel basis, emission intensity from the oil sands decreased by 22% from 2011 to 2018, from approximately 0.086 tonnes carbon dioxide equivalent per barrel (CO_2e/bbl) to 0.067 tonnes CO_2e/bbl. See Figure OS.1. Emissions intensity from in situ production decreased by 12% over this time, while mining and upgrading emission intensity decreased by 19%. In 2013, the first standalone mine, Imperial Oil's Kearl, came into operation, followed in 2017 by Suncor's Fort Hills mine. As described above, these operations produce diluted bitumen and do not upgrade. The upgrading process is particularly energy intensive and removing it lowers Canada's production emissions intensity considerably. However those emissions could be realized when it is upgraded/refined elsewhere. From 2013 to 2018, standalone mining emissions intensity declined by 56% from roughly 0.079 tonnes CO_2e/bbl to 0.035 tonnes CO_2e/bbl as these operations found efficiencies in their processes.

Compared to conventional crude oil production in Canada and the rest of the world, the oil sands is more emissions intensive per barrel, particularly in situ production. For comparison, in 2018, conventional oil production in Canada averaged 0.048 tonnes CO_2e/bbl.[41]

The Evolving Scenario includes technological improvements in extraction and upgrading methods of existing projects that continue to develop at the same pace as recent history. Specifically, we assume increased use of solvents for in situ production, and in-pit extraction for mining. As seen in Figure OS.2, these improvements lead to significantly improved per barrel emissions. At the same time, additional improvement is needed to reach net-zero in the oil sands.

Figure OS.1:
Emissions per Barrel in the Oil Sands are Declining

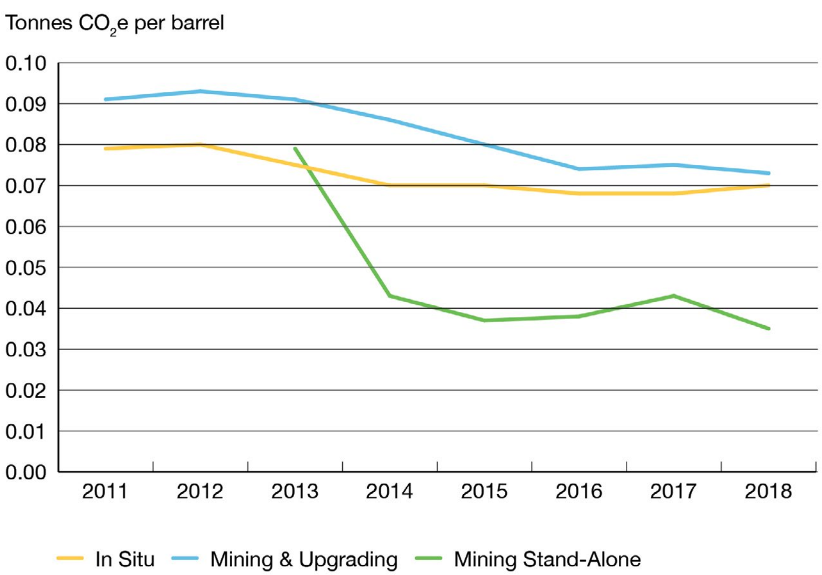
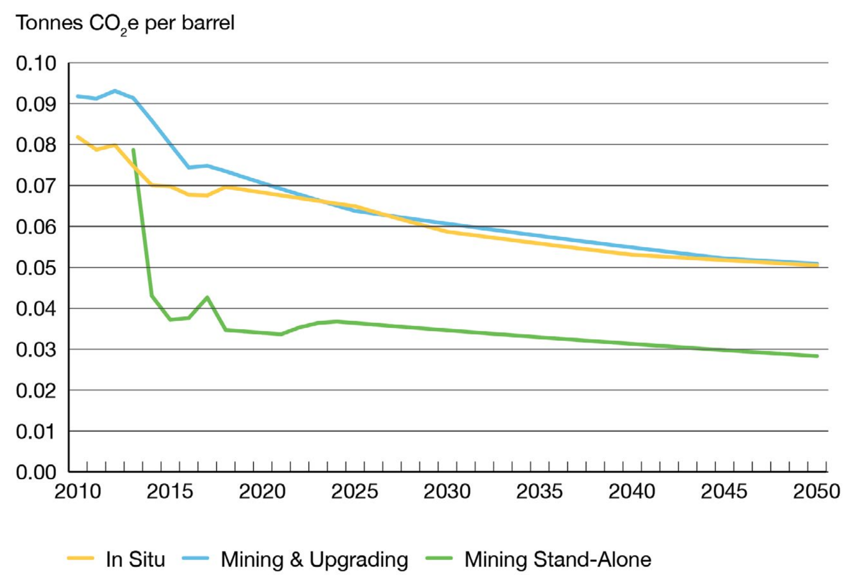


Figure OS.2:
Oil Sands Emissions per Barrel Decline in the Evolving Scenario



Global Context

In a global energy system that does move towards net-zero, global crude oil use is very likely to decrease compared to current levels. If demand is decreasing, global crude oil prices, and hence the price received by Canadian producers, will likely be lower than they would be if demand were higher.[42] Technologies to achieve net-zero oil sands production can be more costly than traditional methods. A lower price environment may create challenges for producers to afford those investments and remain competitive.

Competitiveness

As global efforts to reduce emissions intensity continue, emissions associated with crude oil production could increasingly influence global investment choices and trade patterns. Increasingly, investors like major banks and sovereign wealth funds, are weighing ESG considerations when deciding where to invest capital. In order to access capital, companies will have to show their compliance with ESG parameters. See the “What is ESG?” section.

What is ESG?

ESG is a framework increasingly used by companies to provide information on their environmental, social, and governance components to investors. In order for companies to gain access to capital, they are often required to prove that their ESG structures are acceptable to investors. The investment community is shifting its attention towards firms that align with their values on ESG performance criteria.[1] These criteria can serve as screening mechanisms to scope viable investment opportunities in sustainable companies. In particular, Canadian and global investors are utilizing ESG principles to enhance their potential for future returns, while minimizing their investment risk. Organizations who embed ESG frameworks into their fundamental values can strengthen their resilience to economic and environmental pressures. This heightened resilience provides investors with greater confidence that an organization is prepared for a low carbon energy transition.[2]

- The environmental component of ESG evaluates whether a firm's assets are being responsibly and sustainably stewarded. It determines if resources are being utilized at the lowest cost to the environment. Some examples in the oil sands sector include land use and reclamation, air emissions management, water use and availability, and energy use.[3]
- The social component outlines how firms engage with their internal and external stakeholders. This includes interactions with employees, shareholders, government divisions, and the greater community they serve. Some examples in the oil sands sector include community and Indigenous Peoples engagement, talent management, and culture of inclusion.[4]
- Criteria under the governance component outlines the leadership structure and core principles that influence a firm's operations. Some examples in the oil sands sector include transparent accounting methods, ethical business practices, and diverse governing representation.[5]

1 Responsible Investment Association, 2018 Canadian Responsible Investment Opportunity: Trends Report, pg. 12, October 2018.

2 IPIECA, Oil and Gas Industry Guidance on Voluntary Sustainability Reporting, 8.

3 Husky, ESG Report 2019, Page 4.

4 Husky, ESG Report 2019, Page 4.

5 Husky, ESG Report 2019, Page 4.

Potential Pathways for Deep Decarbonization

The future of the global oil market as Canada and the world move towards a decarbonized energy system is highly uncertain. Future trends in oil sands production will depend on many factors, including future price levels, policies, and technological developments. Oil sands production would need to remain cost competitive in a global context of declining demand, which will likely put downward pressure on global prices. It will also need to compete in an energy system that increasingly demands emission reductions.

It is difficult to predict just how companies operating in the oil sands will achieve this. However, there are a number of technologies that are at varying stages of development which could be part of the solution. Table OS.1 outlines some of the promising options and their emission reduction potential.

