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Energy Efficiency Potential in Canada to 2050

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Executive summary

The Canadian energy system's untapped energy efficiency savings potential is great. Current policies, combined with additional economically and technically feasible energy efficiency investments and measures, could deliver final energy savings of 1.9% per year on average through 2050.

Canada's energy needs are growing

Canada is one of the world's most energy-intensive economies owing to its large size, cold climate, high standard of living and expanding energy industry. Energy demand has grown at 0.8% per year on average for the past 15 years, and this rate of growth is projected to continue under the Current Policies Scenario, which assumes no new policies or changes to policies already enacted. Under this scenario, total primary energy demand (excluding fossil fuel statistical differences) grows from 292 million tonnes of oil equivalent (Mtoe) in 2016 to 364 Mtoe in 2050 and carbon dioxide (CO_2) emissions from fossil fuel combustion follow a similar trajectory. Gas used in fossil fuel extraction and in the power sector is the main driver of primary energy demand, and final energy demand is expected to grow moderately in all end-use sectors except transport. Growth in the Current Policies Scenario would have been higher without the energy savings already achieved by policies enforcing minimum energy performance standards (MEPS) and labelling programmes in buildings; voluntary programmes and other grants and incentives in the industry sector; and fuel economy standards in transport. Taken together, oil- and gas-based fuels account for almost 70% of total energy saved under the Current Policies Scenario: oil savings affect transport specifically, while gas savings are spread evenly across the other sectors of the economy.

Maximising energy efficiency leads to declining long-term energy demand

The Energy Efficiency Case taps into economically viable efficiency potentials in all sectors and incorporates the carbon pricing arrangement of the Pan-Canadian Framework on Clean Growth and Climate Change. Energy efficiency measures in this alternative scenario have the potential to keep both primary and final energy demand on a steadily declining trajectory to 2050, despite increasing economic activity. The potential savings identified could reduce energy demand by around 100 Mtoe below the Current Policies Scenario by 2050 – more than one-third of total primary energy demand (TPED) in 2016. The greatest energy savings would be in buildings (28%), followed by transport (25%), oil and gas extraction (21%) and industry (12%). The power sector's potential for additional energy efficiency improvements are more limited in comparison.

Buildings sector has greatest potential for energy efficiency gains

Policies and measures to maximise energy efficiency could reduce energy demand of residential and services buildings by over 14 Mtoe in 2050. Space heating has the greatest impact, accounting for over 70% of the cumulative savings of 500 Mtoe in the Energy Efficiency Case compared with the Current Policies Scenario. "Net-zero energy ready" (NZER) building codes for new buildings, and more stringent codes for existing ones, are the primary catalysts for energy-efficient space heating: improving building envelopes and switching to electric heat pumps would cut the space heating energy intensity of new residential buildings in Canada by 85% by 2050. Enhanced energy efficiency would have the greatest effect on residential gas demand, and would also cut oil consumption in the services sector. Falling electricity demand would be partially offset by increasing electrification, however, as the share of electricity in buildings sector energy demand rises to 66% in 2050 in the Energy Efficiency Case.

Greater transport energy efficiency and electrification could deliver considerable savings

The transport sector is a reservoir of energy efficiency gains: energy demand in 2050 is projected to be 45% lower in the Energy Efficiency Case than under the Current Policies Scenario. While all modes of transportation contribute to these savings, the most is from road transport, both passenger and commercial vehicles. This sector benefits from the faster deployment of new car designs and measures to improve fuel efficiency, such as engine downsizing, lightweighting and friction-reduction tyres, along with further electrification of the fleet by way of hybridisation or through switching to pure-electric vehicles. As a result, the Energy Efficiency Case projects average on-road, fuel-specific consumption of passenger cars in 2050 to be one-third what it is today, and consumption of heavy-duty trucks to be half. Oil remains the main transport energy source, although its share of over 90% today declines to less than three-quarters in 2050 owing to improved fuel efficiency of internal combustion engines, better vehicle design, freight traffic optimisation and further electrification. Because of greater electrification, transport is the only sector for which electricity demand increases in the Energy Efficiency Case.

High industry energy efficiency potential, especially in oil and gas extraction

Under the Energy Efficiency Case, Canada's performance aligns with that of the United States by 2050 and approaches the global industrial benchmarks for greatest energy efficiency. Energy demand growth from increased activity and adverse structural effects are more than offset by enhanced energy efficiency, and additional energy demand savings in the Energy Efficiency Case are almost evenly split between energy-intensive and non-energy-intensive sectors. Enhanced energy efficiency also leads to a net decrease in oil consumption in light industry, and in gas and electricity consumption in the energy-intensive sectors. In oil and gas extraction, enhanced energy efficiency effectively mitigates growth in own-use energy demand despite soaring domestic production. The energy saved by 2050 from oil and gas extraction activities alone is equivalent to the current space heating requirements of the residential sector. Electricity demand growth to 2050 is slower in the Energy Efficiency Case than under the Current Policies Scenario, as overall efficiency gains more than offset the impact of increased electrification in heat and transport. Lower electricity demand reduces the need for new gas-fired power plants and therefore limits the potential for further energy efficiency savings in the sector, but lower gas consumption helps reduce power sector CO_2 emissions by 1.1 gigatonnes of carbon dioxide (Gt CO_2) in 2050. Power generation cost savings in the Energy Efficiency Case are worth more than USD 9 billion in 2050, with lower fuel costs accounting for more than half of this.

What does this mean for Canada?

While the modelling approach adopted for this analysis has its limits, the results can direct policy makers' attention to those parts of the energy system in which significant energy efficiency savings are possible. Overall, each additional USD 1 billion invested in energy efficiency would deliver more than 2.3 Mtoe of energy savings, resulting in tangible benefits for Canadians: lower CO_2 emissions, increased trade value, reduced household energy expenses and less energy poverty. CO_2 emissions, for example, decline from more than 600 million tonnes of carbon dioxide (Mt CO_2) in 2050 under the Current Policies Scenario to less than 400 Mt CO_2 under the Energy Efficiency Case. While oil and gas production levels are similar in both scenarios over the outlook period, additional energy efficiency improvements realised in the Energy Efficiency Case raise Canada's oil and gas trade balance by USD 70 billion. For households, reduced demand in the Energy Efficiency Case results in cumulative savings of over USD 1.1 trillion between 2017 and 2050, or the equivalent of three-quarters of Canada's gross domestic product (GDP) in 2016, which would lift many families out of energy poverty and boost spending in other sectors.

Part I: Assessing future energy trends in Canada

Introduction and context

This paper presents up-to-date, long-term estimates of Canada's maximum energy efficiency potential by sector. The modelling approach is based on the World Energy Model (WEM), the tool used for the International Energy Agency (IEA) *World Energy Outlook 2017* (*WEO-2017*).[1] While this study assesses how energy efficiency deployment could impact energy demand and emissions for Canada through to 2050, it does not offer any policy recommendations. Instead, it focuses on the economy-wide energy efficiency improvement thought to be achievable according to this model-based analysis.

Canada's surface area of 9.98 million square kilometres (km^2) makes it the world's second-largest country. While TPED in 2016 was 292 Mtoe, total final consumption (TFC) was much lower at 193 Mtoe.[2] The difference between the two is the result of energy demand in the power generation and heat sectors, as well as in other energy sectors, which in the case of Canada is relatively large owing to energy used in oil and gas extraction. TFC remained relatively flat from 2000 to 2016 while the economy grew at 1.9% per year, indicating an already strong decoupling of final energy use from economic growth. Transport and buildings are the largest consuming sectors, each accounting for 32% of TFC in 2016. The industry sector claimed 23%, with agriculture and non-energy use combined accounting for the remaining 13%. Since 2000, energy consumption in transport has increased 18% and in the residential sector 3%, while industry demand declined by 21%. Consumption in other sectors remained largely stable.

Energy efficiency is a key pillar of Canada's climate change policy. The federal government estimated that the country's energy intensity of GDP fell 26.5% between 1990 and 2015 (NRCan, 2016a), and that existing policies saved CAD 38.2 billion in energy costs between 1990 and 2015 and cut greenhouse gas (GHG) emissions by the equivalent of more than 27 million cars' emissions for one year (NRCan, 2016b). Strong policies and measures, such as the Canadian Industry Program for Energy Conservation (CIPEC), have been adopted to achieve greater energy efficiency in industry, and considerable progress has been achieved overall in reducing energy intensity in several energy-intensive industries such as pulp and paper, iron and steel, and cement. In addition, the stringency and coverage of building and appliance efficiency standards are expanding, and various provincial and territorial building codes, as well as federal equipment and appliance energy performance standards, are driving energy efficiency improvements in residential and commercial buildings (Bataille, Sawyer and Melton, 2015). Despite this progress, Canada's per capita energy use is the highest of all IEA member countries – higher than that of the United States, Norway or Finland.

Key energy trends and comparison with other countries

Between 2000 and 2016, Canada's TPED increased by almost 14%, or at an annual average rate of 0.8% (Table 1), while energy intensity fell by around 16%. In contrast, its final energy consumption remained flat over the period. Energy demand growth remained below the average

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[1] IEA, 2017.

[2] Unless otherwise stated, data used in this report are from IEA databases and analyses. The base year for the projections is 2016, as reliable energy data were available up to 2016 only at the time of modelling. Fossil fuel statistical differences are excluded from primary energy demand in the main text, but they are included in the Annex A tables.

annual GDP growth of 1.9%, resulting in a steadily declining energy intensity of GDP. Primary energy demand per capita was 8.1 tonnes of oil equivalent (toe), about twice the average of IEA member countries.

Table 1 • Selected energy and economic indicators for Canada

Indicator	2000	2005	2010	2016	Change 2000-16
GDP (PPP) (2016 USD billion)	1 240	1 408	1 490	1 682	36%
Share of world GDP	1.8%	1.7%	1.5%	1.4%	-
GDP (PPP) per capita (2016 USD)	40 401	43 658	43 809	46 477	15%
TPED (Mtoe)	257	281	273	292	14%
TPED per capita (toe)	8.4	8.7	8.0	8.1	-4%
Total CO_2 emissions (Mt)	516	541	528	541	5%
Energy intensity TPED/GDP (PPP) (toe per USD 1 000)	0.21	0.20	0.18	0.17	-16%
Carbon intensity TPED CO_2/GDP (PPP) (tCO_2 per USD 1 000)	0.42	0.38	0.35	0.32	-23%

Notes: PPP = purchasing power parity; tCO_2 = tonne of carbon dioxide. TPED excludes fossil fuel statistical differences, as including them would affect TPED trends in the analysis and blur the assessment of energy efficiency progress (historical and forward-looking).

Canada has one of the most energy-intensive economies of IEA member countries owing to its scale of energy production and the considerable amount of energy required by industries to extract and process energy resources for export. Its large size also means much energy is needed for transport and inland shipping, the cold climate induces people to consume more energy for heating, and energy is needed to sustain the country's high living standards.

Responsibility for energy efficiency is shared between the federal and provincial/territorial jurisdictions, and national averages overlook important sub-national differences in energy intensity and efficiency. There are substantial regional differences in how energy is produced and consumed, as well as in the regulatory approaches adopted by provincial governments. In the buildings sector, for example, the National Energy Code of Canada for Buildings (2015 and 2017) comes into force only if provinces and territories elect to introduce laws and regulations in line with the code.

The World Energy Model

The WEM and scenarios described later in this paper are used to assess future energy trends. The WEM, developed at the IEA over more than 20 years and updated and enhanced every year, is a large-scale simulation tool designed to replicate how energy markets function.[3] It covers the entire energy system, allowing for a range of analytical perspectives from global aggregates to elements of detail such as prospects for particular technologies or outlooks for end-user prices in specific countries or regions.

The current version models global energy demand and encompasses 25 regions, 12 of which are individual countries including Canada. Global oil and gas supply is modelled in 120 distinct countries and regions, global coal supply in 31. The main modules cover energy consumption, fossil fuel and bioenergy production, and energy transformation (including power generation and

[3] www.iea.org/media/weowebsite/2017/WEM_Documentation_WEO2017.pdf.

refining); supplementary tools allow more detailed analysis of specific areas. Although the WEM is usually used to assess regional or global energy trends because it facilitates detailed global and regional energy market assessments for various energy commodities, it may also be applied to analyse the evolution of a specific country's energy sector (e.g. China in *WEO-2017* and the IEA's 2016 special report *Mexico Energy Outlook*). This report is the first to use the WEM for Canadian analysis, though the provinces of Canada are not modelled individually.

Defining the scenarios

Projections in this analysis extend to 2050 and are derived from the overall methodological approach used in *WEO-2017*. The main scenarios used in this study are the Current Policies Scenario and the Energy Efficiency Case, a new scenario developed specifically for this report. Various elements of Canadian energy policy are continuously evolving, hence the more stable and certain Current Policies Scenario was chosen as the baseline scenario to assess energy efficiency potential. The primary difference between the two scenarios is the assumptions they make about technology uptake and policy levers. For comparison purposes, this paper also occasionally refers to the New Policies Scenario.

In considering only policies and measures firmly in place or enshrined in legislation as of mid-2017, the Current Policies Scenario sets a point of comparison; it therefore excludes recently announced or new policy targets.[4] Furthermore, when policies target a range of outcomes, the Current Policies Scenario assumes that the least ambitious end of this range is achieved (see Annex B.1 for a detailed overview of policies assumed in the Current Policies Scenario for Canada). This scenario therefore provides a more cautious assessment of where existing policy momentum might lead the energy sector in the absence of additional government impetus, and serves as a point of reference to measure the impact of additional policies.

In contrast, the New Policies Scenario incorporates not only the policies and measures already in place both federally and provincially, but the likely effects of announced policies expressed in official targets or plans. The conception of the national policy environment is also informed by policies and targets adopted by sub-national authorities, i.e. provincial entities, cities and municipalities, and by commitments made by the private sector. The New Policies Scenario therefore includes the policy instruments of the Pan-Canadian Framework on Clean Growth and Climate Change, but cautiously views how they are translated at the provincial level and how effective they are in delivering energy efficiency improvements and GHG emissions reductions.

The Energy Efficiency Case, which is a variant of the baseline Current Policies Scenario for Canada rather than a fully developed global energy scenario, is based on ambitious assumptions for energy efficiency deployment that go far beyond the Current Policies Scenario and also consistently exceed the New Policies Scenario. Furthermore, the Energy Efficiency Case does not include many of the measures contained in the Sustainable Development Scenario (a scenario introduced for the first time in *WEO-2017*). This case enables assessment of the economically viable energy efficiency potential of each sector when the key levers described in Annex B.2 are applied. It is a unique scenario, co-developed by the IEA and Natural Resources Canada (NRCan) with a time horizon of 2050 rather than 2040 as in *WEO-2017*. The Energy Efficiency Case maximises energy efficiency deployment in the end-use sectors (industry, buildings and transport) and energy transformation sectors over time in a realistic

[4] See IEA (2017) for more detail on scenario definitions.

and pragmatic way. It excludes structural changes at the macro-economic level (despite some changes at the sectoral level, such as the scrap recycling rate in the steel industry), and does not take into account macro-economic, urbanisation and demographic changes through 2050 beyond those already included in the Current Policies Scenario.

Instead, the same levels of energy services and the same consumption patterns and consumer behaviours are assumed for both scenarios, and altruistic changes in behaviour or in tastes and preferences are not considered. Our approach accounts for an economic response to price signals and intrinsic inertia within the energy system, and includes limited rebound effects of technological adoption in the Energy Efficiency Case. For potential energy savings to fully materialise, therefore, all drivers of energy efficiency need to be applied in a timely manner to put the entire system on a new pathway as early as 2020. This means that the Energy Efficiency Case should be perceived as an aspirational scenario in which conditions align perfectly in every respect and all necessary policy levers are effectively implemented in all sectors of the economy to reach the highest levels of energy efficiency.

Nonetheless, the broader context of the Energy Efficiency Case is the same as that of the Current Policies Scenario:

- International fossil fuel prices are the same (Table 2). Should energy prices turn out to be lower, for example, the potential for energy efficiency savings would fall.
- GDP growth is assumed to be maintained at a relatively constant 1.8% per year on average over the outlook period.
- Domestic oil and gas production levels are the same.

While the CO_2 price is low in the Current Policies Scenario throughout the projection period (slowly increasing from less than USD 10/t CO_2 in 2020 to around USD 40/t CO_2 in 2050), in the Energy Efficiency Case it increases significantly in the short term to account for strict implementation of the Pan-Canadian Framework by 2022. In subsequent years, however, it increases only marginally, reflecting the lack of additional climate constraints over the long term (as in the Current Policies Scenario).