Table OS.1: **Options for Emissions-Reducing Technologies in the Oil Sands**

Stakeholder(s)	Technology Type	Emission Reduction Potential	Description
Acceleware Ltd.	RF XL	50-100%	Radio frequency energy to mobilize heavy oil and bitumen, replacing the need for steam.
Suncor Energy, Harris Corporation, CNOOC Limited, Devon Energy	Enhanced Solvent Extraction Incorporating Electromagnetic Heating (ESEIEH)	80%	Radio frequency energy used in combination with pure solvent to mobilize underground bitumen, replacing the need for steam.
Imperial Oil	Enhanced Bitumen Recovery Technology (EBRT)	60%	Solvent assisted SAGD reduces the steam required to mobilize bitumen within the reservoir by as much as 25%.
MEG Energy	Enhanced Modified Vapour Extraction (eMVAPEX)	43%	Condensable gas (e.g. propane) in lieu of steam is injected after initial SAGD operation to support bitumen extraction.
Canadian Natural Resources Limited (CNRL)	In-Pit Extraction Process	40%	Relocatable, modular extraction plant that can be moved as the mine face advances. Ore processing and bitumen separation occurs adjacent to mining operations, significantly reducing material transportation, reducing emissions from heavy-duty vehicles.
Cenovus Energy	Solvent Aided Process (SAP)	33%	A modified SAGD process where NGL-based solvent is combined with steam for bitumen recovery to reduce the steam requirement by up to 30%.
ConocoPhillips Canada, Total E&P Canada	Non-Condensable Gas (NCG) Co-Injection	15%	Prevents energy loss in the reservoir, reducing the amount of steam required for the extraction process, resulting in emission reductions of up to 15% and operating cost reductions.
Suncor Energy, Devon Energy, Suez	High Temperature Reverse Osmosis (HTRO)	5-10%	High temperature water is recovered, post-SAGD, filtered, and re-used to produce additional steam.

Not all of these technologies will work on all production methods and in all locations. In some cases, these technologies work best when included in the initial design phase of new projects. Some however, like the use of solvents, can be retrofitted onto existing projects. In addition to those listed in the table above, there are other technologies that could play an important role in reducing emission intensities in the oil sands, including:

Small Modular Reactors (SMRs): SMRs are nuclear power plants that have been scaled down in size and capacity. These units can be used to produce the electricity, and heat, used in mining and upgrading operations and in the case of in situ operations, could also produce steam. These units would produce near-zero GHG emissions. Research and development is ongoing,[43] and they could play a role at some point in the projection period.

Carbon Capture, Utilization and Storage (CCUS): While reducing the production of GHGs through processes and clean technology innovation, CCUS offers an opportunity to capture CO_2 for geological storage and utilization. In some cases, the captured CO_2 can also be used for Enhanced Oil Recovery, increasing the production of crude oil by injecting it into active production fields. CCUS is already in use in the oil sands. The Shell Quest CCS facility, in operation since 2015, has been able to store over four million tonnes of CO_2 from the Scotford bitumen upgrader. Approximately 35% of the facility's annual CO_2 emissions have been successfully captured and stored by this technology. CCUS could be combined with cogeneration, or direct air capture, for additional reductions and/or use opportunities.

KEY UNCERTAINTIES:
Oil Sands Emissions

Technological development: The speed with which new technologies are developed and adopted is one of the largest uncertainties.

Oil prices and markets: Future crude oil prices and access to markets for growing crude oil production in Canada are also highly uncertain. These factors can affect future production growth, competitiveness, and investments in new technologies.

Carbon pricing and/or regulations: Future increases to carbon prices, which would make CO_2 more expensive to emit and encourage producers to adopt low-emission technology, are subject to future policy choices by governments. Future regulations limiting CO_2 emissions, or requiring adoption of certain technologies, are also highly uncertain.

Funding for technologies: Government funding may provide the impetus for the development of many technologies. The extent to which federal and provincial governments will fund these developments is uncertain.

Investments in light of ESG trends: Funding will also come from capital markets. The impact of trends related to ESG standards and investor ESG expectations is highly uncertain.

Remote and Northern Communities

Energy Profile of Canada's Remote Communities

There are approximately 270 remote communities in Canada. Communities are identified as remote if they are not connected to the North American electrical grid, nor to the piped natural gas network, and if they are a permanent or long-term settlement with at least 10 dwellings.[44] The largest remote communities in Canada are Whitehorse, Yukon; Yellowknife, Northwest Territories (NWT); and the Magdalen Islands, Quebec.

Table RC.1 organizes Canada's remote communities by province, and by primary power source. It also breaks down community type (commercial remote communities are typically mines), primary electricity generation source, and accessibility (if the community has access to an all-year road or if the community is fly-in only).

Remote communities face challenges in meeting their energy needs that grid-connected communities don't. They are highly reliant on diesel fuel for electricity generation and space heating.

While diesel fuel has many benefits, including being widely available, transportable, and an energy dense fuel, there are also notable drawbacks. The remoteness of many communities (the lack of an all-year road, or fly-in status) creates supply security issues. This remoteness also results in high transportation[45] costs for diesel and higher energy costs. The small population of many communities results in poor economies of scale in providing energy, further adding to costs for residents. In addition, diesel generators and furnaces emit large quantities of GHGs, various pollutants, and particular matter that affect local air quality. Lastly, diesel fuel spills can also occur and may be costly to remediate.[46]

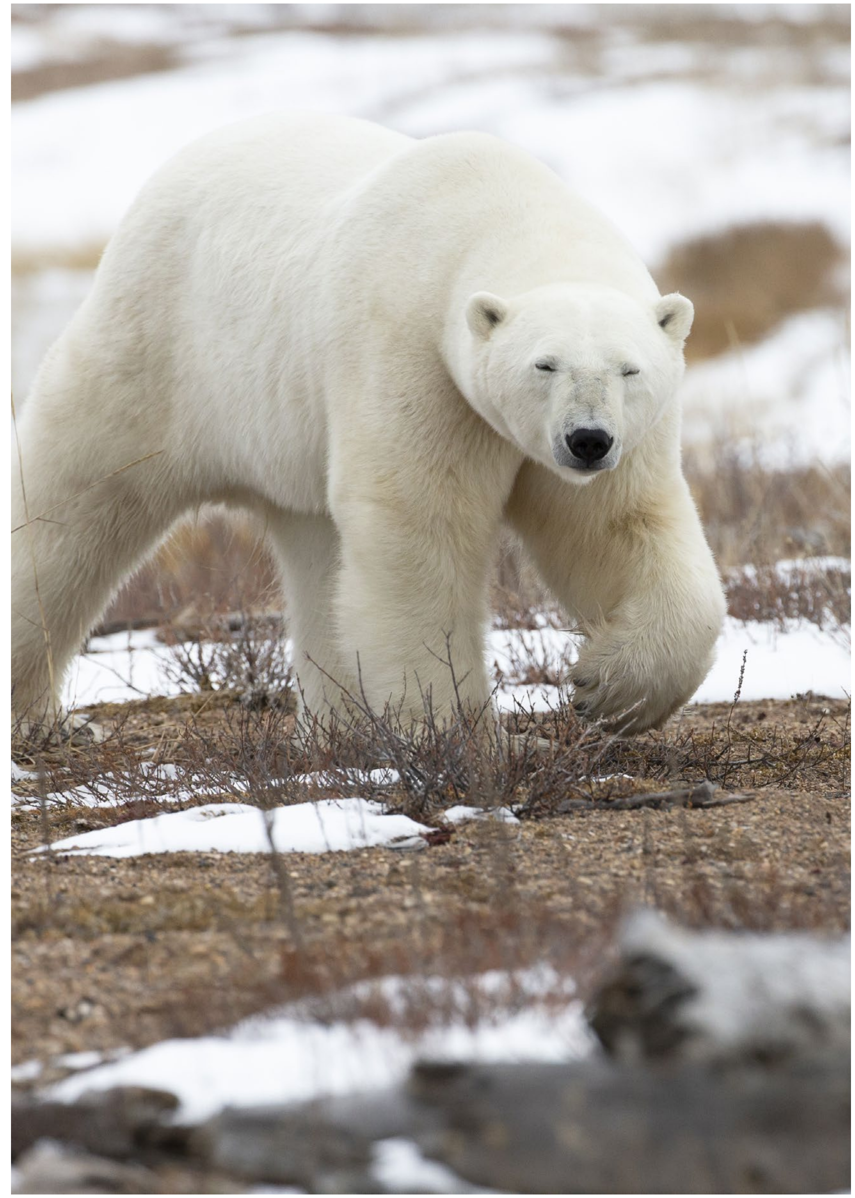


Table RC.1: **Canada's Remote Communities, by the Numbers**

	Canada	Yukon	NWT	Nunavut	B.C.	Alberta	Saskatchewan	Manitoba	Ontario	Quebec	Newfoundland and Labrador
Remote Communities	**270**	**21**	**38**	**28**	**72**	**6**	**1**	**5**	**29**	**42**	**28**
TYPE OF COMMUNITY:											
Indigenous	167	15	31	25	28	3	1	4	24	22	14
Non-Indigenous	86	6	3	0	40	1	0	1	5	17	13
Commercial	17	0	4	3	4	2	0	0	0	3	1
ELECTRICITY GENERATED BY:											
Diesel or Fuel Oil	201	5	27	28	53	6	1	5	29	25	22
Territorial Grid	25	16	9	0	0	0	0	0	0	0	0
Natural Gas	3	0	2	0	0	0	0	0	0	1	0
Hydro	35	0	0	0	14	0	0	0	0	15	6
No Electricity / Other	6	0	0	0	5	0	0	0	0	1	0
ACCESSIBILITY:											
All Year Road Access	102	20	20	0	31	5	1	0	7	5	13
Fly-in Community	102	1	18	28	0	1	0	5	22	20	7
Other Access	66	0	0	0	41	0	0	0	0	17	8
Total Population	**188 828**	**31 454**	**42 061**	**36 672**	**10 425**	**893**	**10**	**3 545**	**16 607**	**38 823**	**8 338**

Source: Natural Resources Canada, Remote Communities Energy Database, CER calculations
Notes: Several communities with no population data were excluded from the above table. Additionally, Pikangikum, Ontario (grid connected in 2018) and Jasper, Alberta (grid connected in 2019) are also excluded. Under Accessibility, "Other Access" includes seasonal roads and some marine.

Considerations for the Energy Transition

The uniqueness of Canada's remote communities will shape their energy transition. Key drivers of potential change are:

Indigenous communities: Table RC.1 indicates that the majority of remote communities (167 of 270, or about 62%) are categorized as Indigenous. Of these communities, 84% are powered with diesel generators. The shift away from fossil fuels for these communities represents one possible pathway to advancing reconciliation and could help advance goals of Indigenous self-determination and self-reliance.[47] Community-led and community-owned projects could lead to improved energy security, as well as economic opportunities for remote and northern Indigenous communities.

Climate: The vast majority of residents in remote communities live in northern climate regions. These regions are defined by long and cold winters and short summers. Heating degree days (HDDs), the standard measure for space heating requirements in an area, are notably higher in northern regions of Canada than in southern regions.[48] Energy is key for survival; making energy security a top priority for remote and northern communities.

Electricity: Table RC.1 illustrates that the majority of remote communities (207 of 270, or about 77%) are powered by diesel fuel, heavy oil, or by personal diesel generators. Some communities are covered by a territorial grid or regional micro-grid. The majority of communities and residents in Yukon are connected through the primarily hydro-based Yukon grid. Communities around the Great Slave Lake in NWT are also connected by one of two (primarily) hydro-based grids. None of these territorial grids are connected to each other, nor are any connected to the main North American electricity grid. Hydro-based electricity generation in Yukon and NWT stands in contrast to electricity generation Nunavut, as shown in Figure RC.1. Nunavut's 25 Indigenous communities and three commercial operations are all disconnected from each other, each relying almost entirely on local diesel generation. Lastly, communities along Quebec's Lower North Shore are connected by an off-grid hydro system that is also connected with the L'Anse au Loup system in southern Labrador.

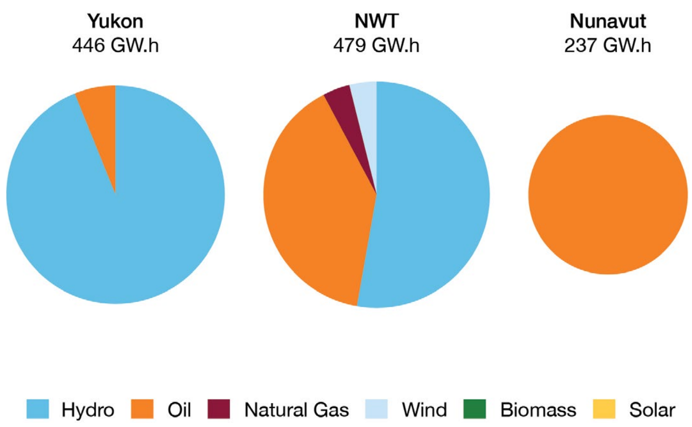
Space heating: In the vast majority of remote communities, space heating is primarily by diesel fuel or heating oil. Less common methods of home heating are with electricity, propane, and wood. Diesel demand for space heating in remote communities is double that of diesel demand for electricity generation.[49] Remote communities connected to a territorial, or small hydro grid, still rely heavily on diesel fuel for space heating as current hydro capacity would be insufficient to handle all winter heating demand if most, or all buildings, were to switch to electric heating.

Transportation: Less than half of all remote communities have all-year road access, and 38% are considered fly-in communities. Communities that do not have an all-year road, but are not considered fly-in, may have access to a winter road, barges, or marine vessels. Personal transportation is more limited in communities lacking an all-year road, and the reliance on air transport for freight and people comes at considerable environmental and financial costs.

Commercial communities: The Remote Communities Energy Database identifies 17 commercial communities in Canada, and the majority of these are mining operations. All commercial operations, with the exception of the natural-gas powered Renard Diamond Mine in northern Quebec, rely on diesel for electricity generation. One of the largest consumers of diesel fuel is the Diavik Diamond Mine in NWT. In 2012, 9.2 megawatts (MW) of wind turbine capacity was installed at the mine, making it the world's largest and northernmost diesel-wind hybrid power facility.[50]

Policy: The Pan-Canadian Framework on Clean Growth and Climate Change commits to reducing GHG emissions by supporting rural and remote communities in their transition towards more secure, affordable, and cleaner sources of energy.[51] In early 2019, the Indigenous Off-diesel Initiative was launched by the federal government and partners to help communities move away from using diesel fuel by developing cleaner community-led energy projects.[52] This initiative builds on over $700 million previously committed funds to help remote communities switch to new energy sources.