Table 2 • Fossil fuel prices by scenario

			Current Policies Scenario				New Policies Scenario		Energy Efficiency Case	
Real terms (2016 USD)	2010	2016	2025	2030	2040	2050	2030	2050	2030	2050
IEA crude oil (USD/barrel)	86	41	97	113	136	154	94	124	113	154
Natural gas (USD/MBtu)	4.8	2.5	4.3	5.1	6.5	8.8	4.4	6.9	5.1	8.8
Steam coal (USD/tonne)	63	49	62	64	67	69	61	62	64	69

Notes: MBtu = million British thermal units. The IEA crude oil price is the weighted average import price among IEA member countries. Natural gas prices are weighted averages expressed on a gross-calorific-value basis. The gas price reflects the prevailing wholesale price on the US domestic market. Steam coal prices are weighted averages adjusted to 6 000 kilocalories per kilogramme. The steam coal price reflects mine-mouth prices (primarily in the Powder River Basin, Illinois Basin, Northern Appalachia and Central Appalachia markets) plus transport and handling costs in the United States.

Therefore, with the exception of the short-term CO_2 price increase, the Energy Efficiency Case employs parameters aimed at improving the efficiency of energy consumption only, regardless of the form of energy, as no additional, exclusively climate-related policy is assumed compared with the Current Policies Scenario. The effect on CO_2 emissions is therefore an outcome of technology and policy levers that focus exclusively on energy efficiency – CO_2 emissions reduction is not a scenario assumption. In the Energy Efficiency Case, it is assumed that all technical and policy levers are applied at end-use level (hence the importance of using a bottom-up approach), and integrating all possible savings provides a complete picture of energy efficiency potential. Challenges and opportunities for each of the sectors are described in greater detail in subsequent sections of this paper.

Nevertheless, the Energy Efficiency Case is not a technical or accounting assessment of energy efficiency potential in Canada, as it also considers the inertia in the energy system and the technical, financial and economic constraints to adopting and deploying the most energy-efficient technologies and processes in each sector. For example, the entire building stock cannot be refurbished overnight, nor can all vehicles go electric in one year. This study therefore identifies maximum achievable potential. It is assumed that the availability of financing is not a constraint, as long as investments deliver effective energy efficiency improvements with positive or neutral long-term economic returns. The Energy Efficiency Case considers stock renewals and some anticipated stock refurbishment as opportunities but also constraints to improved energy efficiency. This report mainly analyses the outcome of the Energy Efficiency Case relative to the Current Policies Scenario, and also provides a brief comparison with the New Polices Scenario. This outlook is based on assumptions that are obviously subject to change, and it considers only economically and technically feasible options available at the time of writing. Rapid technological changes through digitalization – and resulting implications for higher (or lower) energy savings – pose a significant risk to the accuracy of this outlook.

Part II: Canada's energy efficiency prospects to 2050

Overview of scenario outcomes

In the Current Policies Scenario, TPED increases from 292 Mtoe in 2016 to 364 Mtoe by 2050, or by about 0.7% per year on average, excluding fossil fuel statistical differences.[5] This is less than half Canada's average annual GDP growth of 1.8%, a divergence that results in a significant decline in energy intensity (Table 3). Electricity demand increases by 0.9% per year over the same period, while the carbon intensity of the sector falls by an average of 1.3% per year owing to a greater share of renewables and natural gas and the displacement of coal in the power mix.

Table 3 • Key energy indicators for Canada by scenario

		Current Policies Scenario		New Policies Scenario		Energy Efficiency Case	
	2016	2030	2050	2030	2050	2030	2050
TPED (Mtoe)	292	312	364	294	321	269	258
Share of fossil fuels (%)	74%	75%	75%	72%	71%	71%	67%
Final consumption (Mtoe)	193	205	220	197	203	177	148
Electricity demand (TWh)	547	611	734	595	693	567	639
Energy intensity of GDP (2016=100)	100	84	69	79	61	72	49
Carbon intensity of power (2016=100)	100	73	64	49	57	41	42

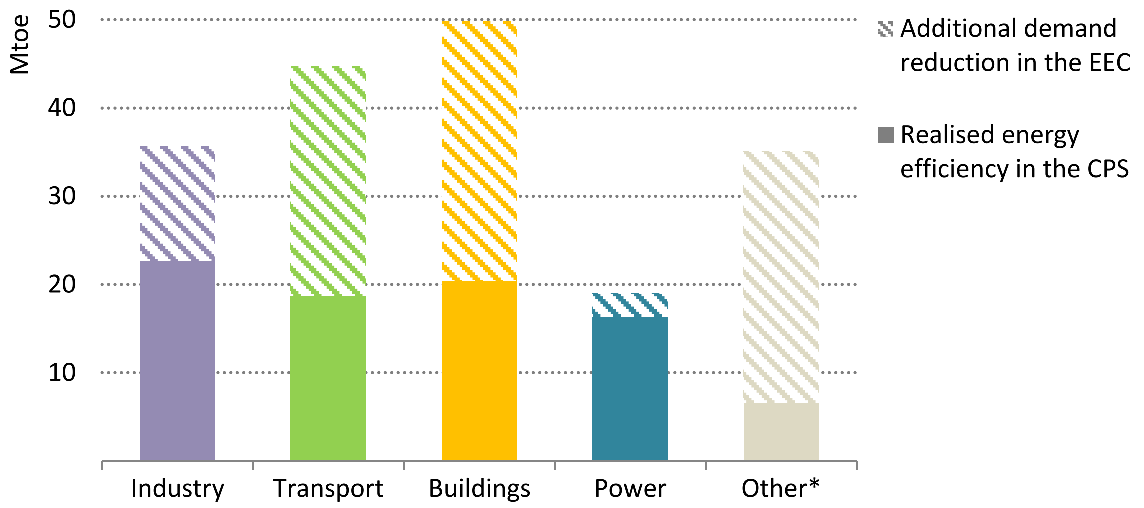
Notes: TWh = terawatt hour. TPED excludes fossil fuel statistical differences.

In the Energy Efficiency Case, TPED decreases to 258 Mtoe in 2050, or almost 0.4% per year on average, while average annual GDP growth remains constant at 1.8%, resulting in an even greater decline in energy intensity than under the Current Policies Scenario. The higher rate of decline in the Energy Efficiency Case reflects implementation of ambitious policies, including more stringent building energy codes, the highest energy efficiency standards for electric motor systems, and stricter fuel economy standards for both light- and heavy-duty vehicles. All sectors contribute to around 100 Mtoe of additional energy savings delivered by the Energy Efficiency Case (Figure 1).

The greatest contributions to energy savings are from buildings (28%), followed by transport (25%), the oil and gas extraction sectors (21%) and industry (12%). In the buildings sector, energy demand in 2050 falls from 77 Mtoe in the Current Policies Scenario to 47 Mtoe in the Energy Efficiency Case; in transport it drops 26 Mtoe and in industry 13 Mtoe (detailed analysis by sector is provided later in this paper). Other energy supply sectors combined contribute an additional 28 Mtoe to the fall in energy demand. The potential for additional energy efficiency improvements in the power sector in the Energy Efficiency Case versus the Current Policies Scenario is comparatively more limited.

[5] Annex A of this document contains summary tables of the results under each scenario.

Figure 1 • Avoided energy demand owing to energy efficiency measures in the Current Policies Scenario and the Energy Efficiency Case, 2050



* Non-power energy supply and transformation sectors, and agriculture.

Notes: EEC = Energy Efficiency Case; CPS = Current Policies Scenario. For the power sector, the reduction in primary energy demand excludes the effect of declining electricity demand but includes improvements in power grid efficiency. Realised energy efficiency in the Current Policies Scenario does not include energy demand reductions resulting from structural changes within a sector.

Key message • Although significant energy savings are achieved in the Current Policies Scenario with existing policies and rising energy prices, further potential exists in most sectors.

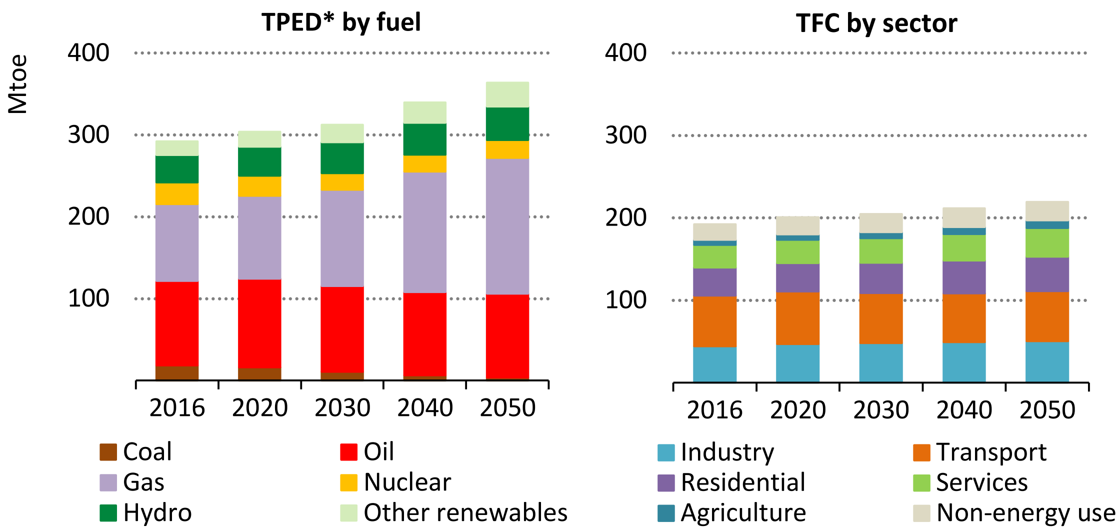
Energy efficiency trends in the Current Policies Scenario

In the Current Policies Scenario, which depicts the impact of policies and measures enacted in legislation up to mid-2017 only, TPED increases from 292 Mtoe to 31Mtoe by 2030, and to 364 Mtoe by 2050 (Figure 2). Natural gas is the main driver of growth, with demand rising from around 94 Mtoe in 2016 to 166 Mtoe by 2050.[6] Although gas consumption in the power sector grows over the outlook period, much of the demand increase is tied to oil and natural gas extraction. Oil demand is stable over the period at just over 100 Mtoe, with increases in some sectors (feedstock use, other energy supply sectors) offsetting decreases in others (transport, buildings, manufacturing industries). In contrast, coal demand declines steeply from around 19 Mtoe in 2016 to 4 Mtoe in 2050 as coal-fired power is gradually phased out in all provinces to comply with emissions performance standards for coal-fired power plants introduced in 2015. Demand for nuclear power output falls to 2050, largely the result of a decline in nuclear generating capacity in the early 2020s.

In final energy consumption, gas use increases by only 14 Mtoe by 2050, with buildings and agriculture accounting for 6 Mtoe of the increase, transportation for 4 Mtoe (mostly from gas consumption in oil and gas pipelines) and industry for close to 4 Mtoe. In the buildings and agriculture sector, most of the increase (3.5 Mtoe) is due to greater gas usage in residential buildings. Policies in the road transport sector drive oil consumption down by 7 Mtoe: despite a 37% increase in vehicle fleet size, oil consumption declines from 47 Mtoe in 2016 to 40 Mtoe in 2050. Bioenergy consumption grows by 5 Mtoe, with the paper industry accounting for one-fifth of the increase.

[6] Demand values for fossil fuels exclude statistical differences.

Figure 2 • Canada's primary energy demand by fuel, and final consumption by sector in the Current Polices Scenario



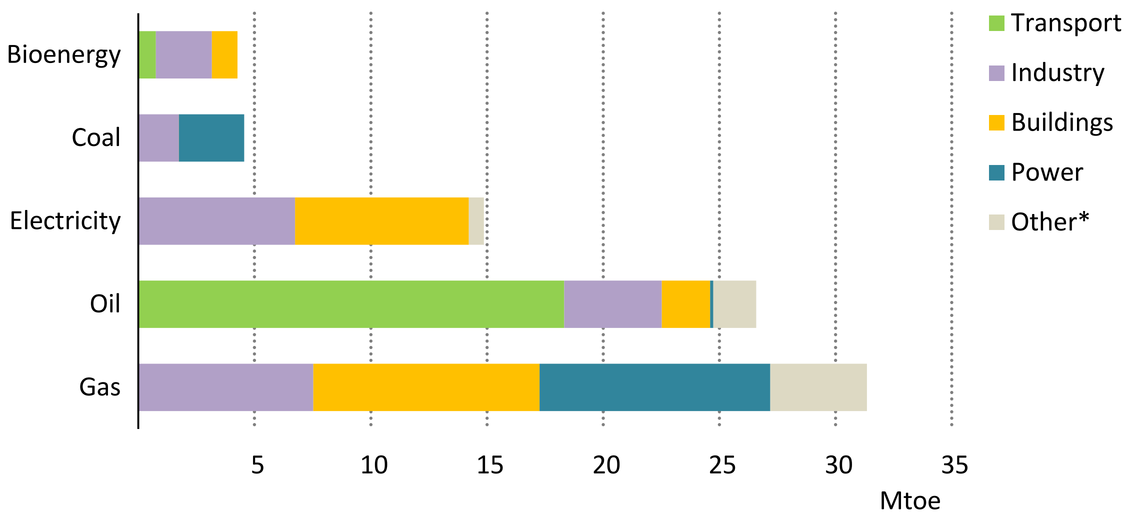
* Primary energy demand excludes fossil fuel statistical differences.

Note: TPED = Total primary energy demand; TFC = Total final consumption.

Key message • Gas demand in the power and other transformation sectors drives up primary energy demand in the Current Policies Scenario. Final energy demand grows moderately in all end-use sectors but transport.

Reductions in energy demand vary significantly depending on the fuel and the sector (Figure 3), but it should be noted that these savings are already being made in the Current Policies Scenario as a result of more efficient technologies, higher fuel prices and effective policies (for example, oil savings from tighter standards in transport, and industry savings from rising fuel prices and, to a lesser extent, stronger policies).

Figure 3 • Avoided energy demand in 2050 by fuel and sector in Canada in the Current Policies Scenario



* Non-power energy supply and transformation sectors, and agriculture.

Note: Primary energy savings attributed to the power sector result solely from increased power plant and system grid efficiency; savings from reduced electricity demand in end-use sectors are excluded.

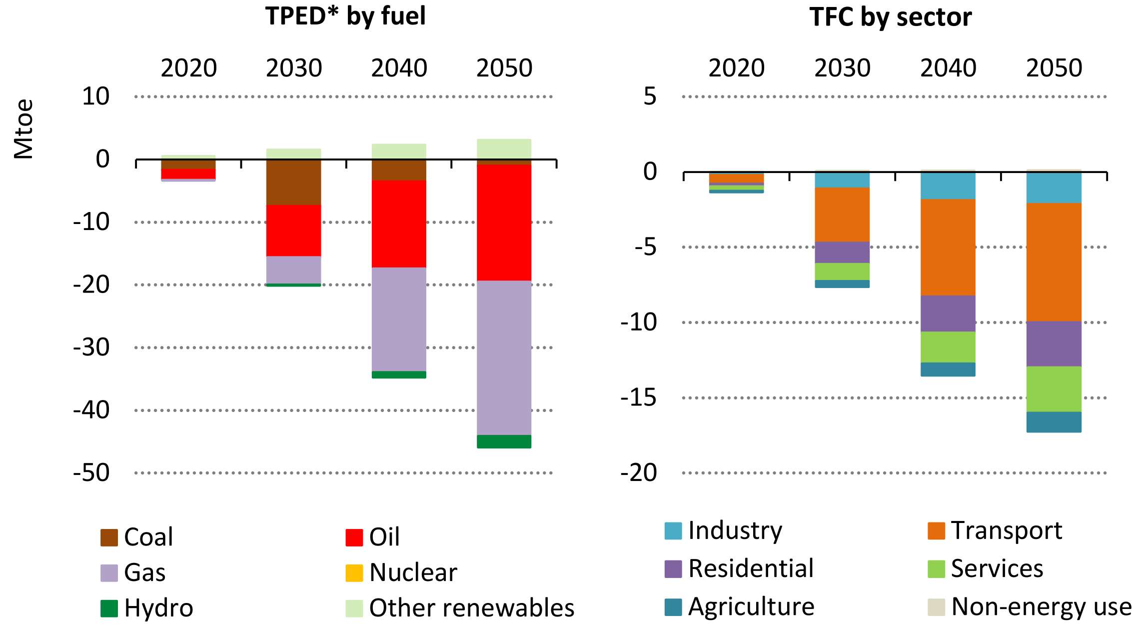
Key message • Oil and gas account for almost 70% of total energy saved in the Current Policies Scenario. Oil is saved primarily in transport, while gas savings are spread evenly across the other sectors.

Understanding the potential of the New Policies Scenario

The New Policies Scenario, one of the main scenarios of *WEO-2017*, is designed to show where existing policies and announced policy intentions could lead the energy sector. Compared with the Current Policies Scenario, it includes additional climate-related policy intentions, for example those that could lead to greater production from renewable energy technologies such as solar photovoltaic (PV) and bioenergy. In primary energy demand, the main difference in the New Policies Scenario is reduced supply-side activity – for example, lower oil and gas production, refinery runs and liquefied natural gas (LNG) export levels – partially a result of lower prices that make international markets less attractive. The result is a decline of 25 Mtoe in gas demand and 18.5 Mtoe in oil demand in 2050 compared with the Current Policies Scenario (roughly equivalent to saving around 30 billion cubic metres [bcm] of gas and 390 000 barrels per day [bbl/d] of oil). The phase-out of coal is also more complete in the New Policies Scenario, resulting in a projected coal demand reduction of 7.5 Mtoe in 2030.