Figure RC.1:
Electricity Generation in the Northern Territories in 2018

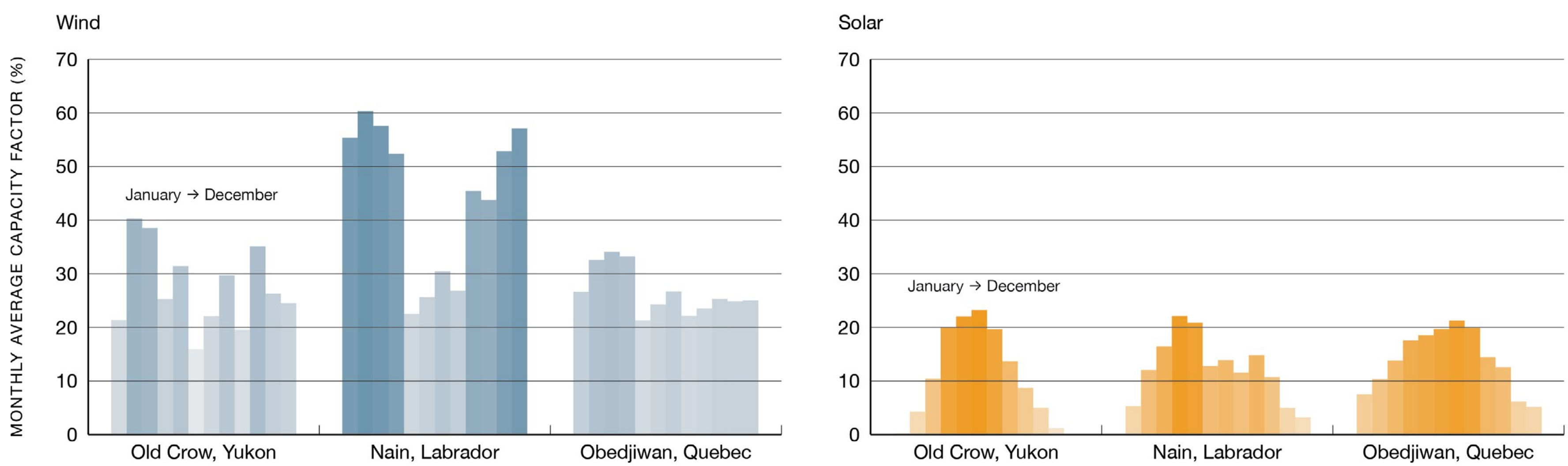


Variable Renewable Energy in Remote Communities

Figure RC.2 displays estimated capacity factors for wind and solar in three remote communities: Old Crow, Yukon; Nain, Labrador; and Obedjiwan, Quebec. In Nain, for example, the estimated capacity factor for wind averages 56% between November and April (peaking at 60% in February), but averages 26% between May and August. In Old Crow, the estimated capacity factor for solar averages 20% between April and August (peaking at 23% in June), but averages 2% between October and February. Located above the Arctic Circle, the estimated capacity factor for solar in Old Crow declines to 0% for December and January.[1] The variability of monthly average capacity factors illustrate the importance of choosing the right renewable generation source, or mix of sources, for each community.

[1] Numbers represent a monthly average. Solar PV systems can experience rapid changes with cloud cover over the solar panels.

Figure RC.2:
Monthly Capacity Factors for Wind and Solar: Three Examples



Source: Renewables Ninja, CER calculations
Notes: Graphs illustrate monthly average capacity factors for wind and solar energy from January to December.

Potential Pathways for Deep Decarbonization

The diversity and unique challenges of remote and northern communities will shape the future of their energy systems in a world moving towards net-zero. This section will discuss the options that exist, or could exist, in the near and longer term to help remote communities transition away from carbon-emitting fossil fuels.

KEY TRENDS:
Transitioning Remote Communities

- More renewables, like wind, solar, biomass and hybrid systems, are being explored and implemented to offset diesel consumption.
- Movements are being made away from diesel for home heating, and there is potential for biomass in many communities. This is in addition to improved building envelopes and building with higher standards to improve energy efficiency.
- More community-led and owned projects are being implemented, particularly with an Indigenous component.
- Stronger policies are being implemented at the provincial, territorial and federal levels to help remote communities reduce and eliminate their reliance on diesel.

KEY UNCERTAINTIES:
Transitioning Remote Communities

Policies in place: Government support for off-diesel initiatives and community led projects are key to transitioning remote communities towards net-zero. However, future policies and project economics are uncertain.

Technological advancements: Improvements in efficiencies and costs for traditional renewables, next generation renewables, and energy storage have significant implications for remote communities. For instance, technological advancements might allow renewables to operate more reliably in extreme cold. But, the pace at which technologies are developed and adopted is uncertain, in part depending on government funding.

Costs: Roughly one-third of communities considered in this section are fly-in, and less than half have an all-year road. Estimating the environmental and financial costs of transporting materials to, and building in, very remote communities is uncertain.

Table RC.2: **Potential Options for Partial or Full Decarbonization of Remote Communities**

Electricity	**Traditional renewables:** Traditional renewables, including wind, solar, small and large hydro, and biomass, are currently helping several remote communities displace diesel used for electricity generation.[53] Other than large (reservoir) hydro (which is limited by geography), traditional renewables by themselves have a very limited role in providing stable baseload generation for remote communities, particularly during the winter peaks. (See text box: Variable Renewable Energy in Remote Communities) **Emerging technologies:** Could include next generation biofuels, hydrogen, geothermal, and nuclear in the form of SMRs. For stable, long-term baseload generation, SMRs could hold the most promise. Canadian SMR Roadmap notes that very small SMRs could address the electricity needs for remote communities, while small to medium SMRs could be used for off-grid heavy industry.[54] The roadmap notes that SMRs could also open up remote communities to further economic development by offering reliable bulk energy. **Grid connection:** Remote communities can move away from diesel for electricity generation by connecting to bulk electricity grids. A connection to the North American grid would provide abundant and stable electricity for remote communities.	Generally, the shorter the distance from a transmission line, and the larger the community being connected, the more feasible the choice of a grid connection becomes.[55] The largest drawback of this option may be cost.[56] **Demand-side measures:** Demand-side changes to decarbonize electricity production include the introduction of more stringent building standards and energy efficiency measures, demand-side management and smart metering, and dual metering (for example, one meter used for household use, another used for space heating).[57] **Energy storage:** Energy storage can be an important part of integrating variable renewable energy, particularly with respect to short term variations. Energy storage may be particularly helpful for micro-grids, in providing essential reliability services such as frequency support and reserve capacity.[58] As costs fall and technology improves, energy storage could play an increasing role in remote communities.
Space Heating	**Biofuels:** Space heating needs for remote communities could be achieved through biomass or next generation biofuels, either through point source heating, or more centralized methods like district heating or combined heat and power.[59] A study of wood pellet district heating in NWT noted that favourable economic potential exists in several all-year road and winter road communities.[60] The economics for biomass district heating are higher when wood pellets are substantially cheaper than other fuels, when buildings are clustered together, and when project costs are low.	Another study that focused on Inuvik, NWT noted that the cost of wood pellets were lower per unit of energy than any other fuel options for residents. While high capital costs associated with converting furnaces to wood pellet boilers may negate lower fuel costs, the study noted that large commercial and institutional customers have short payback periods on investments.[61] **Alternative district heating options:** SMRs could generate enough electricity to meet peak winter needs for space heating, as noted in Canada's SMR roadmap. A project to develop an SMR for district heating was recently launched in Finland.[62]
Transportation	**Zero emission vehicles:** The transition to ZEVs presents a challenge for remote communities.[63] Adoption could be slower in communities located in the coldest regions in Canada, and for communities that are not connected to a larger regional grid, or the North American grid. A case study in Yellowknife involved a plug-in hybrid vehicle.[64] While the study noted issues related to operating a plug-in hybrid in extreme cold,[65] the study did conclude that plug-in hybrids are viable vehicles for northern climates with a battery range suitable for city driving.	The study also noted that battery EVs with a longer range would require a network of fast charging stations along NWT's highways. A more recent test study found a roughly 18.5% reduction in range, and that charging complications can be expected from EVs in the cold.[66] **Next generation biofuels and hydrogen:** Other options such as next generation biofuels and hydrogen fuel cells could be useful for areas where energy density is valuable, including personal and freight road transportation, as well as marine and air travel.

Appendix A: Domestic Climate Policy Assumption Overview

The "Scenarios and Assumptions" chapter discusses the domestic climate policy assumptions included in the Evolving Energy System Scenario (Evolving Scenario) and the Reference Energy System Scenario (Reference Scenario). The Reference Scenario includes only policies currently in place. The Evolving Scenario assumes greater policy action over time, at roughly the same pace as historical policy implementation. It does this by assuming a hypothetical suite of policy initiatives that build upon current policies. Table 1 describes the criteria for inclusion of current policies, and assumed future policies. Table 2 provides a brief[67] overview of several key current policies. Table 3 provides an overview of future policies assumed in the Evolving Scenario.

Table 1: **Policy Inclusion Overview**

Criteria for Inclusion of Current Policies Included in Reference and Evolving Scenarios	Considerations for Future Policy Assumption Included in the Evolving Scenario Only
The Reference Scenario includes only current policies. In the Evolving Scenario, current policies provide a baseline that is built upon over the projection. In order to determine whether a policy was included in the analysis, the following criteria were applied: → The policy was publically announced prior to 1 August 2020. → Sufficient details exist to model the policy. → Goals and targets, including Canada's international climate targets, are not explicitly modelled. Rather, policies that are announced, and in place, to address those targets are included in the modelling and analysis.	The Evolving Scenario includes a hypothetical suite of future policy developments. These policy assumptions take into account several considerations: → Announced policies that are currently in the development stage (such as those included in Environment and Climate Change Canada's (ECCC) "With Additional Measures" GHG scenarios) are included to the extent possible. Generally their inclusion requires simplifying assumptions, as final regulations are not available and there is a lack of details sufficient to model the policies. The Evolving Scenario should not be taken as analysis of any individual policy or program. → The types of future policies assumed have historical precedence in previous climate policies implemented at various levels of government. → Evolving Scenario policy assumptions gradually strengthen over time, rather than assuming large clusters of policy development at a given time.

Table 2: **Key Current Policies Included in the Reference and Evolving Scenarios**

POLICY	DESCRIPTION
Pan-Canadian Framework on Clean Growth and Climate Change	In December 2016, Canada's First Ministers released the Pan-Canadian Framework on Clean Growth and Climate Change (Pan-Canadian Framework), which outlined the actions that will contribute to meeting, or exceeding, Canada's 2030 climate change target of a 30% reduction below 2005 GHG emission levels. Pillars of the Pan-Canadian Framework include: **1)** pricing carbon pollution **2)** complementary actions to reduce emissions **3)** adaptation and climate resilience **4**) and clean technology, innovation, and jobs. The framework describes many new actions associated with the four pillars. Several elements of the framework are in place and qualify as a current policy, as described in this table.
Vehicle Emission Standards	**Light Duty Vehicles** In 2014, the federal government adopted phase 2 of the light-duty vehicle GHG regulations which progressively increased GHG standards. Given these standards are harmonized with the U.S., the recent U.S. rollback of standards starting with model year 2021 is included. **Heavy Duty Vehicles** Phase 2 heavy duty vehicle standards, which increase stringency to model year 2027, are included. The regulation reduces GHG emissions from on-road heavy-duty vehicles through emission standards applicable to manufacturers and importers of new heavy-duty vehicles, engines and trailers.
Pricing Carbon Pollution	EF2020 includes provincial and territorial carbon pricing systems, as well as the Federal Carbon Pricing Backstop (Backstop). Implementation of carbon pricing systems currently varies across the country, and details on each region's approach are available from Environment and Climate Change Canada. Most provinces have an end-user carbon price at similar levels to the Backstop, which is C$30 per tonne in 2020, increasing to $40/tonne in 2021 and $50/tonne in 2022, where it remains for the remainder of the projection. For provinces such as Quebec and Nova Scotia that have adopted a cap-and-trade program, the price of carbon is market-based, determined by the supply and demand of emission permits. Like crude oil and natural gas prices, EF2020 makes simplifying assumptions for the future outlook of carbon pricing. EF2020 assumes the carbon price in these provinces remains below the Federal Backstop in the early 2020s, before converging to $50 per tonne in 2025 and remaining at that level for the remainder of the outlook. Many provinces, as well as the Federal Backstop, include specific programs for large industrial emitters. For provinces where these systems are fully detailed and implemented, they are included in EF2020 as current policies. Examples include: → British Columbia's CleanBC Program for Industry, which includes both the CleanBC Industrial Incentive Program and the CleanBC Industry Fund. → Alberta announced plans to replace its existing carbon pricing program for large industrial emitters, with the Technology Innovation and Emissions Reduction (TIER) program. Large emitters must improve their emissions intensity relative to their historical levels. Emitters pay a carbon price if they fail to meet the required emissions intensity reductions, and can earn credits if they surpass their required reductions. → In 2018, Saskatchewan enacted its own regulation for large industrial emitters: *Management and Reduction of Greenhouse Gases Act - Large Emitters Intensity Standards*. Like Alberta, sector benchmarks are set from historical emission intensity levels. Saskatchewan is also developing its own emissions offset system, which is expected to come into force in 2020. → The Federal government recently approved New Brunswick's industrial output based pricing system. → The Newfoundland and Labrador government passed legislation in June 2016 that enables the regulation of GHG emissions from industrial facilities in the province: *Management of Greenhouse Gas Act*. The plan will include a form of carbon pricing for industrial emitters, the revenues of which will support funding of emission-reducing technology. Large industrial emitters can choose between a historical facility-specific benchmark or a larger industry-wide established benchmark. → Created under Ontario's Emission Performance Standards Regulation, the province's Emission Performance\Standards program applies to large emitters, with the option for smaller emitters to opt in.
Canada-U.S. joint action to reduce methane emissions from the oil and gas sector	In March 2016, Canada and the U.S. announced joint action to reduce methane emissions from the oil and gas sector by 40 to 45% below 2012 levels by 2025. In May 2017, the federal government released a technical backgrounder detailing the proposed regulations to deliver on this commitment. The regulations will apply to oil and gas facilities responsible for the extraction, production and processing, and transportation of crude oil and natural gas, including pipelines. The first federal requirements come into force in 2020, with the rest of the requirements coming into force in 2023.
Federal phase-out of traditional coal-fired generation by 2030	In November 2016, the federal government announced it is amending the regulations applicable to coal-fired electricity generation to ensure that all traditional coal-fired units are phased out by no later than 2030. Alberta, Saskatchewan, New Brunswick, and Nova Scotia have coal-fired power plants that are impacted by these regulations. Prior to this announcement, Alberta had already committed to phasing out pollution from coal-fired plants by 2030.