The greatest declines in energy use by 2050 relative to the Current Policies Scenario are in transport (8 Mtoe) and the buildings sector (6 Mtoe) (Figure 4). The transport sector plays a greater role in mitigating energy demand growth over time because of additional, more stringent fuel economy standards and greater penetration of electric vehicles (EVs) than under the Current Policies Scenario. Falling buildings sector energy consumption in the New Policies Scenario is driven by adoption of a model NZER code, new energy efficiency standards, and a mandatory national labelling framework for residential buildings.

Figure 4 • Difference in Canada's primary energy demand by fuel, and in final consumption by sector, between the New Policies Scenario and the Current Policies Scenario



* Excludes fossil fuel statistical differences.

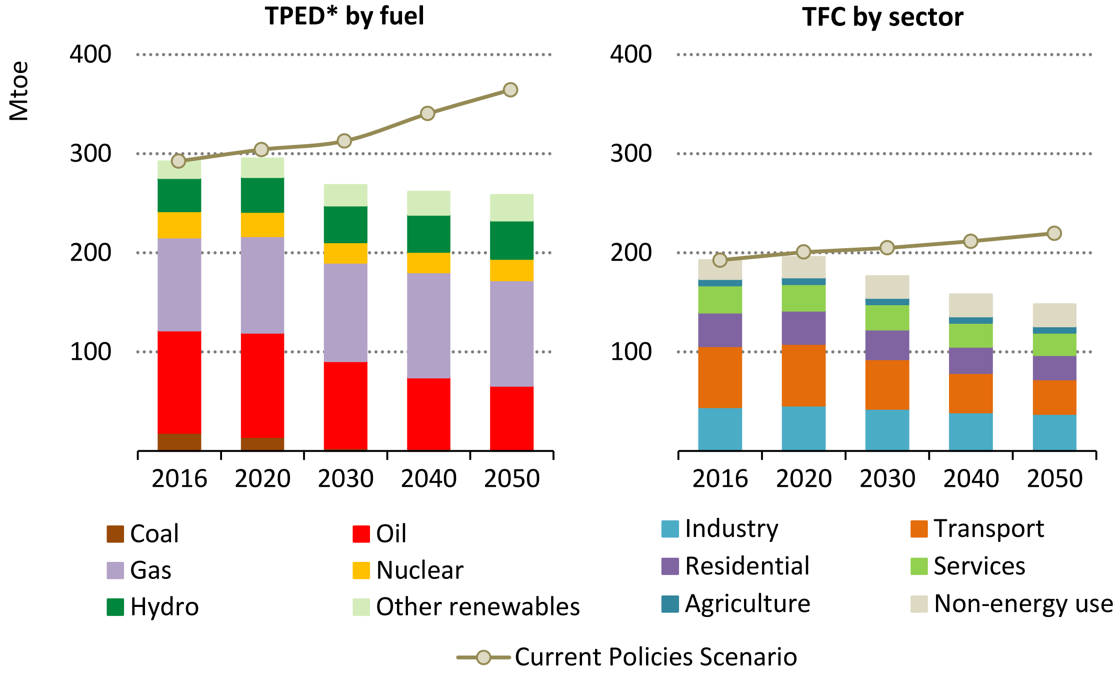
Note: TPED = Total primary energy demand; TFC = Total final consumption.

Key message • Additional energy and climate policies considered in the New Policies Scenario reduce fossil fuel consumption in all sectors compared with the Current Policies Scenario.

A closer look at the Energy Efficiency Case potential

The Energy Efficiency Case far exceeds both the Current Policies Scenario and the New Policies Scenario in energy efficiency deployment in Canada. Despite rising GDP growth and strong growth in upstream activities, TPED in 2050 in the Energy Efficiency Case is approximately 100 Mtoe less than in the Current Policies Scenario (Figure 5). The most noticeable outcome of this is a trend reversal: falling instead of rising demand for both primary and final energy.

Figure 5 • Canada's primary energy demand by fuel and final consumption by sector in the Energy Efficiency Case and the Current Policies Scenario



* Excludes fossil fuel statistical differences.

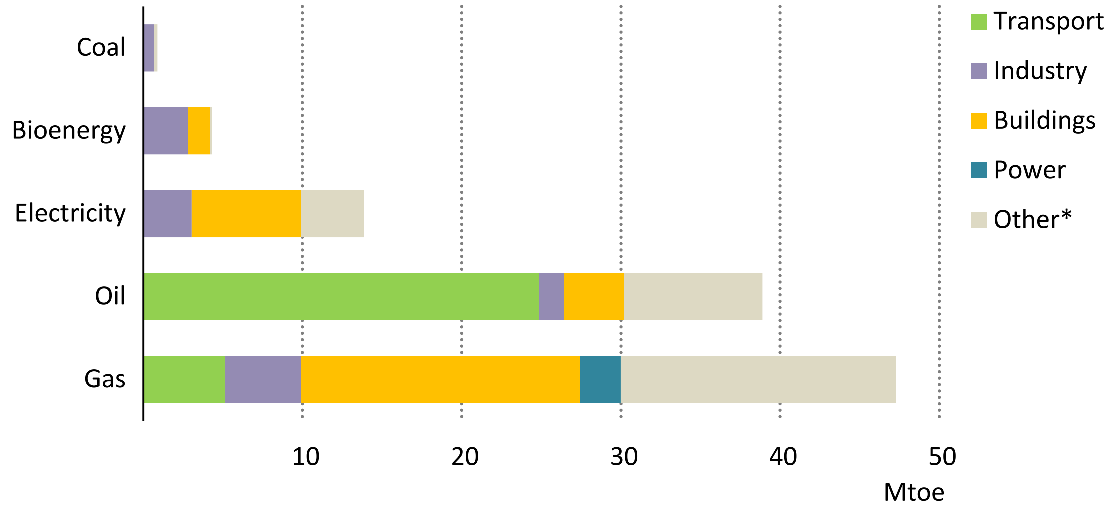
Note: TPED = Total primary energy demand; TFC = Total final consumption.

Key message • Reinforced energy efficiency measures in the Energy Efficiency Case lead to steadily falling primary and final energy demand by 2050, despite rising economic activity.

In the Energy Efficiency Case, oil demand drops significantly, from 103 Mtoe in 2016 to 88 Mtoe by 2030, and to 64 Mtoe by 2050. Conversely, demand for natural gas rises from 94 Mtoe in 2016 to around 100 Mtoe by 2030, and to just over 106 Mtoe in 2050. Coal demand all but collapses as coal use in the power sector disappears over time.

Final consumption in this case is lower than in either the Current Policies Scenario or the New Policies Scenario: 148 Mtoe in 2050, some 72 Mtoe below that projected in the Current Policies Scenario and well below 2016 consumption of 193 Mtoe. The greatest potential savings relative to the Current Policies Scenario are in the buildings sector (consumption 29 Mtoe lower) and in transport (26 Mtoe lower). Overall, more than 90% of avoided energy demand in the Energy Efficiency Case is in the form of oil and gas (Figure 6). Two-thirds of avoided oil demand in 2050 is in transport, while gas savings are spread more evenly across sectors. Nevertheless, the buildings and other energy supply sectors account for the bulk of additional gas and electricity savings above the Current Policies Scenario.

Figure 6 • Avoided energy demand by fuel and sector in Canada in the Energy Efficiency Case relative to the Current Policies Scenario, 2050



* Refers to savings in other energy supply and transformation sectors and agriculture.

Notes: Primary energy savings attributed to the power sector result solely from increased power plant and system grid efficiency; savings due to reduced electricity demand in end-use sectors are excluded. Avoided gas demand from enhanced energy efficiency in the transport sector primarily reflects reduced gas demand for pipeline transport.

Key message • Enhanced energy efficiency in the Energy Efficiency Case reduces gas and oil demand the most, thanks to improvements in the buildings, transport and energy supply sectors.

Main results by sector

Buildings

With final energy consumption of 61 Mtoe in 2016, the buildings sector accounts for 32% of Canada's TFC, used mostly for space heating. Owing to the important role of electricity and gas as important sources of energy in Canadian buildings, the sector is responsible for 64% of final electricity consumption and 54% of final gas consumption. Total building energy demand is split between residential (55%) and services buildings (45%).[7] Notably, the residential share has notably fallen from nearly 60% in 1990 as the services sector has grown in importance. Canada's cold climate (and consequent space heating needs) means its buildings are more energy-intensive than those of other developed economies. Despite recent improvements, residential buildings in Canada consume around 10% more energy per square metre (m^2) than buildings in countries with a similar climate such as Sweden and Norway, and 50% more than residential buildings in the United States.

Under the Current Policies Scenario, the average energy intensity of residential buildings per m^2 of floor area falls 20% between 2016 and 2050. For services buildings, energy intensity is expressed as energy demand per unit of sectoral value added, and this indicator shows a 35% decrease from 2016 to 2050 in the Current Policies Scenario. Several factors contribute to energy efficiency gains in this scenario, including policy measures such as building codes, voluntary standards and labelling programmes, projected technology efficiency improvements, falling costs of best available technologies, carbon pricing incentives and rising end-user prices. Reduced energy demand for space heating has the largest impact, as

[7] Services buildings' energy demand encompasses all energy consumed by commercial and institutional buildings.

additional energy efficiency improvements to building envelopes and space heating equipment contribute half of total savings in 2050.

The Energy Efficiency Case, however, reveals the additional savings possible when energy efficiency is pushed to its maximum achievable potential. For the buildings sector, this implies energy codes for new buildings that are far more stringent than current targets for 2030, and the development of building energy codes to cover existing buildings – in line with Pan-Canadian Framework commitments to develop a model code. The Energy Efficiency Case also assumes that standards for existing buildings encourage increasingly deeper retrofits, and it addresses the split incentives that divide building owners and their tenants. Tapping into the energy efficiency potential of existing buildings involves overcoming obstacles that do not apply to new constructions, such as disturbance to building tenants and new capital spending requirements for building owners. Surmounting these barriers requires careful building code design and implementation.

Maximising achievable energy efficiency potential would result in a 70% decrease in average energy intensity of new residential buildings by 2050, while the average energy intensity of the residential building stock overall would drop by more than 50%. At the same time, the average energy intensity of services buildings per unit of services sector value added would decrease by nearly 60%. In this rapid transition towards more efficient building envelopes and energy usage, almost 100% of new residential buildings would be NZER buildings by 2050, driving down average building energy intensity, especially for space heating. More stringent MEPS and labelling programmes are also important: as existing stock is gradually replaced with best available technologies, such as the best-performing heat pumps and household appliances, average efficiency of the total stock in each end-use rises.

In comparing energy intensity reductions between the Energy Efficiency Case and the Current Policies Scenario, factors such as increasingly efficient technologies and policy measures already in place induce similar improvements in both scenarios for certain end uses in new buildings (Table 4). For other end uses, however, the two scenarios display major differences, highlighting the need for stringent policy measures to realise greater improvements in energy efficiency. The competitiveness of light-emitting diodes (LEDs) compared to other lighting technologies drives greater energy efficiency in lighting across all scenarios, especially as the share of LEDs in lighting sales is projected to rise to almost 100%; this contrasts with energy demand for space heating.

Differences in energy codes for building envelope performance, as well as MEPS for new space heating equipment, lead to major divergence in projected space heating energy efficiency in the Current Policies Scenario and the Energy Efficiency Case. For example, additional policy measures to hasten adoption of heat pump technology in buildings in the Energy Efficiency Case, as well as better insulation and passive solar design, produce much greater reductions in space heating energy intensity (improvements of over 85% to 2050 for new residential buildings), in line with the Passive House standard. The same applies to space cooling: in the Current Policies Scenario, many houses have space cooling equipment added without any improvement to building envelope performance, while more stringent building energy codes in the Energy Efficiency Case result in more space cooling demand being met by insulation and passive cooling, facilitated by improved building design. Remaining demand is met by more efficient cooling equipment.

Table 4 • Energy efficiency indicators for buildings in Canada, by scenario

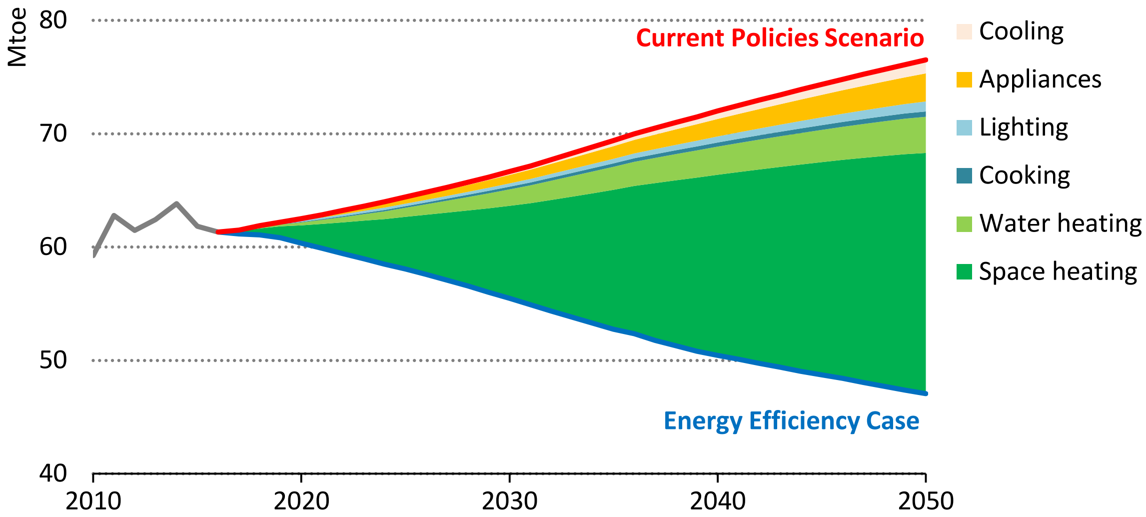
		Current Policies Scenario		New Policies Scenario		Energy Efficiency Case	
	2016	2030	2050	2030	2050	2030	2050
Residential buildings' average energy intensity (kWh/m^2)	204	181	166	174	154	148	96
Indexed energy intensity in new residential buildings	100	91	80	70	57	35	29
Space heating	*100*	*85*	*73*	*58*	*43*	*16*	*12*
Water heating	*100*	*86*	*71*	*85*	*70*	*70*	*54*
Space cooling	*100*	*98*	*93*	*85*	*80*	*14*	*11*
Lighting	*100*	*33*	*29*	*54*	*29*	*36*	*27*
Refrigeration	*100*	*97*	*94*	*93*	*90*	*80*	*70*
Cleaning	*100*	*97*	*94*	*95*	*92*	*91*	*80*
Brown goods	*100*	*97*	*94*	*94*	*90*	*75*	*59*
Services buildings' average energy intensity (kWh/USD 1 000)	299	249	195	240	178	211	128

Notes: kWh = kilowatt hour; toe/USD 1 000 = tonne of oil equivalent per USD 1 000 of services sector value added. Indexed end-use energy intensity is the average energy consumption per unit of floor area or per appliance in new and renovated buildings, when equipment or appliances have been replaced.

The disaggregation of energy efficiency savings by end use in the Energy Efficiency Case relative to the Current Policies Scenario demonstrates that space heating is the end use with the greatest potential for energy demand savings in the buildings sector – a cumulative reduction of 370 Mtoe to 2050 in the Energy Efficiency Case (Figure 7). Additional insulation (including improved glazing) in the Energy Efficiency Case leads to a four-fold increase in the share of space heating service demand met by insulation relative to the Current Policies Scenario, with an average of nearly 30% of heating service demand met by insulation in residential buildings by 2050.

The increased use of insulation is also facilitated by more frequent retrofitting of existing buildings. In addition, thanks to the impact of adding or replacing insulation, retrofits often involve installing lower-rated-capacity space heating equipment. Overall, insulation is responsible for nearly half of energy demand savings in residential space heating in the Energy Efficiency Case relative to the Current Policies Scenario in 2050, and the remainder of the space heating energy demand reduction is from switching to more efficient technologies. For example, the market share of conventional gas boilers for space and water heating is projected to fall rapidly in the Energy Efficiency Case, to close to zero by 2050. Gas-fired condensing boilers fill part of the gap, increasing the efficiency of gas-fired space and water heating by up to 20% relative to conventional gas boilers, but the primary equipment-related source of energy efficiency improvement is the electrification of space heating through greater installation of heat pumps (see section on power below).

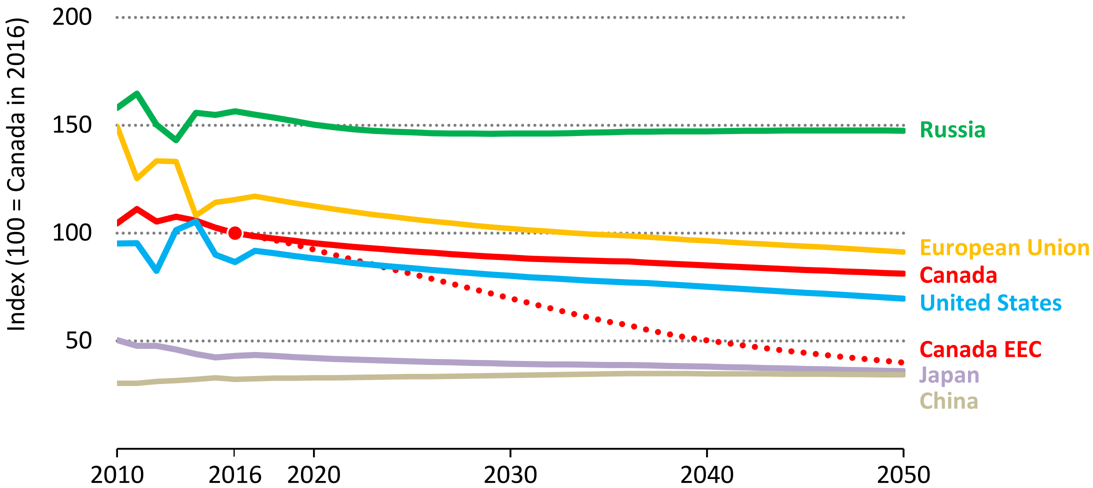
Figure 7 • Avoided energy demand by end use in the buildings sector in Canada in the Energy Efficiency Case relative to the Current Policies Scenario



Key message • Improved space heating energy efficiency provides the majority of buildings sector energy savings in the Energy Efficiency Case, resulting in a net energy demand decrease from today.

Rapid improvement in space heating efficiency in the Energy Efficiency Case allows Canada to improve its position relative to the space heating intensity of other developed and developing economies. Despite having much higher residential space heating energy intensity than the United States, when weighted to account for differences in climate, Canada's energy intensity is currently only 15% higher; nonetheless, it is more than double Japan's. Although Canada's residential space heating energy intensity declines slightly to 2050 under the Current Policies Scenario, reduced energy demand in the Energy Efficiency Case causes it to drop to well below the level of the United States, in line with Japan's projected intensity in the Current Policies Scenario (Figure 8).

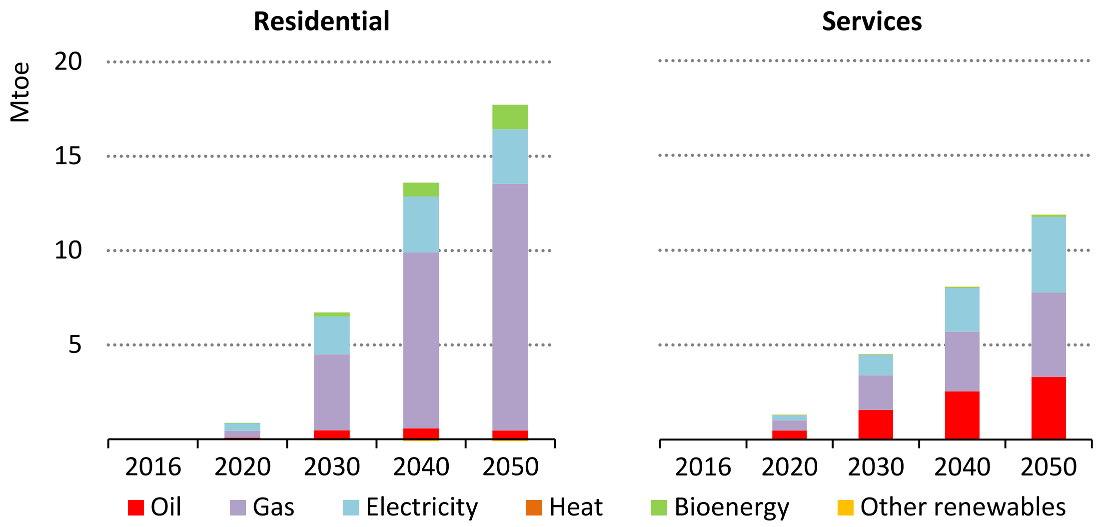
Figure 8 • Climate-weighted residential space heating energy intensity in the Current Policies Scenario and the Energy Efficiency Case for Canada



Notes: EEC = Energy Efficiency Case. Climate-weighted residential space heating energy intensity is defined as the energy demand for space heating per population-weighted heating degree day per m^2 of floor area. All trajectories except Canada EEC are for the Current Policies Scenario.

Key message • Under the Energy Efficiency Case, Canada's residential space heating energy intensity drops to the level of the best global performers while maintaining the same level of comfort.

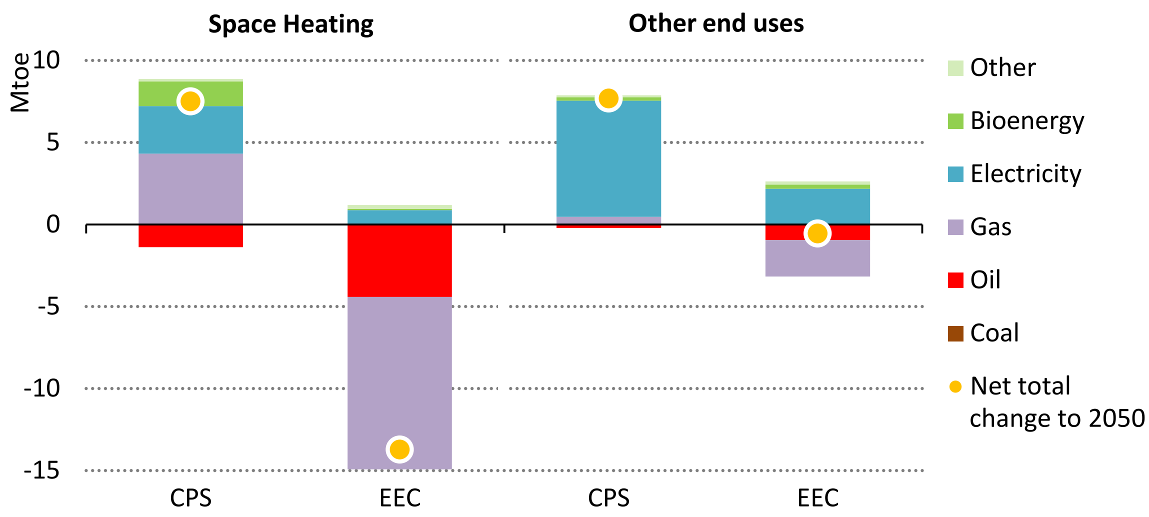
Figure 9 • Avoided residential and services buildings' energy demand by fuel in Canada in the Energy Efficiency Case relative to the Current Policies Scenario



Key message • Enhanced energy efficiency in buildings affects gas demand in the residential sector the most. Reduced electricity demand is partially offset by increasing electrification in all buildings.

Due to the prominence of gas and electricity in Canada's buildings' energy mix, savings in the Energy Efficiency Case compared with the Current Policies Scenario are most pronounced for these two energy sources (Figure 9). Gas demand reductions are driven by better building envelope performance, the switch to electricity and the adoption of more efficient gas space and water heating equipment.

Figure 10 • Change in energy demand in Canada for buildings by main end use and fuel in the Current Policies Scenario and the Energy Efficiency Case, 2016-50



Note: CPS = Current Policies Scenario; EEC = Energy Efficiency Case.

Key message • Enhanced energy efficiency has the greatest impact on gas and oil demand for space heating, and almost cancels out demand growth from other end uses in the Energy Efficiency Case.

Improved envelope performance for new and existing buildings also drives reduced electricity demand for space heating in the Energy Efficiency Case, and significant electricity savings in other end uses are achieved as more efficient equipment and appliances reduce electricity demand for lighting, cooling, refrigerators, cleaning appliances and brown goods. However, despite more efficient electricity consumption in end-use technologies, electricity demand in the buildings sector continues to grow in the Energy Efficiency Case – the only major fuel to do so (see section on power below). Oil demand in buildings drops as the use of oil for space heating is phased out in services and residential buildings in the Energy Efficiency Case in favour of more efficient alternatives (Figure 10).

Manufacturing industries

Canada's highly developed industry sector benefits from the country's natural resources and competitive advantages. Energy-intensive industry accounts for a relatively large share (65%) of energy consumption in the sector (approaching the level of Japan and exceeding that of Western Europe and the United States).[8] The high share of heavy industry in the economy makes reducing energy consumption and decarbonising the industrial sector challenging. Nonetheless, the sector's energy efficiency has been improving steadily.

In the Energy Efficiency Case, maximum potential energy efficiency is achieved in the industry sector by deploying all energy efficiency options that offer a payback period of up to twenty years, and by implementing structural changes in several energy-intensive sub-sectors (e.g. increased recycling of metals and paper and increased clinker substitution). These actions are cost-effective within the economic design lifetime of the industrial equipment. Non-economic barriers to deployment of energy efficiency measures, such as lack of awareness or technical expertise, are assumed to be overcome within the Energy Efficiency Case framework, allowing full efficiency potential to be realised when it becomes cost-efficient. Under these ambitious assumptions, Canada's aggregated industrial energy intensity declines 38% by 2050 compared with 2016 – 15 percentage points beyond the Current Policies Scenario (Table 5).

Table 5 • Energy efficiency indicators in industry for Canada, by scenario

		Current Policies Scenario		New Policies Scenario		Energy Efficiency Case	
	2016	2030	2050	2030	2050	2030	2050
Aggregated industrial energy intensity (toe/USD 1 million)	130	119	100	117	97	109	80
Indexed sub-sectoral energy intensity							
*Iron and steel**	*100*	*97*	*84*	*96*	*81*	*89*	*61*
Cement	*100*	*98*	*93*	*97*	*91*	*92*	*80*
*Chemicals and petrochemicals***	*100*	*93*	*86*	*92*	*83*	*87*	*70*
Aluminium	*100*	*93*	*75*	*92*	*74*	*85*	*61*
Pulp and paper	*100*	*95*	*93*	*93*	*88*	*83*	*63*
Other industry	*100*	*91*	*85*	*87*	*80*	*77*	*61*

* Includes blast furnaces and coke ovens.

** Excludes feedstock use.

Note: Indexed energy intensity is expressed in tonnes of output for all sub-sectors except 'other industry', for which the sum of all other industry sub-sectors' value added in constant 2016 US$2016 in market exchange rate (MER) terms is used instead of physical production. Output for chemicals and petrochemicals is the sum of basic production in tonnes, including ethylene, propylene, aromatics, ammonia and methanol.

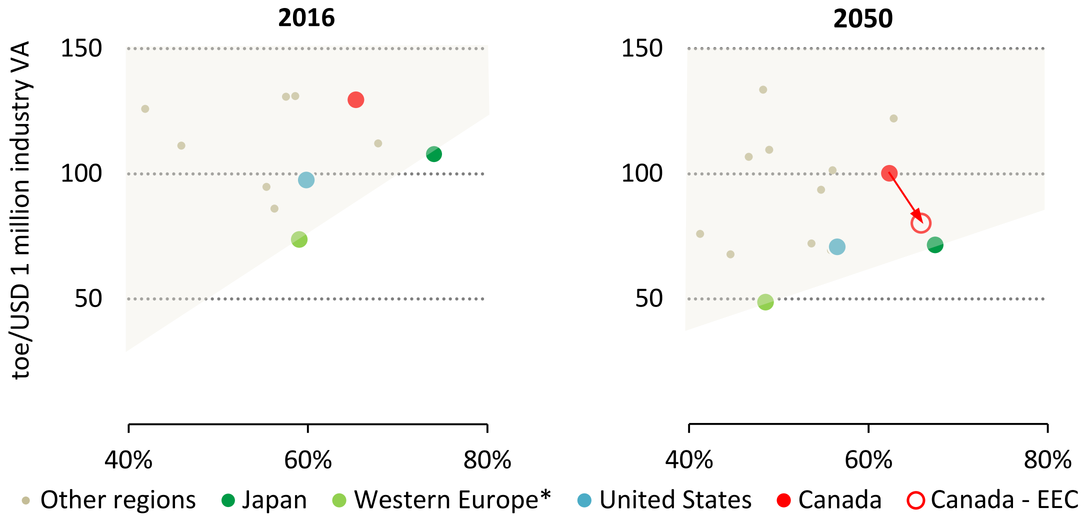
Canada already performs well in terms of industrial energy intensity, especially in comparison with emerging economies: for example, China's industrial energy intensity in 2016 was 280 toe/USD 1 million of industrial value added and India's was 380 toe/USD 1 million, compared

[8] Energy-intensive sectors are iron and steel, cement, aluminium, pulp and paper, and chemicals and petrochemicals.

with Canada's 130 toe/USD 1 million.[9] The efficiency of Canada's industry sector continues to improve in the Current Policies Scenario thanks to the existing policy framework, rising energy prices and the continuous adoption of improved technologies. Economies that are able to capture considerable energy efficiency potential at low cost can also improve quickly and approach Canada's industrial energy intensity (e.g. China by 2050).

Even though Canada's energy intensity improves significantly to 100 toe/USD 1 million in the Current Policies Scenario, in most sub-sectors it remains behind that of the best global performers in 2050 (Figure 11). Existing policies are not sufficient for energy efficiency improvements to offset increasing activity in the industry sector. Energy demand is projected to grow by 0.5% per year on average, for an increase of 8.5 Mtoe by 2050.

Figure 11 • Industry energy intensity as a function of the share of heavy industry in total industry energy use in selected regions under the Current Policies Scenario and in the Energy Efficiency Case for Canada



* France, Germany, Italy and the United Kingdom.

Notes: VA = value added. Industry energy use includes energy demand from blast furnaces and coke ovens and petrochemical feedstocks. The lower boundary of the shaded grey area, defined by performance of the main world regions in the WEM, represents the "frontier" of industrial energy efficiency.

Key message • Canada approaches the benchmarks for most energy-efficient industry in 2050 under the Energy Efficiency Case, aligning with United States' performance.

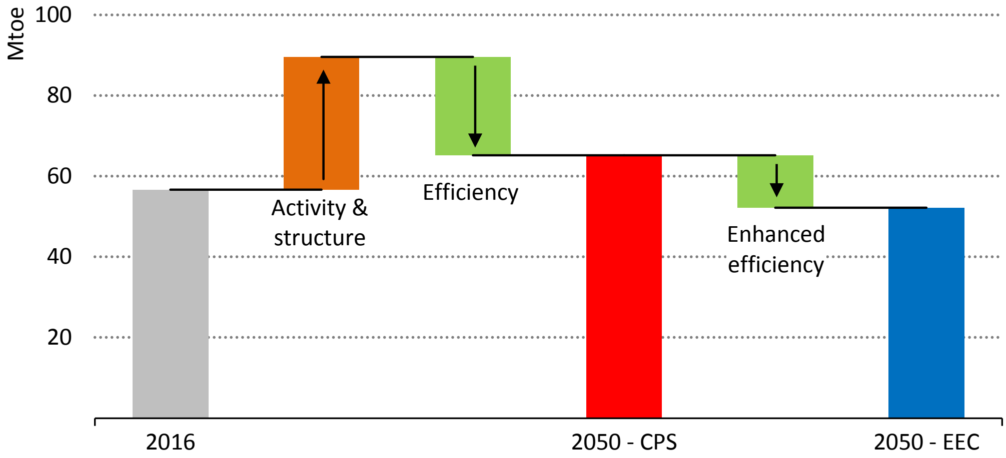
In the Energy Efficiency Case, heavy industry claims a slightly larger share of total industrial energy use because potential for improvement varies among the different sub-sectors.[10] Capturing all energy efficiency potential under the Energy Efficiency Case would allow Canada to almost catch up to the best heavily industrialised performers by 2050 (e.g. Japan) and align with the United States, taking into account its greater share of heavy industry.[11] Under these conditions, Canada approaches the "frontier" of energy efficiency, even as that frontier advances with technology progress and investment. Canada's energy intensity would therefore decline to about 80 toe/USD 1 million by 2050 in the Energy Efficiency Case.

[9] In Figure 11, which focuses on the best industrial energy efficiency performers today and in the future, China's and India's current industrial energy intensities are well beyond the Y-axis scale, and this is the case for many other countries.

[10] This shift in the Energy Efficiency Case results from less energy-intensive industries having greater energy efficiency potential than energy-intensive sub-sectors (see more detailed discussion on sectors below).

[11] By 2050, the axis defined by the United States and Canada-EEC parallels the axis defined by Western Europe and Japan.