POLICY	DESCRIPTION
Renewable Fuel Regulations	There are various renewable fuel blending requirements in place across Canada. **Gasoline and Diesel** On average, federal regulations require 5% ethanol blending in gasoline and 2% biodiesel blending in diesel. Various provinces have their own renewable fuel regulations that go beyond these limits. Recent provincial regulations include: → Manitoba Biofuel Standard: In late 2019, Manitoba announced they would increase their minimum ethanol content to 10% and biodiesel to 5% in 2020. → Ontario Greener Gasoline Regulation: In 2020, gasoline suppliers will be required to maintain an average of 10% ethanol in gasoline. → British Columbia's CleanBC plan includes extending its low carbon fuel standard to reduce the carbon intensity of transportation fuels by 20% by 2030. **Natural Gas** In recent years, Quebec and British Columbia have established regulations for consumed natural gas to contain a minimum content of renewable natural gas. → Quebec Renewable Gas Mandate: Quebec recently mandated that all consumed natural gas contain a minimum of 5% renewable natural gas by 2025. → British Columbia's CleanBC plan includes a renewable natural gas standard of 15% by 2030. **Clean Fuel Standard** A federal Clean Fuel Standard is currently under development, which aims to reduce the emission intensity of liquid, gaseous, and solid fuels through increased use of low carbon fuels, energy sources, and technologies. In June 2019, ECCC released the Proposed Regulatory Approach for the Clean Fuel Standard. Proposed regulations for the liquid fuel class of the Clean Fuel Standard are expected to be published for consultation in fall 2020. Regulations for gaseous and solid fuel classes will follow. The Clean Fuel Standard is not included in the EF2020 scenarios, as regulations are still in development for all fuel streams. The Evolving Scenario includes a hypothetical emission intensity standard that reflects preliminary details of the Clean Fuel Standard where available.
Energy Efficiency Programs and Regulations	**Federal** → In June 2019, Amendment 16 to the Energy Efficiency Regulations was published. → Initiative to green the federal government: The federal government announced in November 2016 that it would act to reduce its own GHG emissions. This includes initiatives to reduce energy consumption in government buildings through repairs and retrofits, and investments to shift the government vehicle fleet to electric and hybrid vehicles. → Other various energy efficiency, innovation, or emissions reduction programs. Some examples include Natural Resource Canada's Energy Innovation Program, Energy Manager Program, and the Low Carbon Economy Fund. **Various Provincial** → Saskatchewan - Energy Efficiency Standards for Buildings: In 2019, Saskatchewan adopted the National Building Code of Canada (for residential and small commercial), and the National Energy Code of Canada (for large buildings). → *Efficiency Manitoba Act*: Manitoba recently established Efficiency Manitoba, a new crown corporation whose sole purpose is to ensure Manitoba reaches its goal of saving 22.5% of domestic electricity demand, and 11.25% of domestic natural gas demand over the next 15 years. When fully established, Efficiency Manitoba will take over the role of providing consumers with rebates, other incentives, and education, which is currently provided by Manitoba Hydro. Current rebates and incentives provided by Manitoba Hydro and/or Efficiency Manitoba are included in the EF2020 Scenarios. → In 2019, Ontario amended its building codes to align with the 2015 National Building Codes. → Ontario's current Demand Side Management Framework is set to expire at the end of 2020. The Evolving Scenario assumes a new framework will come into effect. → Quebec currently offers various rebates and incentives through its Chauffez Vert Program intended to increase the adoption of energy efficient appliances. New Brunswick - Provincial Energy Retrofit and Renewable Energy Program: This program provides various rebates for purchasing more energy efficient appliances. → Nova Scotia: EfficiencyNS offers various rebates for energy efficient appliances, such as heat pumps, biomass heating, solar systems, and water heating. → Newfoundland and Labrador – Energy Efficiency Programs: These programs include a Home Energy Savings Program, a Heat Pump Rebate Program, and Commercial sector rebates. → Prince Edward Island – EfficiencyPEI Rebates: EfficiencyPEI offers various rebates on energy efficient appliances, such as heat pumps, solar systems, biomass heating, and fuel efficient furnaces. → Yukon, Nunavut, and Northwest Territories – Incentives and Rebates: All three territories offer incentives and rebates for improving energy efficiency.
Northern REACHE Program	In 2016, the Federal Government implemented the Northern Responsible Energy Approach. This program intends to reduce diesel use for electricity and heat.
Support for Electric Vehicles	Many provinces have policies and initiatives to support low and zero emission vehicles (ZEV). This includes Quebec's ZEV mandate, as well as British Columbia's *Zero-Emission Vehicles Act*. Federal action includes subsidies for electric vehicles, as well as support for charging infrastructure through the zero emission vehicle infrastructure program. These initiatives are included as current policies.
Renewable Electricity Generation	Many utilities, and provincial and territorial governments, provide support for increasing levels of renewable generation. EF2020 electricity capacity expansion outlooks generally align to province and territory utility, government, and system operator expansion plans and expectations in the near-to-medium term.

Table 3: **Overview of Future Policies Assumed in the Evolving Scenario**

POLICY	DESCRIPTION	
Rising Carbon Price	The Evolving Scenario assumes carbon prices continue to rise beyond 2022. The price rises to 2019 CDN $60 in 2030, $75 in 2040, and $125 by 2050. Currently, carbon price systems across Canada are diverse. The increasing price in the Evolving Scenario should be taken as a hypothetical increase. It should not be taken as analysis of any particular carbon pricing scheme.	Carbon pricing revenue is redistributed through the economy. Credits for large emitters are reduced over the projection period. On average, emitters from large energy-intensive trade-exposed sectors pay 50% of carbon costs in 2040 and 75% in 2050.
Low Carbon Fuel Standard/Clean Fuel Standard	The Evolving Scenario includes a country-wide low carbon or clean fuel standard aimed at reducing the lifecycle emission intensity of fuels. Targets and structure are generally consistent with the approach outlined in the proposed Clean Fuel Standard's Proposed Regulatory Approach for Liquids. It is important to note that the Clean Fuel Standards are not final, and additional information would be necessary to model the policy. As such, EF2020 projections should not be taken as analysis of the Clean Fuel Standard, or any other single policy initiative. Further, the Clean Fuel Standard is only proposed to 2030. In the Evolving Scenario we extrapolate reductions beyond 2030, which again should be taken as hypothetical. **Liquid Fuel Class** → Target: Average emission intensity is reduced 10% by 2030, 20% by 2040, and 30% by 2050 compared to fossil fuel baseline. → Per the Clean Fuel Standard proposed regulatory approach, lifecycle emission intensity from oil products (gasoline, diesel, jet fuel, etc.) will be reduced approximately 13% by 2030. The Evolving Scenario targets an average 10% incremental reduction to 2030 and extrapolates this reduction linearly over the next two decades. Emission intensity is reduced in a variety of ways, including use of alternative technologies (such as EVs), blending renewable fuels, and reducing upstream emissions intensity.	**Gaseous and Solid Fuel Classes** → At the time of analysis, there was no target for emission intensity reductions in the Clean Fuel Standard for these classes, other than the general targeted GHG reductions of 30 MT by 2030 across all streams. → The Evolving Scenario assumes a reduction of gaseous emission intensity of 2.5% in 2030, increasing to 6% in 2040, and 10% in 2050. This is met by blending renewable natural gas into the gas stream. → For solid fuels, we do not assume a specific intensity reduction target. Rather, the emphasis is on phasing out coal use in power generation to 2030, and reducing coal use for industrial applications in the latter decades of the projection period.
Energy Efficiency Regulations	Canada has a long history of improving energy efficiency through standards, regulations and policies. The Evolving Scenario continues this trend. Specifically: → Federal Efficiency Regulations Amendment 17 is currently in the pre-consultation phase, and is reflected in the Evolving Scenario.	→ Post 2030, the fuel economy of light duty vehicles continues to improve, at approximately 1% per year. → Net zero ready building codes are currently under development. The Evolving Scenario assumes these are gradually adopted by provinces and territories, leading to efficiency improvements in building shell, as well as heating and cooling technologies.
Zero Emission Vehicle Standards	The adoption of low and ZEVs in the Evolving Scenario is driven by technology, consumer choice, and policy. A minimum ZEV requirement is assumed in the Evolving Scenario, requiring a national minimum of 5% sales by 2030, 25% by 2040, and 50% by 2050.	Given the other factors that influence ZEV adoption, individual provinces vary in their adoption of ZEVs, with some having greater or less than the national minimum. The provincial levels are based on economics and/or provincial policies that exceed these minimums. See "Towards Net Zero" for discussion of higher penetration of ZEVs.
Support for Clean Energy Technology and Infrastructure	The continuing energy transition shown in the Evolving Scenario requires significant levels of technology and infrastructure development. Historically, governments have played key roles, in collaboration with specific industries, regulators, and other participants in these areas. This trend continues in the Evolving Scenario. It assumes government infrastructure and technology development are key contributors to the deployment of new energy technologies, including:	→ Deployment of EV charging infrastructure to accommodate the rising levels of ZEVs in the Evolving Scenario. → Increased electric transmission. → Increased support for CCUS development and deployment. → Support for technologies currently with limited commercial application to achieve greater adoption in the 2035-2050 period. Examples include: high efficiency natural gas heat pumps for buildings, hydrogen fuel cells for heavy trucking and industry, utility scale battery storage, electrification and efficiency improvements in the industrial sector, and reduced emission intensity of oil and gas production.