Figure 12 • Change in industrial energy demand in Canada in the Current Policies Scenario and the Energy Efficiency Case by key driver, 2016-50

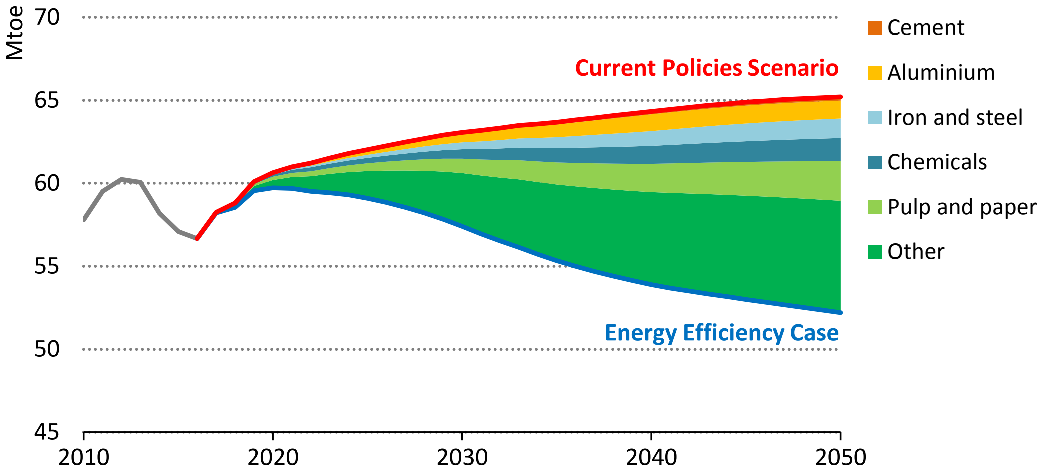


Notes: Includes energy demand from blast furnaces and coke ovens and petrochemical feedstocks. CPS = Current Policies Scenario; EEC = Energy Efficiency Case.

Key message • Enhanced energy efficiency in the Energy Efficiency Case more than offsets energy demand growth from increasing activity and adverse structural effects.

During the period from 2016 to 2050 in the Energy Efficiency Case, industrial activity (measured in terms of value added) increases by 50% while energy consumption declines; without all the additional measures of the Energy Efficiency Case, industrial energy consumption would be 13 Mtoe higher (Figure 12). All fuels contribute savings in the Energy Efficiency Case, though the potential depends on how those fuels are used in specific industrial applications; savings are achieved in each sector where they are best suited and most cost-effective. Gas contributes the largest net savings in 2050, as it is used widely across the industry sector, but electricity and biomass are also important.

Figure 13 • Avoided energy demand by industrial sub-sector in the Energy Efficiency Case relative to the Current Policies Scenario

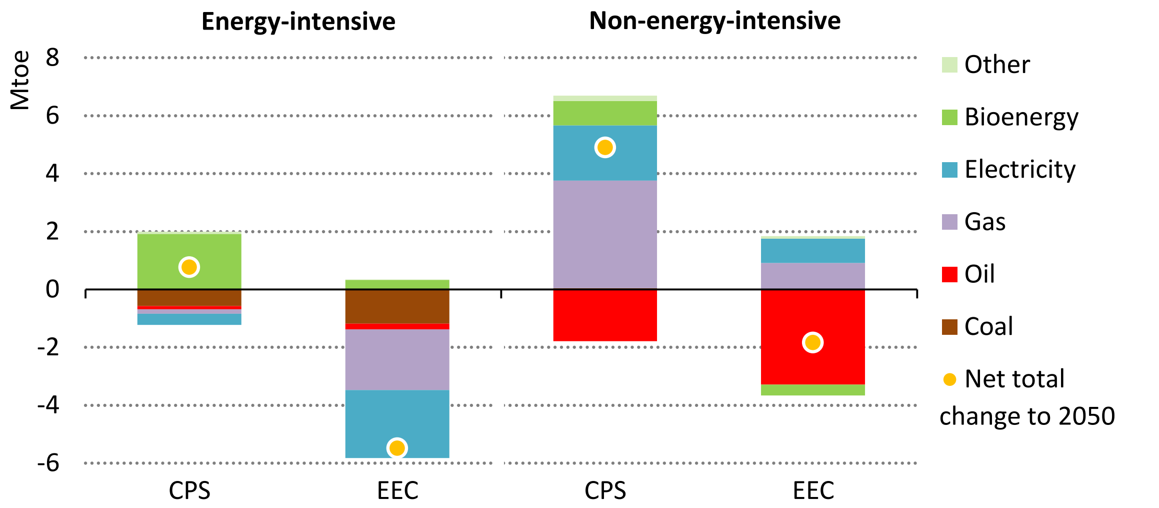


Note: Includes energy demand from blast furnaces and coke ovens and petrochemical feedstocks.

Key message • Additional energy demand savings in the Energy Efficiency Case are split almost evenly between energy-intensive and non-energy-intensive sectors.

Within the sector, the less energy-intensive industries (such as automotive, mechanical, textile, electronics and food and beverage) contribute more than half the cumulative energy use savings in the Energy Efficiency Case (Figure 13, 'other' category). Even though energy demand is expected to grow continuously throughout the outlook period along with Canada's GDP, energy efficiency potential is significant. In the Energy Efficiency Case, energy demand from these lighter industries declines to almost 30% below the Current Policies Scenario level by 2050, and nearly 10% below the 2016 level. This results from wider deployment of fuel- and electricity-efficient technologies and processes in all types of industrial activities, including among others efficient boilers and furnaces, improved heat exchangers, heat recovery, better insulation and efficient lighting. Cross-cutting efficiency measures benefit various industrial sectors, especially smaller industries. A further 6 Mtoe of fuel (about 3 Mtoe of gas, 1.5 Mtoe of oil and 1.5 Mtoe of other fuels) is saved from directly applying energy efficiency measures (especially heat pump deployment) to less energy-intensive industries in the Energy Efficiency Case (Figure 14).

Figure 14 • Change in industrial energy demand in Canada by sector and fuel in the Current Policies Scenario and Energy Efficiency Case, 2016-50



Notes: Includes energy demand from blast furnaces and coke ovens and petrochemical feedstocks. CPS = Current Policies Scenario; EEC = Energy Efficiency Case.

Key message • Enhanced energy efficiency leads to a net decrease in oil consumption in light industry, and a net decline in gas and electricity consumption in the energy-intensive sub-sectors.

Furthermore, strong deployment of the most efficient electric motor systems contributes an additional 28 TWh of electricity savings in 2050 in the Energy Efficiency Case, keeping electricity usage for motors almost flat over the outlook period despite greater energy services from motor systems overall. By comparison, electricity usage for industrial motor systems increases steadily by almost 1% per year in the Current Policies Scenario. To reach the Energy Efficiency Case's level of efficiency improvement, efficiency class IE3 is assumed for all motors by 2020, and IE4 super-premium efficiency as soon as 2025.[12] Although greater efficiency of the motors themselves is important, it is not the only element to consider: the Energy Efficiency Case also assumes maximum diffusion of variable speed drives (VSDs) (used in more than 50% of the stock), and further improvement in the efficiency of end-use devices. Together with the assumptions mentioned above, further actions such as the increased adoption of energy management systems (e.g. ISO 50001) improve the overall efficiency of electric motor systems by more than 25 percentage points by 2050.

Of the energy-intensive sub-sectors, **pulp and paper** contributes the most to net energy savings in the Energy Efficiency Case, with energy consumption decreasing by 28% from 2016 to 2050.

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[12] IE3 and IE4 are International Electrotechnical Commission (IEC) standards. For more information on energy implications for electric motor systems, see the *WEO-2016* section on motor efficiency (IEA, 2016).

Improved paper recycling reduces consumption of all fuels, in particular biomass for virgin wood pulp production, and efficiency measures such as using continuous and efficient digesters, heat recovery, new drying techniques, and improved process control and maintenance save energy.

The **chemicals and petrochemicals** industry, including feedstock, consumed the most fuel of any industrial sector in Canada in 2016 – one-third of total industrial consumption. By 2050 in the Energy Efficiency Case, only the chemicals and cement sectors demonstrate net energy consumption growth, with chemicals accounting for more than 90% (in the Current Policies Scenario, consumption in light industry and pulp and paper also grow). This growth comes from feedstock use, mostly in the form of oil, so excluding fossil fuel consumption for feedstock purposes (no efficiency measures are considered for non-energy use of fuels in this scenario) reduces energy consumption by 12% from 2016 to 2050, despite large increases in chemical production.

Energy consumption in the **iron and steel** industry in the Energy Efficiency Case in 2050 is more than 30% lower than in 2016 and more than one-quarter below that of 2050 in the Current Policies Scenario. Most of the savings are in coal and gas, the major fuels used in this sector, though improved electricity efficiency is also important. Electricity consumption is 24% lower in 2050 in the Energy Efficiency Case than in the Current Policies Scenario, despite a higher share of electric arc furnace-based steel production.

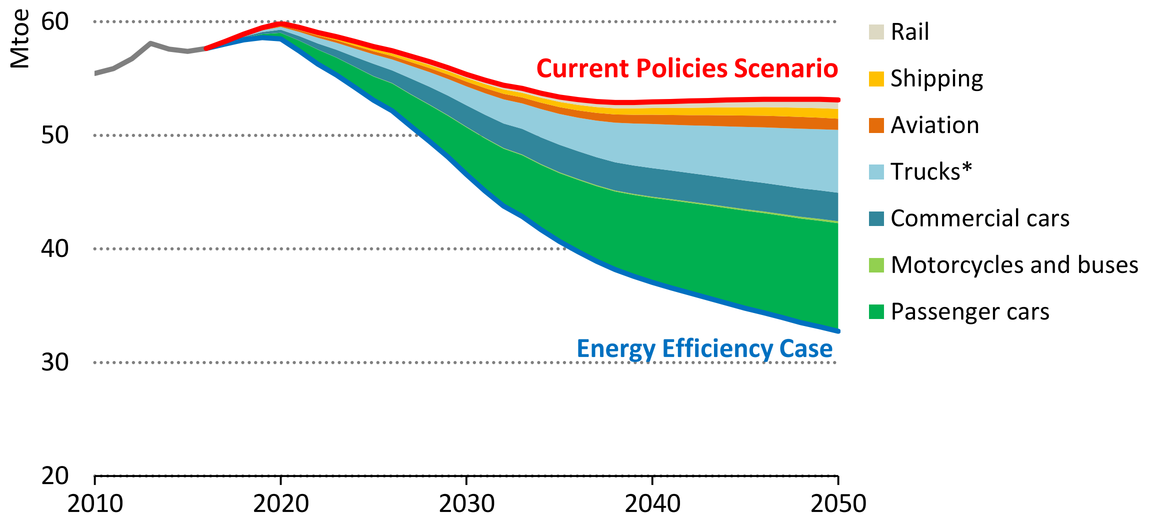
Aluminium production is projected to grow steadily through 2050. At the same time, but the share of recycled production is 14 percentage points higher in the Energy Efficiency Case than in the Current Policies Scenario. Savings from shifting to lower-energy-intensity secondary production, and from efficiency improvements in primary production, fully offset activity-related increases and result in lower energy consumption in 2050 than in 2016 under the Energy Efficiency Case, even though production is more than 2 million tonnes (Mt) higher. Approximately 90% of the net change in fuel consumption, compared with the Current Policies Scenario, is in electricity. More efficient alumina refining and anode production, along with improved efficiency in refining and re-melting processes, also reduce fossil fuel consumption.

Cumulatively, energy savings from **cement** production are the smallest of the energy-intensive sub-sectors, accounting for 2% of the total savings gained in the Energy Efficiency Case compared with the Current Policies Scenario. Despite reducing the clinker-to-cement ratio, limited savings reflect both the relatively small share of this sector in Canada's overall industry energy use and the small number of cost-effective measures available to reduce energy intensity at present.

Transport

Canada has already adopted several measures to improve energy efficiency in the transport sector, especially in road transport, which accounts for 80% of energy consumption in the sector. Regulations on GHG emissions of light- and heavy-duty vehicles has reduced average fuel consumption of both passenger and road freight vehicles, and free SmartDriver for Highway Trucking training is offered through the FleetSmart programme to help truckers and trucking companies reduce fuel use, cut costs, increase profits and improve competitiveness. The SmartWay Transport partnership helps businesses reduce fuel costs associated with the transportation of goods by measuring, benchmarking and improving freight transportation efficiency through fuel-saving technologies and operational best practices, and fleet analysis tools are being developed for heavy-duty vehicles and for the federal fleet. Canada has also implemented a programme aimed at raising awareness of the benefits of more efficient driving techniques as well as a labelling system for fuel consumption of new cars (EnerGuide) to better inform customers. The EnerGuide Label for Vehicles provides model-specific fuel consumption information for new light-duty vehicles available for retail sale in Canada, including passenger cars, vans, pickup trucks and sport utility vehicles (SUVs). The EnerGuide label and online fuel consumption ratings tool can be used to compare new-vehicle fuel consumption and identify the most fuel-efficient new vehicle. Canada also benefits from an extensive rail network and, in terms of tonne-kilometres (tkm), 42% of goods transported in Canada are carried by rail, resulting in substantial emissions savings compared with transporting goods by road.

Figure 15 • Avoided energy demand by transport mode in Canada in the Energy Efficiency Case relative to the Current Policies Scenario



* Includes medium- and heavy-duty trucks.

Note: Excludes energy used for pipeline and non-specified transport.

Key message • Energy efficiency measures reduce energy demand for all modes of transport, especially road passenger and road freight.

The transport sector is an important reservoir of energy efficiency gains: energy demand in 2050 is around 45% lower in the Energy Efficiency Case than in the Current Policies Scenario, with all modes contributing to the reduction (Figure 15). The main potential resides in improvement of combustion engines (from drag or wheel friction reduction, to mild or even full hybridisation), light-duty vehicles and the public bus fleet, and in the more efficient organisation of logistics networks with advances in information and communications technologies.

Passenger light-duty vehicles (passenger cars, light passenger trucks and SUVs) offer significant energy efficiency potential. This sub-sector accounts for 45% of total transport energy demand. Importantly, Canada's sales of light-duty trucks (which present low efficiency performance because of their large size) are among the highest in the world (IEA, 2017). Although formulated in terms of GHG emissions rather than energy efficiency, Canada's GHG emissions regulations urge strong fuel efficiency improvements that are already noticeable in the Current Policies Scenario and account for most of the steep decrease in energy demand from 2020 onwards. In the Energy Efficiency Case, however, the faster deployment of cars equipped with efficiency improvement features (engine downsizing, start-stop systems, direct injection, lightweighting, friction-reduction tyres, braking energy recovery systems, etc.) as well as the rapid switch to electricity increase the fuel efficiency of the fleet by almost 50% compared to the Current Policies Scenario in 2050. These savings are bolstered by better driver training, such as through the AutoSmart driver programme already in place, which boosts fuel savings by up to 25%. As a result, driving 100 km in an average gasoline-fuelled internal combustion engine car in 2050 will require 4.5 litres (L) of fuel in the Energy Efficiency Case, compared with more than 10 L today.

Canada already supports further electrification and is developing a nation-wide strategy for zero-emissions vehicles for 2018, and federal, provincial and territorial governments are working with private-sector partners to accelerate demonstration and deployment of infrastructure such as electric vehicle charging stations to support zero-emissions vehicles. Federal, provincial and territorial governments are also investing in public-transit upgrades and expansions, building more efficient trade and transportation corridors (including transportation hubs and ports) and supporting refuelling stations for alternative fuels (natural gas, electricity and hydrogen) for light- and heavy-duty vehicles. In the Energy Efficiency Case, even greater electrification is assumed: more than 4 million electric passenger light-duty vehicles (PLDVs) in 2030 (almost 20% of the PLDV stock) compared with around 1 million in the Current Policies Scenario. Their number is projected to reach 16.5 million in 2050 in the Energy Efficiency Case, meaning two out of three PLDVs sold will be electric. The strong penetration of electric PLDVs cuts average on-road (PLDV) fuel consumption in 2050 in half, from 5.9 litres of gasoline equivalent per 100 kilometres (Lge/100 km) in the Current Policies Scenario to 3.2 Lge/100 km in the Energy Efficiency Case (Table 6).

Table 6 • Transport energy efficiency indicators for Canada, by scenario

		Current Policies Scenario		New Policies Scenario		Energy Efficiency Case	
	2016	2030	2050	2030	2050	2030	2050
Average on-road specific fuel consumption (PLDVs) (Lge/100km)	10.1	7.6	5.9	6.7	4.8	6.3	3.2
Overall road freight efficiency (MJ/tkm)	1.23	1.02	0.77	1.01	0.69	0.87	0.49
Aviation efficiency (index 100 in 2016)	*100*	*74*	*63*	*74*	*63*	*68*	*54*
Rail efficiency (index 100 in 2016)	*100*	*77*	*58*	*72*	*48*	*65*	*34*
Shipping efficiency (index 100 in 2016)	*100*	*69*	*44*	*68*	*43*	*52*	*19*

Notes: MJ/tkm = megajoules per tonne-kilometre. PLDV = passenger light-duty vehicles; Lge = litre of gasoline equivalent.