Footnotes

Executive Summary

[1] "Action" in this context is led by increasing policies, while also considering behavioural decisions by consumers and firms.

[2] Bataille, C., Sawyer, D., & Melton, N. (2015). *Pathways to deep decarbonization in Canada*. SDSN-IDDRI. Trottier Energy Futures Project. (2016). *Canada's Challenge & Opportunity: Transformations for major reductions in GHG emissions*; Trottier Energy Futures Project; Vaillancourt, K., Bahn, O., Frenette, E., & Sigvaldason, O. (2017). *Exploring deep decarbonization pathways to 2050 for Canada using an optimization energy model framework*. Applied Energy, 195, 774-785.

Energy Supply and Demand in a Pandemic: Effects of COVID-19

[3] Leach, A., N. Rivers, and B. Schaffer. "Canadian electricity markets during the COVID-19 pandemic: An initial assessment." Canadian Public Policy (2020). See the CER Market Snapshot series for more information on Ontario and Alberta electricity trends.

[4] These provinces are focused on because of the availability of real-time data.

Scenarios and Assumptions

[5] "Action" in this context is led by increasing policies, while also considering behavioural decisions by consumers and firms.

[6] For example, the proposed Clean Fuel Standard has been announced, but is not included as regulations are currently under development.

[7] For illustration purposes: In the EF2020 analysis, carbon prices are modeled based on individual provincial and territorial systems, many of which differ from the federal backstop system. The Federal Backstop price includes the announced increase to $50/tonne by 2022 in nominal terms. For the remainder of the Reference Scenario projection, this is held constant, and the price in inflation-adjusted terms declines by the rate of inflation.

[8] Full benchmark price assumption data is available in the accompanying data appendices, described in the "Access and Explore Energy Futures Data" section.

[9] In the case of Trans Mountain, the portion of pipeline capacity that is typically used to transport RPPs, 50 Mb/d, has been removed from that pipeline's available capacity. Likewise, 50 Mb/d has also been removed from the future capacity of TMX.

[10] Capacity factors are the actual energy produced by a generator divided by the maximum possible generation over a given period.

[11] The range around the capital costs is +/- 20%, which reflects the variability across different estimates of current, and future, wind and solar costs. Costs and performance characteristics can vary across regions and time. The ranges around the levelized costs include the variation in capital costs shown in the figure, ranges in other costs and capacity factors shown in Table A.2, as well as higher and lower project financing costs

Results

[12] Projections were finalized in August 2020, so 2020 values are estimates.

[13] On an energy equivalent basis, EVs use less energy to travel a given distance than conventional vehicles. As EVs gain market share, the offsetting reduction in gasoline demand will be larger than the electricity added, leading to a net reduction. Additional details on EV efficiency and economics can be found in CER Market Snapshot: Levelized Costs of driving EVs and conventional vehicles.

[14] Information on crude oil ultimate potential and remaining reserves is available in the EF2020 Data Appendices.

[15] For more information see *Western Canadian Crude Oil Supply, Markets, and Pipeline Capacity and Optimizing Oil Pipeline and Rail Capacity out of Western Canada – Advice to the Minister of Natural Resources*.

16 In the case of Trans Mountain, the portion of pipeline capacity that is typically used to transport RPPs, 50 Mb/d, has been removed from that pipeline's available capacity. Likewise, 50 Mb/d has also been removed from the future capacity of TMX.

17 Responsible Investment Association, 2018 Canadian Responsible Investment Opportunity: Trends Report, pg. 12, October 2018.

18 IPIECA, Oil and Gas Industry Guidance on Voluntary Sustainability Reporting, 8.

19 This value of natural gas demand is lower than the primary natural gas demand value discussed earlier because it does not include non-marketed natural gas used directly by those that produce it. Examples of this include flared gas, natural gas produced and then consumed by in situ oil sands producers, and natural gas produced and consumed by offshore oil production.

20 Net exports are equal to exports less imports. Declines in net exports do not necessarily equate to declines in exports.

21 Responsible Investment Association, 2018 Canadian Responsible Investment Opportunity: Trends Report, pg. 12, October 2018.

22 IPIECA, Oil and Gas Industry Guidance on Voluntary Sustainability Reporting, 8.

23 Renewable and nuclear shares refer to total electricity generation, including cogeneration.

24 From 2010 to 2019, annual net exports average 49 TW.h, ranging between 25 and 64 TW.h.

25 Data sets are also available through the Government of Canada's Open Government portal.

26 As defined in ECCC's national inventory report, energy related emissions includes stationary combustion sources, transportation, fugitive sources, and CO_2 transport and storage.

Towards Net-Zero

27 Climate Ambition Alliance: Nations Renew their Push to Upscale Action by 2020 and Achieve Net Zero CO_2 Emissions by 2050.

28 Government of Canada releases emissions projections, showing progress towards climate target.

29 Rogelj et al. (2015) discuss the appropriateness of net-zero GHG emissions goals serving as benchmarks for achieving global temperature targets.

30 Davis et al. (2018) review what it would take to achieve decarbonization of the energy system.

31 In addition, Davis et al. (2018) provide a recent review of carbon management methods.

32 These reduction levels are for illustrative purposes, and reflect existing government targets (30% below 2005), as well as levels of reduction (60 and 90%) covered in various studies of deep emissions reductions, such as Trottier Energy Futures Project (2016), Canadian Deep Decarbonization Pathway Project (2015), and Canadian Energy Outlook 2018 – Horizon 2050 (2018). Canada's Mid-Century Long-Term Low-Greenhouse Gas Development Strategy examines an emissions abatement pathway consistent with net emissions falling by 80% from 2005 levels.

33 (Trottier Energy Futures Project, 2016) For example, the Trottier Energy Futures Project (2016) found that energy conservation initiatives can eliminate a large share of future demand for commercial sector space heating.

34 For further explanation see Bataille, Sawyer, & Melton (2015), Trottier Energy Futures Project (2016), and Vaillancourt, Bahn, Frenette, & Sigvaldason (2017).

Personal Vehicle Passenger Transportation

[35] See for example N. Rivers and B. Schaufele (2015) "Salience of carbon taxes in the gasoline market." *Journal of Environmental Economics and Management*. Volume 74; J.T. Bernard and M. Kichian (2019). "The long and short run effects of British Columbia's carbon tax on diesel demand" *Energy Policy*. Volume 131.

[36] Bloomberg New Energy Finance forecasts $100/kW.h to be reached by 2024.

[37] MIT Energy Initiative. 2019. Insights into Future Mobility.

[38] Based on current data on battery degradation, and the lower maintenance and repairs required by EVs, we are assuming longer lifespans for EVs.

[39] In discussing the passenger transportation sector, the vehicles being analyzed are those weighing less than 4 500 kg; these will also be referred to as light-duty vehicles (LDVs). The historical annual growth rate of the vehicle stock from 2002 – 2018 was 1.74%, the projected growth rate is slightly less at 1.4%.

Oil Sands Production

[40] Bitumen mixed with diluent.

[41] See Figure 2-25 in ECCC's latest National Inventory Report.

[42] For example, the International Energy Agency's "Sustainable Development Scenario," in the World Energy Outlook includes a lower crude oil price compared to the scenarios with less policy action and higher crude oil demand.

[43] Canadian SMR roadmap.

Remote and Northern Communities

[44] Natural Resources Canada, Remote Communities Energy Database.

[45] Via truck (on an all-year road, or winter road), ship, barge, or even air.

[46] Knowles, J. (2016). Power Shift: Electricity for Canada's Remote Communities. The Conference Board of Canada.

[47] Heerema, D. and Lovekin, D. (2019). *Power Shift in Remote Indigenous Communities.* The Pembina Institute.