Canada is one of only five countries in the world to have implemented efficiency and emissions intensity standards for **heavy-duty trucks**.[13] In the Current Policies Scenario, the resulting efficiency improvements for medium-duty trucks is 18% and for heavy-duty trucks 26% in 2050. A set of technical and organisational measures could also deliver additional energy savings; examples of technical options are tyre pressure systems, lightweighting, automatic transmissions and hybridisation. In the Energy Efficiency Case, the push for greater energy efficiency leads to on-road fuel consumption of the average-duty truck being one-third lower than in the Current Policies Scenario in 2050. Options for better road-freight management include load factor optimisation for the different modes (light-, medium- and heavy-duty trucks) as well as a higher share of heavy-duty trucks, as they offer the best energy efficiency performance. Examples of organisational measures are backhauling and platooning (enabled by truck automation and connectivity). With adoption of these measures, energy consumed transporting goods by road (in MJ per tkm) is 37% lower in the Energy Efficiency Case.

Domestic aviation accounts for less than 10% of current Canadian transport energy demand, but this share could increase quickly if no further efficiency measures are taken. A portfolio of measures in line with the International Civil Aviation Organization's (ICAO's) target to reduce fuel

[13] The others are China, India (full enforcement in April 2018), Japan and the United States.

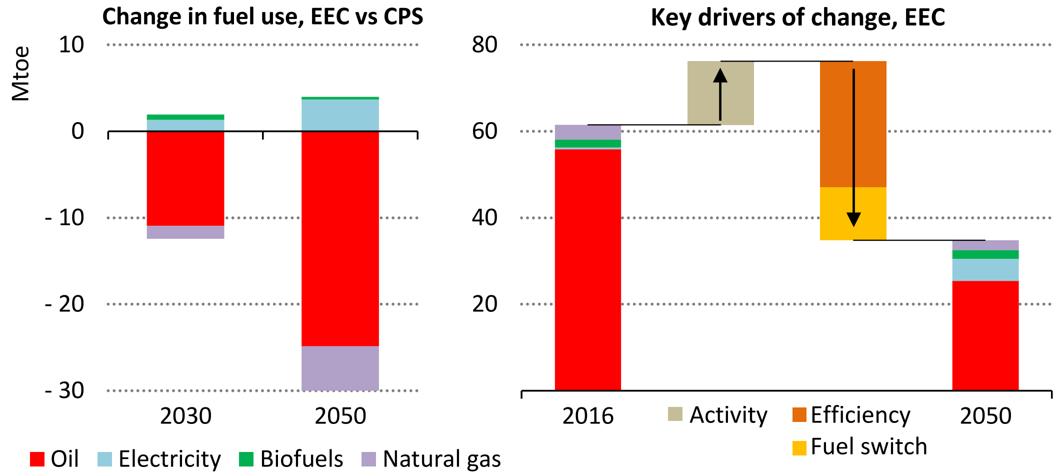
intensity by 2% per year could be deployed to push airlines beyond current commitments. The first suite of measures concerns the aircraft itself: reducing its weight, improving the aerodynamics of the tube and the wing through better design, and further hybridisation (e.g. replacing hydraulic or pneumatic systems with electric ones, or equipping wheels with electric engines). The second involves better air traffic management: higher utilisation rates, optimised routes and reduced fuel for taxiing (routes on the ground). Third, better fleet management, including refurbishment of less efficient aircraft, could help maximise energy consumption savings. The fuel intensity of the aviation sector in 2050, expressed in toe per million revenue passenger kilometres, is 15% lower in the Energy Efficiency Case than in the Current Policies Scenario, with fuel intensity falling to half what it is today, in the Energy Efficiency Case.

Rail transportation is already relatively efficient, but untapped potential remains. Most of the current fleet is diesel electric, and since electrification of many railways is impractical (and often very costly given their length and the utilisation rate), energy efficiency improvements consist of start-stop, anti-idling and throttle-control systems. Better maintenance of infrastructure and tracks, as well as heat switchers, rail lubrication and welded rails would further reduce locomotive consumption. Finally, earlier replacement of aged locomotives would also increase the energy efficiency of the fleet. As a result, rail freight activity (expressed in tkm) is 1.5 times higher in 2050 in the Energy Efficiency Case than today, but energy consumption is halved.

Even though **shipping** is the most efficient mode for transporting goods, it is limited to certain routes and increasing its use would require measures to promote multimodal switching. In addition, there may be conflict between the search for efficiency gains and reducing sulphur emissions from ships.

Finally, while intermodal shift is not considered in detail in this analysis, it is clear that other measures such as promoting soft transportation through sound urban planning (e.g. dedicated pathways and cycle lanes) and incentivising public transportation would help avoid energy use; also outside the scope of this study is the impact of ride-hailing and autonomous, connected and shared vehicles.

Figure 16 • Change in transport energy demand by fuel in the Energy Efficiency Case compared with the Current Policies Scenario, and key drivers of change in the Energy Efficiency Case, 2016-50



Note: CPS = Current Policies Scenario; EEC = Energy Efficiency Case.

Key message • Oil loses ground to electricity in the Energy Efficiency Case, mainly owing to improved energy efficiency of conventional vehicles and deployment of electric vehicles.

Oil is, and remains, the mainstay transportation fuel, but its demand is cut drastically in the Energy Efficiency Case (Figure 16) while electricity and biofuels consumption rise. For example, ethanol, a high-octane biofuel that improves the combustion of fuel in the engine, raises the efficiency of gasoline-fuelled engines.

Power sector

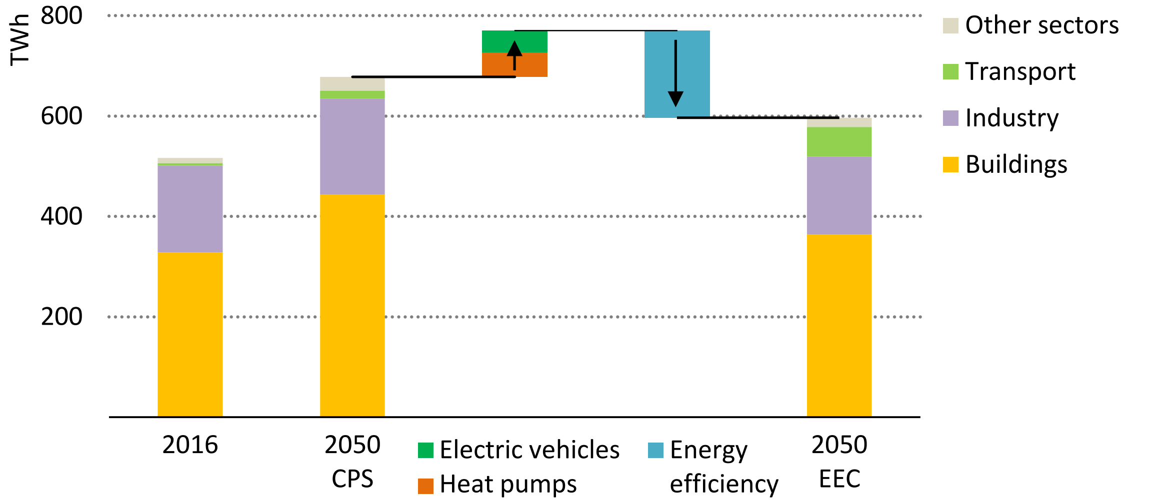
Electricity demand

Electricity demand is set to increase 34% from 2016 to 2050 in the Current Policies Scenario, driven largely by demand growth in the buildings sector. In the Energy Efficiency Case, electricity demand growth is slower, as increased electrification from additional heat pumps and electric vehicles (additional 90 TWh in 2050) is more than offset by energy efficiency savings across all sectors (-170 TWh) (Figure 17).

In the buildings sector, improved insulation drives down electricity demand the most, while the primary equipment-related source of efficiency improvement is the switch from electric resistance heating to heat pumps for space heating. At the same time, however, the effects of increasingly efficient electric heating are partially offset by rising demand resulting from fuel switching to electricity in the Energy Efficiency Case. Heat pumps fill the gap as inefficient equipment is retired, meeting 60% of the remaining demand for heating services in 2050 after building envelope improvement. The electrification of space and water heating results in major decreases in gas and oil demand over time in the buildings sector.

In the industry sector, the electrification of heating through the deployment of heat pumps leads to additional electricity demand of just over 11 TWh by 2050 but avoids consumption of almost 4 Mtoe of heating fuels. Wider deployment of heat pumps in the industry sector causes average heat supply efficiency to exceed 100% in 2050, more than 10 percentage points higher than in the Current Policies Scenario. In the enhanced efficiency scenario, electrification mostly affects smaller industries, for which the share of heat pumps in new heat capacity sales grows to more than 15% by 2050; heat pumps are also deployed in the paper and chemicals sectors.

Figure 17 • Electricity demand by sector in the Current Policies Scenario and the Energy Efficiency Case, and key drivers of change in the Energy Efficiency Case for Canada



Note: CPS = Current Policies Scenario; EEC = Energy Efficiency Case.

Key message • Energy efficiency improvements more than offset increased electrification resulting from further deployment of heat pumps and electric vehicles in the Energy Efficiency Case.

Transport is the only sector for which electricity demand increases in the Energy Efficiency Case compared with the Current Policies Scenario, but wider deployment of EVs, especially electric PLDVs, leads to important total energy demand savings. For same-size cars, an electric powertrain is 2.5 times more efficient on average than a combustion engine. Considering the full energy chain (power plant efficiency, grid losses, etc.), an EV driven in Canada is around 30% more efficient than a conventional, petroleum-powered vehicle. In the Energy Efficiency Case, transport electricity demand grows at an unprecedented 7.4% per year to 2050, with road electricity consumption multiplied by a factor of 50 to reach 55 TWh by 2050. The vast majority of the increase comes from PLDVs, and the remaining from motorcycles.

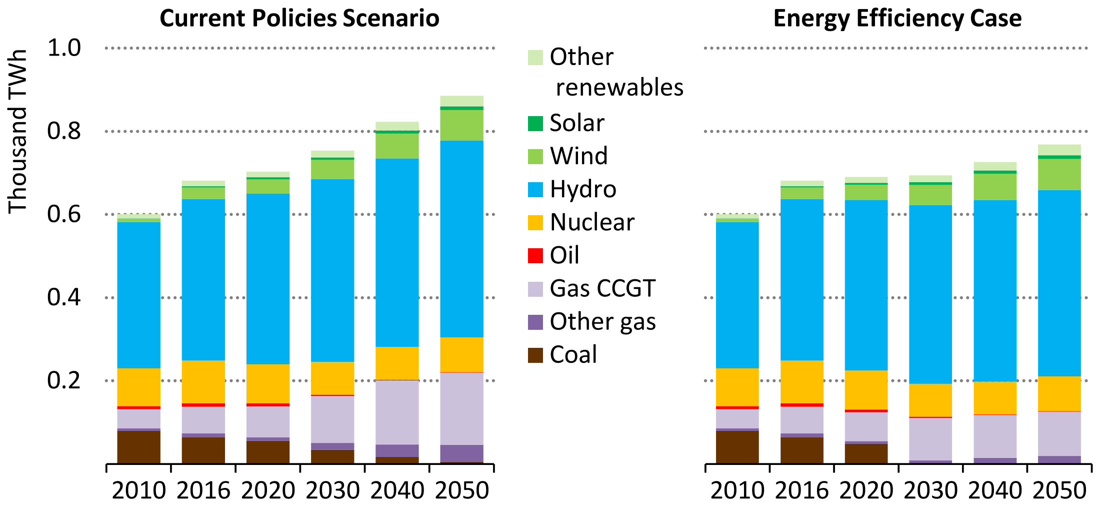
Electricity supply

In the Current Policies Scenario, the technology mix evolves as electricity supply grows to meet rising demand. Renewable energy already provides the bulk of electricity in Canada, nearly two-thirds of the total in 2016, and will continue to dominate as its share increases slightly over time. Hydropower provides more than half of total electricity generation through to 2050, and wind power contributes much of the remaining renewables-based output. Projected declines in nuclear power generation reduce its share in the mix from 15% today to about 10% by 2030 and beyond. The most striking transition in the power mix is in fossil fuels, with a strong shift away from coal and towards gas. Electricity generation from coal-fired power plants declines sharply, from 10% of electricity supply in 2016 to 5% by 2030. While the federal government announced a phase-out of traditional coal-fired electricity in support of its overall goal of 90% non-emitting electricity by 2030, this target is not fully realised by that year under the Current Policies Scenario, as the plan has not been adopted by all coal-burning provinces. In place of coal, electricity production from gas-fired power plants increases by three-quarters to 2030 and continues to rise thereafter.

Owing to greater energy efficiency in the end-use sectors, electricity generation is 117 TWh (13%) lower in 2050 in the Energy Efficiency Case than in the Current Policies Scenario (Figure 18). Slower electricity demand growth in the Energy Efficiency Case facilitates an accelerated phase-out of unabated coal-fired power plants. It also means slower growth of generation from gas-fired power plants and hydropower, as they are the dominant technologies used to meet new demand. While coal use in power generation is phased out in both scenarios (and oil use is very minor), gas consumption is around 40% (18 bcm) lower in 2050 in the Energy Efficiency Case as a result of greater energy efficiency in end-use sectors. Consequently, emissions of 1.1 gigatonnes of carbon dioxide (Gt CO_2) are avoided in the power sector from 2017 to 2050 than in the Current Policies Scenario.

Given less need for thermal power plants because of reduced electricity demand, efficient gas-fired power plants – combined-cycle gas turbine (CCGT) technology – play a diminished role in the Energy Efficiency Case. In this case, CCGTs provide only 13% of total electricity supply in 2050, compared with 18% in the Current Policies Scenario. However, CCGTs account for about three-quarters of all gas-fired generation in both scenarios, indicating virtually no additional gas savings from supply-side efficiency in power in the Energy Efficiency Case that year. Transmission and distribution losses in the power sector fall by two percentage points by 2050 in the Energy Efficiency, to about 8% of total electricity generation; at this level, network losses in Canada would remain among the highest in IEA member countries, and nearly 2 percentage points higher than current loss rate in the United States. Reduced losses would augment power system efficiency, even though it represents only a small percentage of the total reduction in fuel use between the Energy Efficiency Case and the Current Policies Scenario, while energy efficiency from end-use sectors contributes about 85%.

Figure 18 • Electricity generation by source in Canada in the Current Policies Scenario and the Energy Efficiency Case

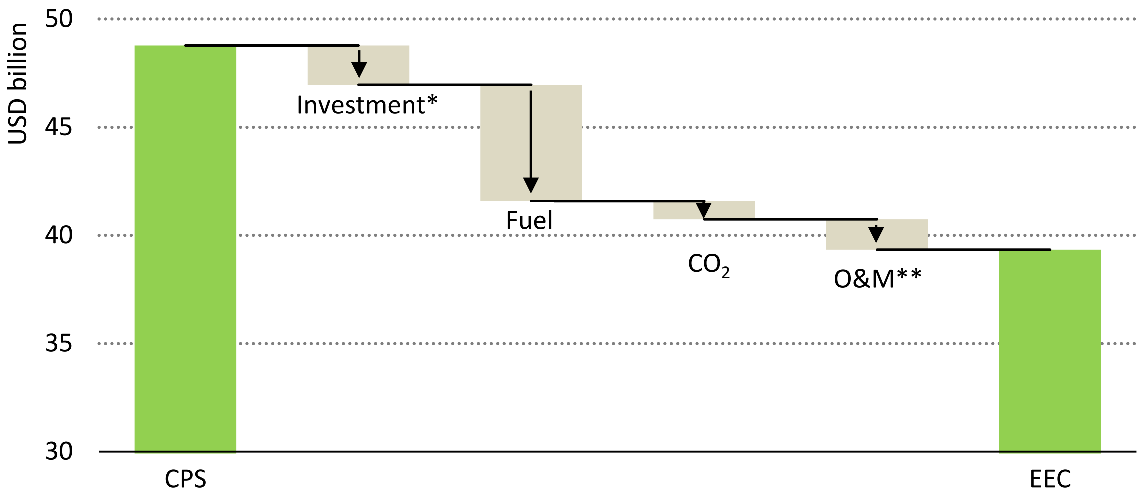


Note: CCGT = combined-cycle gas turbine.

Key message • Lower electricity generation in the Energy Efficiency Case reduces the contribution of gas in the power mix, limiting the potential for further energy efficiency savings in the sector.

Total power generation costs are estimated at just below USD 40 billion in 2050 in the Energy Efficiency Case – USD 9 billion (almost 20%) lower than in the Current Policies Scenario. The cost reduction is due mostly to fuel savings from declining gas consumption, which accounts for more than half of the cost reductions in 2050 (Figure 19). In addition, lower electricity demand means fewer new power plants need to be built, saving almost USD 2 billion in 2050 in annuity payments to recover initial capital investments made in previous years. It also means lower operation and maintenance costs along with costs associated with paying a CO_2 price save more than USD 2 billion in 2050 alone.

Figure 19 • Reduction in total power generation costs by component in the Energy Efficiency Case compared with the Current Policies Scenario for Canada, 2050



* Includes annuity payments to recover initial capital investments made in previous years.

** Includes fixed as well as variable operation and maintenance costs.

Notes: O&M = operations and maintenance. CPS = Current Policies Scenario; EEC = Energy Efficiency Case.

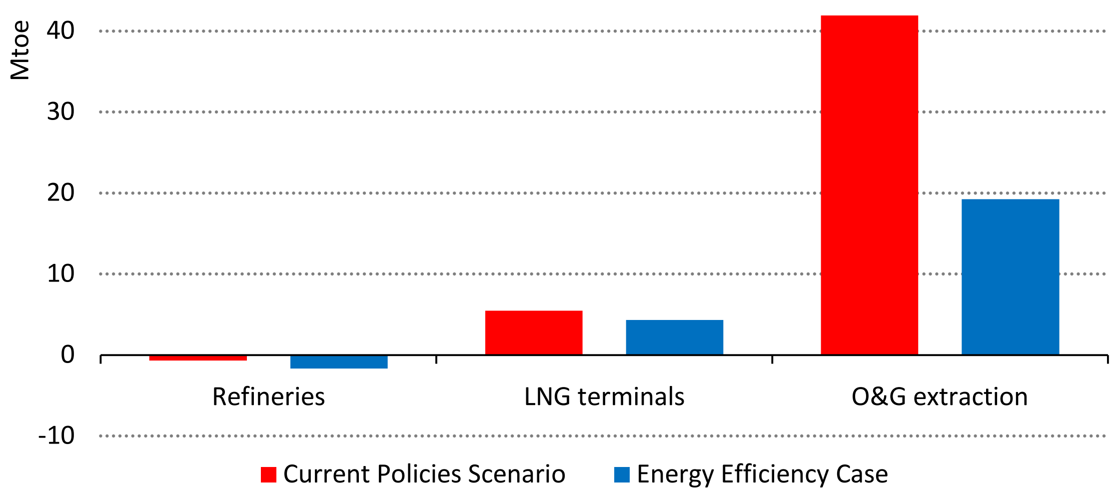
Key message • Efficiency in end-use sectors and in the power sector saves more than USD 9 billion in total generation costs in 2050, mostly through lower fuel expenditures.

Other energy industries

Upstream oil and gas activities in Canada are projected to increase dramatically by 2050 in the Current Policies Scenario, mostly in unconventional oil and gas production (e.g. in-situ bitumen production and shale gas) as conventional production declines steadily. In this scenario, unconventional oil production doubles to 2050 and unconventional gas production almost triples. Canada capitalises on its large domestic oil and gas resources by increasing production as global demand grows (global oil demand approaches 1% average growth per year, and global gas demand 2% per year by 2050). Overall oil and gas production in Canada increases at an average rate of 1.6% per year to 2050, which translates into extremely important additional volumes available on the international market. Net oil trade more than doubles by 2050, adding almost 3 million barrels per day (mb/d) to Canadian exports. LNG exports are also expected to begin in the mid-2020s, reaching about 5 bcm in 2030 before ramping up quickly to almost 70 bcm in 2050 (see later section on trade co-benefits).

Following the strong rise in upstream oil and gas activities and structural evolution towards developing unconventional resources, energy consumption within the sector soars in the Current Policies Scenario and is the main source of primary energy demand growth by 2050 (see section describing the Current Policies Scenario). Gas demand growth in the oil and gas extraction sector alone is responsible for more than one-third of total gas demand growth, even more than power sector gas demand. The realisation of energy efficiency potential in the energy supply sectors is limited in the Current Policies Scenario, making only a small dent in energy demand growth from supply-side activities.

Figure 20 • Change in own-use energy demand for selected energy supply and transformation sectors in Canada, in the Current Policies Scenario and the Energy Efficiency Case, 2016-2050



Note: O&G = oil and gas.

Key message • Enhanced energy efficiency effectively mitigates growth in own-use energy demand for oil and gas extraction in the Energy Efficiency Case, despite soaring domestic production.

In the Energy Efficiency Case, however, energy efficiency improvements in the upstream oil and gas sector lead to significant savings (Figure 20). The main source of supply-side energy savings is in this sector, with amounts approaching those of other end-use sectors such as buildings and transport. Together with other incremental actions taken in the Energy Efficiency Case, such as wider diffusion of improved steam-assisted gravity drainage (SAGD) technologies for in-situ oil and gas extraction, the use of solvent-based technologies for bitumen production from oil sands reduces the industry's own-use energy intensity almost 30% by 2050 compared with the Current

Policies Scenario (CERI, 2017).[14] The resulting 23 Mtoe of energy demand saved by 2050 from oil and gas extraction activities alone is roughly equivalent to the space heating requirements of the residential sector today. Without these savings, total primary demand would barely stabilise in the Energy Efficiency Case, even with strong energy efficiency measures in all other sectors. It must also be stressed that strong action to reduce methane emissions could relieve some pressure on – and make better use of – domestic natural gas resources. Reducing methane leaks in oil and gas operations would not, however, be reflected in TPED, as they are not reported at this level in energy statistics.

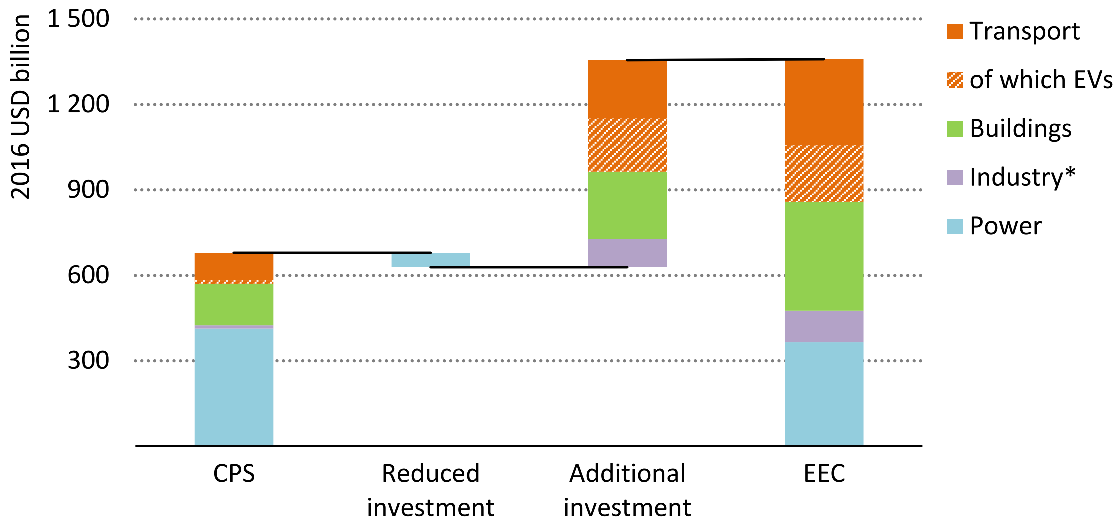
[14] A change in energy mix for oil and gas extraction is not considered in the Energy Efficiency Case, which focuses purely on energy efficiency benefits.

Part III: Implications of energy efficiency

Investments

Enhanced energy efficiency has the potential to significantly reduce Canada's energy demand: final energy demand in the Energy Efficiency Case is one-third lower than in the Current Policies Scenario and primary energy demand is about 30% lower. To achieve these levels of energy efficiency, however, additional investment is required. In the Energy Efficiency Case: the level of investment needed in the power sector and in end-use energy efficiency, including EVs, is twice that needed in the Current Policies Scenario. Over 2017-50 period, USD 680 billion is required for power sector and end-use efficiency measures under the Current Policies Scenario, with over 60% of this investment in the power sector. In contrast, the Energy Efficiency Case requires an additional investment of USD 540 billion in end-use energy efficiency and a further USD 190 billion for wider EV deployment (Figure 21).

Figure 21 • Cumulative investment in the power sector and for energy efficiency in the Current Policies Scenario and the Energy Efficiency Case, 2017-2050



* Includes investment in non-power energy supply and transformation sectors.

Note: CPS = Current Policies Scenario; EEC = Energy Efficiency Case. EVs = electric vehicles.

Key message • Additional investment is concentrated in the transport and buildings sectors, while reduced electricity demand results in lower power sector investment in the Energy Efficiency Case.

Additional energy efficiency investments are dominated by the buildings and transport sectors. The higher rate of refurbishment of existing buildings and stricter building envelope standards in the Energy Efficiency Case drive up spending on insulation (including glazing), and higher-efficiency appliances and equipment incur additional capital expenditure relative to conventional technologies. Within the transport sector, more stringent fuel economy standards engender greater investment in new vehicles, while the additional cost of switching to EVs from conventional internal combustion engine vehicles is significant. In industry, additional energy efficiency gains are achieved primarily through incremental measures and retrofits to existing facilities, rather than through major redesigns.

Electricity demand savings resulting from greater energy efficiency in end-use sectors reduce net electricity demand and therefore cut power sector investment by around USD 50 billion over the period. Although the additional Energy Efficiency Case investments are significant, they are more than offset by end-use energy expenditure savings and by other benefits to the Canadian economy, such as increased energy export revenues. The average cost of conserved energy is approximately USD 440/toe, which is usually below end-user energy prices in most sectors throughout the period. Energy efficiency is therefore a viable investment opportunity.

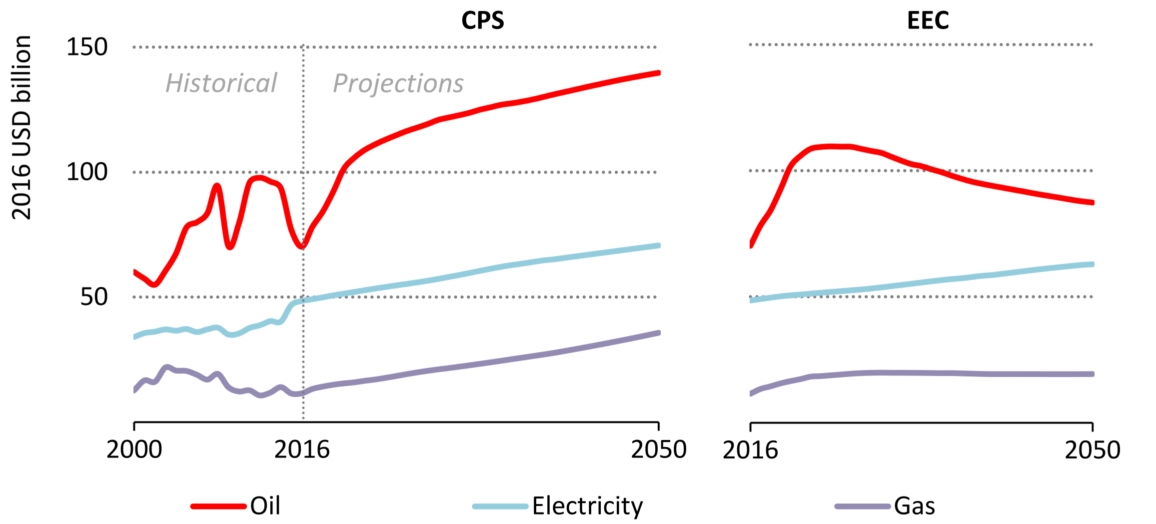
Multiple benefits of energy efficiency

Expenditures

Canadian consumers spend an estimated USD 130 billion per year on energy products, from household electricity bills to industrial gas and oil products in transport. While this expenditure has fluctuated over the past ten years, recently it has declined. As the largest single source of expenditure is oil used in transport, total expenditure trends have largely followed international oil prices.

In the Current Policies Scenario, total end-user energy expenditures for oil products, gas, coal and electricity reach around USD 250 billion in 2050. Increases in energy expenditures are driven largely by oil, oil expenditures double by 2050 to reach USD 140 billion and represent more than half of total expenditures that year as international oil prices emerge from the current low-price environment and demand recovers. The energy expenditures trajectory is markedly different in the Energy Efficiency Case, as reduced energy demand in all sectors relative to the Current Policies Scenario causes total expenditures to increase only slightly over time, reaching USD 170 billion in 2050 – almost USD 80 billion less than in the Current Policies Scenario (Figure 22).

Figure 22 • End-user energy expenditures for Canada by fuel and scenario



Note: CPS = Current Policies Scenario; EEC = Energy Efficiency Case.

Key message • Enhanced energy efficiency helps avoid dramatic increases in end-user energy expenditures, with the greatest savings in oil.

In the Energy Efficiency Case, oil expenditures also rise rapidly to 2020 as oil prices recover. From this point on, however, enhanced energy efficiency, especially in the transport sector, drives down expenditures from their peak in the 2020s to USD 52 billion lower than in the Current Policies Scenario. Growth in gas expenditures also slow considerably as the effects of energy efficiency result in savings of over USD 16 billion per year by 2050 relative to the Current Policies Scenario. Although electricity expenditures rise at a lower rate in the Energy Efficiency Case than in the Current Policies Scenario, the difference is less dramatic than for gas, as growing electrification of transport and heat energy demand offset some of the savings. Cumulatively, reduced demand in the Enhanced Efficiency Case results in savings of over USD 1.1 trillion between 2017 and 2050, equivalent to three-quarters of Canada's GDP in 2016.

Within the buildings sector, most savings result from lower electricity, gas and fuel oil bills as additional insulation and improved space heating technology cut heating energy demand in both residential and services buildings. Thanks to considerable improvements in heating energy efficiency, buildings contribute 36% of overall expenditure savings in the Energy Efficiency Case relative to the Current Policies Scenario. Within industry, oil product and electricity expenditures are reduced in the Energy Efficiency Case, saving a total of nearly USD 50 billion on both electricity and gas over 2017-50.

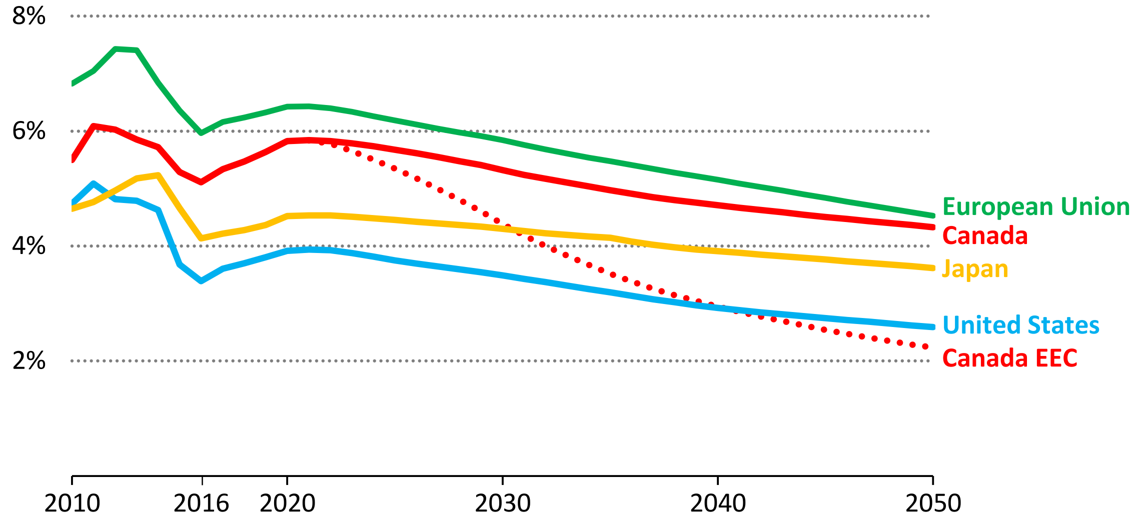
Total current Canadian end-use energy expenditure is equivalent to 8.5% of GDP, higher than in other similarly developed economies. In the Current Policies Scenario, energy expenditure increases to 10.5% of GDP in the early 2020s before declining to 9% of GDP by 2050. This is a stark contrast to the United States, where energy bills are currently equal to only 5.5% of GDP and the Current Policies Scenario projects this value to fall to about 5% by 2050. The same is true for other Organisation for Economic Co-operation and Development (OECD) countries, with average energy expenditure as a percentage of GDP falling from 7.1% today to 6.4% in 2050 in the Current Policies Scenario. Reduced energy demand in Canada in the Energy Efficiency Case would cause energy expenditure to fall to below 6% of GDP in 2050, in line with the OECD average.

Energy poverty

Energy poverty is most often measured in terms of share of household income spent on energy; reducing household energy bills therefore benefits households suffering from energy poverty more than it does others. In Canada, a household may be described as experiencing energy poverty when more than 10% of households income is spent on energy (NEB, 2017; Green et al., 2016), although 6% has also been used as a threshold (Rezaei, 2017). Using a guideline of 10% and including only home energy expenditures, Canada's National Energy Board (NEB) estimates 8% of households to be in a situation of energy poverty based on 2015 household spending data (when 2011 data and a benchmark of 6% are used, the share rises to 21% [Rezaei, 2017]). If passenger car fuel bills are included in household energy expenditures, the number of households in energy poverty more than doubles according to work by the Fraser Institute (Green et al., 2016). There is strong justification for including fuel expenses, as about four out of five working Canadians commute to work in a privately owned motor vehicle (Statistics Canada, 2011).