[48] HDDs are defined as the number of degrees Celsius (°C) the daily mean temperature is below 18°C. HDDs in Iqaluit, Nunavut averaged 10 282 between 1976 and 2005. By contrast, HDDs in Montreal and Toronto over this period averaged 4 349 and 3 762, respectively. In Vancouver, one of Canada's warmest cities, HDDs averaged 2 776. The source for this data is the Prairie Climate Centre's Climate Atlas of Canada.

[49] Moorhouse, J., Lovekin, D., Morales, V., and Salek, B. (2020). *Diesel Reduction Progress in Remote Communities*: Research Summary (p. 1). The Pembina Institute.

[50] NRCan (2017). "Diavik Diamond Mine – Northwest Territories".

[51] NRCan (2020). "Reducing diesel energy in rural and remote communities".

[52] Government of Canada (2019). "Canada Launches Off-Diesel Initiative for Remote Indigenous Communities".

[53] Moorhouse, J., Lovekin, D., Morales, V., and B. Salek (2020) *Diesel Reduction Progress in Remote Communities: Modelling approach and methodology.* The Pembina Institute.

[54] NRCan (2018). "Canadian Small Modular Reactor (SMR) Roadmap".

[55] Grid connections have already been accomplished in Pikangikum, Ontario (2018) and Jasper, Alberta (2019). Hydro Quebec is planning to connect the Magdalen Islands with a sub-sea cable by 2025. The project would serve 6 600 customers and eliminate 40 million litres of fuel oil burned on the islands for electricity generation annually.

[56] Knowles, J. (2016). Power Shift: Electricity for Canada's Remote Communities (pp. 22-23). The Conference Board of Canada.

[57] Moorhouse, J., Lovekin, D., Morales, V., and Salek, B. (2020). *Diesel Reduction Progress in Remote Communities: Modelling approach and methodology.* The Pembina Institute.

[58] NRCan (2018). "Towards Renewable Energy Integration in Remote Communities: A Summary of Electric Reliability Considerations."

[59] Moorhouse, J., Lovekin, D., Morales, V., and B. Salek (2020) *Diesel Reduction Progress in Remote Communities: Modelling approach and methodology* (p. 3). The Pembina Institute.

[60] Arctic Energy Alliance (2010). "NWT Community Wood Pellet District Heating Study".

[61] Arctic Energy Alliance (2012). "Inuvik Wood Pellet Infrastructure Study".

[62] World Nuclear News (24 February 2020). "Finnish firm launches SMR district heating project".

[63] Motor vehicle ownership is more common in communities with an all-year road, but for the approximately 140 communities without an all-year road, private vehicle ownership can be very low.

[64] Arctic Energy Alliance (2016). "Electric Vehicle Study: Chevrolet Volt Plug-in Hybrid Electric Vehicle 2015-16".

[65] These issues include range reduction, frequent battery conditioning during extreme cold, charger drop-off, and failure to start from a cold auxiliary battery.

[66] Norwegian Automobile Foundation (2020). "20 popular EVs tested in Norwegian winter conditions"

Appendix A: Domestic Climate Policy Assumption Overview

[67] For an exhaustive review of climate measures in Canada, see Environment and Climate Change Canada's *Fourth Biennial Report on Climate Change*.

Access and Explore Energy Futures Data

Datasets related to EF2020:

- **Figure Data:**
  [Download the EF2020 figure data](#)

- **Data Appendix:**
  The Energy Futures Data Appendix has customizable, downloadable tables arranged by variable (macroeconomic drivers, end-use demand, crude oil production, etc.) and publication year.

- **Machine Readable Files:**
  Looking to download all of the EF2020 data at once? It is available on Open Government.

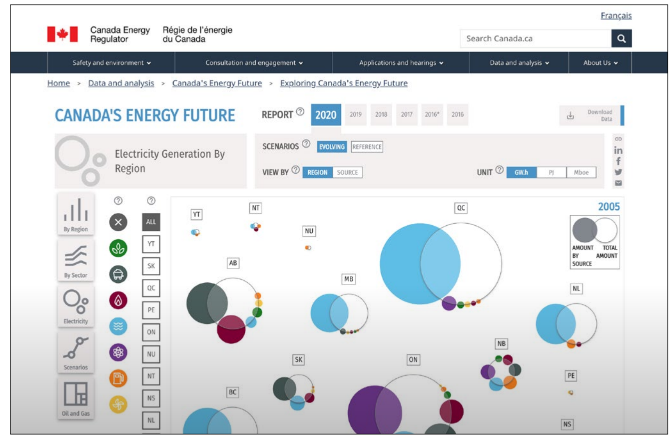
Energy Futures Fact Sheets

- Deep dive into the projections with more detailed datasets, including monthly projections for:

  EF2020 Overview | Electricity | Demand | Conventional Oil | Natural Gas | Natural Gas Liquids | Oil Sands

Explore Energy Futures – Interactive Data Visualization

Explore Canada's Energy Future with an interactive tool that allows users to visualize, download, and share the data behind the long-term energy outlooks.



Student Resources

In partnership with Ingenium, the CER developed educational activities based on Canada's forecasted energy demand and supply.

Targeted at students between the grades of 9 and 11, the activities encourage students and educators to explore Canada's energy ecosystem using an interactive tool. This tool allows users explore how the future of energy in Canada changes over the long term. The material and student resources are available here.

Data Science with Open Data

Partnered with Fireside Analytics, this course is an introduction to data science with open data sets and R Studio. Learn common buzzwords used in data science and get hands-on labs visualizing and analyzing open data from the *Energy Futures* series. This course is designed for learners who are new to computer programming and data science.

About the Canada Energy Regulator

The Canada Energy Regulator (CER) works to keep energy moving safely across the country. We review energy development projects and share energy information. We enforce some of the strictest safety and environmental standards in the world in a manner that respects the Government of Canada's commitments to the rights of the Indigenous peoples of Canada. The CER regulates:

- Oil & Gas Pipelines – Construction, operation, and abandonment of interprovincial and international pipelines and related tolls and tariffs.
- Electricity Transmission – Construction and operation of international power lines and designated interprovincial power lines.
- Imports, Exports & Energy Markets – Imports and exports of certain energy products; monitoring aspects of energy supply, demand, production, development and trade.
- Exploration & production – Oil and gas exploration and production activities in the offshore and on frontier lands not covered by an accord.
- Offshore renewables – Offshore renewable projects and offshore power lines.

Energy Information Program is one of four core CER responsibilities. We collect, monitor, analyze, and publish fact-based information on energy markets and supply, sources of energy, and the safety and security of pipelines and international power lines. Using tools like interactive pipeline maps and visualizations we make complex pipeline and energy market data user-friendly and accessible.

Our Commitment:

- Canadians have access to and use energy information for knowledge, research and decision making.
- Canadians have access to community-specific information about CER-regulated pipelines, powerlines, and other energy infrastructure.
- Broader and deeper collaboration with stakeholders and partners informs our energy information.

About this Report

The CER's Energy Information core responsibility is closely linked to its mandate and responsibilities under the *Canadian Energy Regulator Act* (the Act), which include advising and reporting on energy matters. As well, under Part 7 of the Act, the CER regulates the export and import of natural gas and the export of natural gas liquids, crude oil and petroleum products, and electricity. The CER must ensure that, if authorized, oil and gas exports are surplus to Canadian requirements. The CER's monitoring of energy markets and assessments of Canadian energy requirements and trends helps support the discharge of its regulatory responsibilities. This report, *Canada's Energy Future 2020*: Energy Supply and Demand Projections to 2050, is the continuation of the *Energy Futures* series, and projects long-term Canadian energy supply and demand trends.

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If a party wishes to rely on material from this report in any regulatory proceeding before the CER, it may submit the material, just as it may submit any public document. Under these circumstances, the submitting party in effect adopts the material and that party could be required to answer questions pertaining to the material.

www.cer-rec.gc.ca/energyfutures