While energy poverty is not always confined to low-income households, it disproportionately affects them, with 16% to 42% of low-income households estimated to be in this class (Rezaei, 2017; Green et al., 2016). Given the inverse correlation between income and energy poverty (and its consequences), energy efficiency policies should aim to ensure that financing is not a barrier to energy efficiency retrofits and the installation of more efficient heating equipment. Spending a large portion of disposable income on energy often results in households lowering their comfort standards to reduce energy bills or in being cut off from electricity or gas services entirely when they fail to pay bills. This often leads to increased incidence of respiratory problems and mental stress, with health risks most pronounced for children and the elderly. Given the cold climate, the consequences of energy poverty may be especially acute for some Canadian households. Improvements in the energy efficiency of the housing stock and the passenger car fleet in the Energy Efficiency Case allow households to meet energy service demands at a lower cost, reducing the incidence of energy poverty (and the likelihood of energy services being cut off).

Figure 23 • Energy expenditure as percentage of total household income in selected regions in the Current Policies Scenario and the Energy Efficiency Case for Canada



Notes: EEC = Energy Efficiency Case. Household energy expenditure includes both home energy bills and passenger vehicle fuel expenditures. All trajectories except Canada EEC are for the Current Policies Scenario.

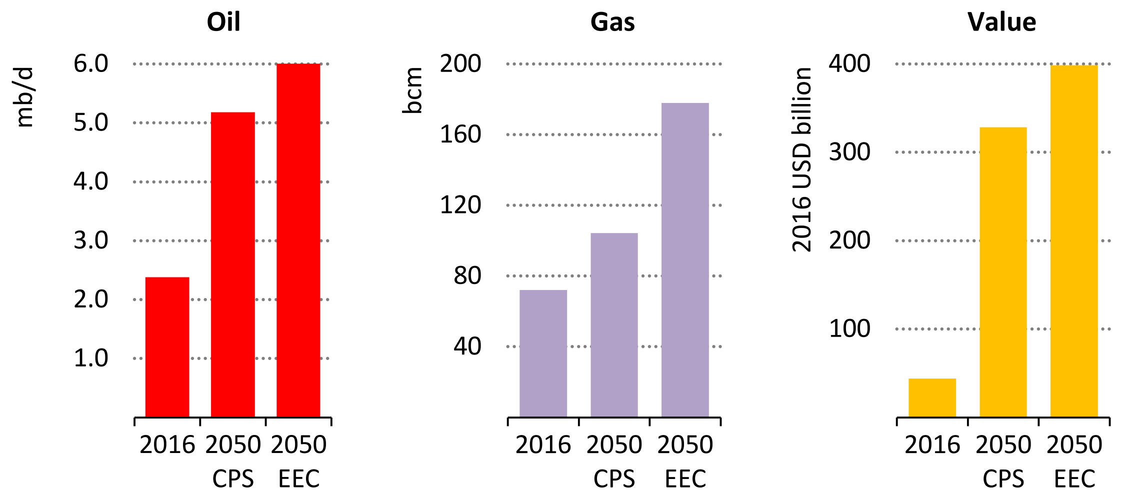
Key message • Enhanced energy efficiency allows Canadian households to reduce the share of income used for energy expenditures to below that of US households, despite higher heating requirements.

Improved energy efficiency of residential buildings and light-duty vehicles in the Energy Efficiency Case significantly impacts household energy consumption and, as a result, household energy bills (Figure 23). Total household expenditure on energy products falls from 5.1% of gross household income today to only 2.2% in 2050, a decline that is largely attributable to lower spending on oil products for passenger cars. In contrast, weaker improvements in passenger car energy efficiency in the Current Policies Scenario cause the share of energy expenditure in household income to stay relatively flat to 2050. The average share of household income spent on energy in Canada is much higher than in the United States, where it is 3.4% including passenger car fuel expenses and 1.7% without. In the Current Policies Scenario, the US share of energy expenditure in household income is expected to decline further to 2.6% in 2050 (1.3% without transportation fuel costs). In Canada in the Energy Efficiency Case, when only energy used in residential buildings is considered, energy expenditure falls from 2.6% of gross national income today to 1.5% in 2050. This is a much stronger improvement than the small decrease to 2.3% in the Current Policies Scenario. Reducing the average cost of household bills directly impacts the number of Canadians in energy poverty: increased investment in insulation in buildings, for example, and more efficient space heating equipment could drastically reduce household energy consumption for heating, and greater passenger car efficiency would reduce private transport expenditures drastically in the Energy Efficiency Case relative to the Current Policies Scenario. Lower household bills will, of course, be the result of structural changes in household spending on energy: greater energy efficiency requires higher upfront investments in more efficient equipment and retrofits, with a potential impact on house prices, and operational costs such as battery leasing for EVs must be planned for. These investments would reduce variable running costs in the long run.

Trade

International energy trade is a cornerstone of the Canadian economy, as the country is one of the world's largest net exporters of energy. In 2016, net fossil fuel exports were valued at USD 44 billion and went mostly to the United States (Figure 24). In the Current Policies Scenario, the strong increase in oil and gas production (output for both being more than two-thirds higher in 2050 than today) and the recovery of international energy prices clearly lead to a better trade balance. Oil is the main factor in this positive trend: the oil price almost quadruples from 2016 to reach USD 154/bbl in 2050, and net oil exports more than double. Gas accounts for only 10% of the increase in trade value in the Current Policies Scenario, though its price more than triples and net exports increase by 45%. Coal also makes a marginal contribution.

Figure 24 • Net trade balance of oil and gas in volume and value terms for Canada



Note: CPS = Current Policies Scenario; EEC = Energy Efficiency Case.

Key message • Energy efficiency co-benefits in terms of physical trade are higher for gas than for oil, but in value terms the increase in oil exports in the Energy Efficiency Case has a larger impact.

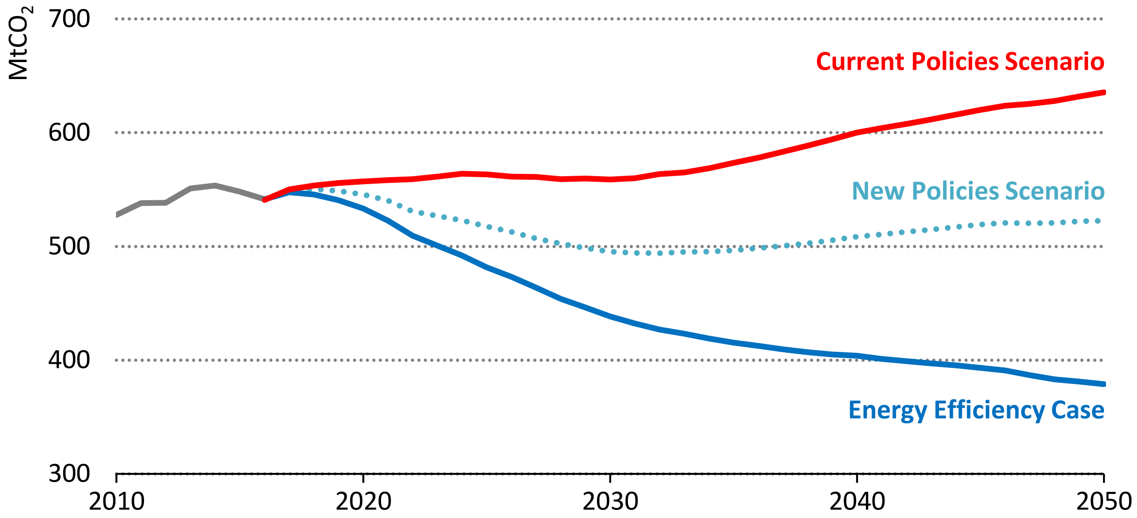
The energy trade surplus in 2050 under the Current Policies Scenario exceeds current total Canadian federal budget expenditures. As oil and gas production to 2050 is similar in both the Energy Efficiency Case and the Current Policies Scenario, the additional energy efficiency realised in the Energy Efficiency Case would further improve Canada's trade balance. In the Energy Efficiency Case, 0.8 mb/d more oil is exported in 2050 than under the Current Policies Scenario, and more than 70 bcm more gas is exported. The result is additional cumulative fossil fuel trade revenues of more than USD 1 000 billion over the period.

CO_2 emissions

Under the existing policy framework in the Current Policies Scenario, CO_2 emissions continue to increase slowly through 2030 and then accelerate to 2050 as increased activity in several sectors overtakes efficiency gains. In the Energy Efficiency Case, however, total annual energy-related CO_2 emissions decline through 2050, although the pace is slower after 2030 (Figure 25). In contrast, the New Policies Scenario, which captures only some of the energy efficiency potential of the Energy Efficiency Case, indicates declining CO_2 emissions through 2030, albeit at a slower rate than in the Energy Efficiency Case, followed by a rebound in the decades after. This demonstrates the diminishing returns of the policy framework in the longer term, as increased activity eventually overtakes the emissions savings that result from the short- to medium-term climate and energy policies adopted in the New Policies Scenario.

Cumulatively, CO_2 emissions in the Energy Efficiency Case are 4.8 Gt CO_2 lower than in the Current Policies Scenario over the outlook period, roughly equivalent to the total annual CO_2 emissions of the United States today. Energy efficiency therefore proves a powerful tool for decarbonisation: even in the absence of additional targeted climate policies, annual energy-related CO_2 emissions fall. This is a notable achievement, particularly considering the strong growth in oil and gas output; however, the Energy Efficiency Case on its own is not sufficient to achieve Canada's 2030 Nationally Determined Contribution (NDC) for total GHG emissions. Furthermore, a continued decline in emissions beyond 2050 is not guaranteed, as enhanced energy efficiency policies alone would not trigger the significant transformative changes to the economy necessary for a low-carbon transition in the longer term. Reinforcing specific climate-focused policies compared with what is already included in the Energy Efficiency Case, such as raising the carbon price in the medium and longer term, strengthening mandates and regulations to support low-carbon fuels, and introducing incentives to reduce emissions from non-combustion sources, could mitigate even more GHG emissions.

Figure 25 • CO_2 emissions in Canada from fuel combustion by scenario

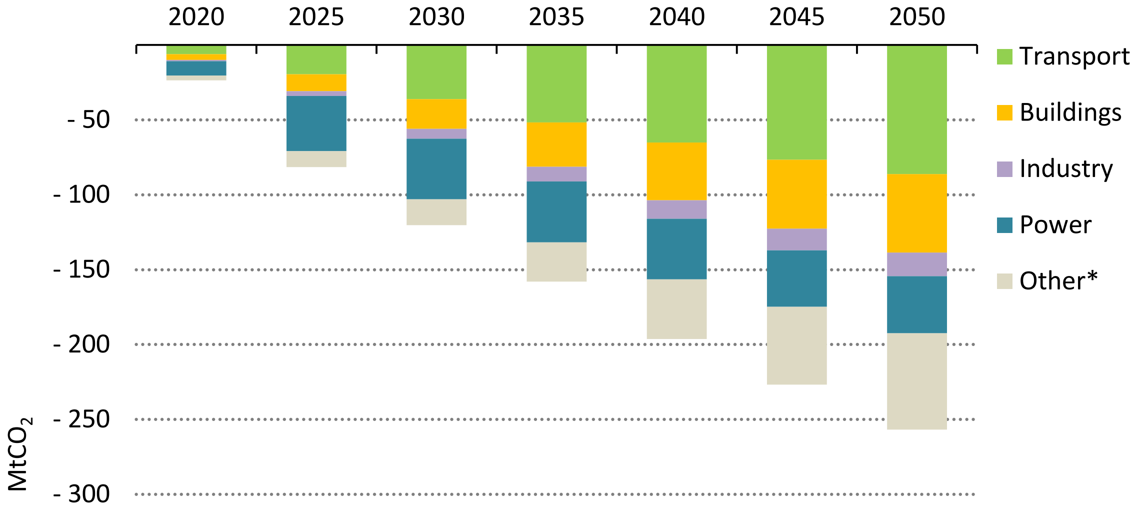


Key message • Enhanced energy efficiency enables a sharp decline in CO_2 emissions by 2030 and a steady decrease after 2030, avoiding the rebound demonstrated in the other reference scenarios.

The transport sector is currently Canada's largest CO_2 emitter, and in the Energy Efficiency Case it contributes the greatest CO_2 emissions reductions of any sector by far, with 1.5 Gt CO_2 avoided cumulatively through 2050, or one-third of total reductions (Figure 26). In the Energy Efficiency Case, transport sector CO_2 emissions decline for all modes except domestic aviation. In this case, energy efficiency gains are offset by rising air mobility demand of almost 3% per year. Road transport emissions, which accounted for around 80% of transport emissions in 2016, peak around 2020 in both scenarios, however, they decline more rapidly to 2050 in the Energy Efficiency Case, to less than half the level of the Current Policies Scenario.

The buildings sector delivers one-fifth of cumulative avoided CO_2 emissions in the Energy Efficiency Case, with annual emissions declining steadily to 60% lower than today by 2050. The greatest emissions reductions are linked to space heating, as higher efficiency often requires households to switch away from oil- and even gas-based heating towards high-efficiency, electricity-based technologies, amplifying CO_2 emissions savings at the sectoral level.

Figure 26 • Change in Canada's direct CO_2 emissions by sector in the Energy Efficiency Case relative to the Current Policies Scenario



* Non-power energy supply and transformation sectors, and agriculture.

Key message • The power sector contributes the greatest CO_2 emissions abatement in the short term in the Energy Efficiency Case, while transport plays a more important role in the long term.

CO_2 emissions from the power sector have been in decline since around 2000 with generation shifting away from coal and towards gas and renewables. This trend accelerates in the Energy Efficiency Case in the medium term, causing the power sector's share of CO_2 emissions to drop from around 20% today to 10% in 2030. Emissions rebound slightly towards the end of the outlook period as demand grows and the margin for additional fuel switching becomes narrower.

Aggressive energy efficiency deployment in the supply and industry sectors is responsible for more than 20% of the cumulative CO_2 emissions reduction in the Energy Efficiency Case. Oil and gas extraction emissions in 2050 are 54 Mt CO_2 lower in the Energy Efficiency Case than in the Current Policies Scenario, and account for the bulk of emissions reductions from wider industrial activities. The manufacturing industry accounts for 6% of cumulative savings over the period, mostly in non-energy-intensive industries. Annual CO_2 emissions from manufacturing industries decline by more than 20% from today to 2050 in the Energy Efficiency Case.

Conclusion

Comparison of the Current Policies Scenario with the Energy Efficiency Case has demonstrated that Canada's economically viable energy efficiency potential could reduce its energy demand by around 100 Mtoe by 2050, or by more than one-third its 2016 TPED.

We acknowledge that other factors not considered in this outlook could increase the projected energy efficiency potential: for example, this analysis does not fully take into account the impact of digitalisation and other breakthrough technologies in improving energy efficiency. Other factors that fall beyond the scope of the Energy Efficiency Case, such as the positive influence of changes in consumer behaviour or structural changes in the economy triggered by new policies and technologies, are excluded. For example, for the buildings sector it excludes densification of urban areas, further decentralisation of renewable energy production, and reduced per capita floor space requirements from better layout design. In the transport sector it excludes demand management strategies (e.g. carpooling, car-sharing, teleworking), the impact of autonomous driving and intermodal shift beyond what is considered in the Current Policies Scenario. In the industry sector, switching to higher-value light industry further than what is covered in the Current Policies Scenario has been excluded. There are also risks, however, that realising the potential identified in this analysis may be limited by the failure to address barriers to adopting efficient technologies, processes and organisations. Timely implementation of new and strengthened policies targeting all sectors and addressing the threat posed by rebound effects is therefore needed, and policies must be supported by effective monitoring and be reinforced over time.

While the approach adopted in this study is subject to limitations, this outlook's primary contribution is to identify the parts of the energy system in which timely, effective and strong energy efficiency policies can reduce energy consumption. Secondary benefits for Canadians include lower CO_2 emissions, increased trade value, a decline in household energy expenditures and lower energy poverty levels. While this analysis remains neutral regarding Canada's policy choices, the evidence strongly suggests most effort should be directed towards the sectors with the greatest potential for energy savings: buildings, transport, and industry, including extractive industries.

Annexes

Annex A.1 • Canadian energy demand: Current Policies Scenario

	Energy demand (Mtoe)							Shares (%)		CAAGR (%)
	2000	2015	2016e	2025	2030	2040	2050	2016e	2050	2016e-50
TPED	**257**	**276**	**274**	**296**	**305**	**340**	**364**	**100**	**100**	**0.8**
Coal	32	19	18	15	10	6	4	7	1	-4.6
Oil	87	94	95	102	101	102	103	35	28	0.2
Gas	74	87	85	103	114	147	166	31	46	2.0
Nuclear	19	26	27	21	21	21	22	10	6	-0.6
Hydro	31	33	33	37	38	39	41	12	11	0.6
Bioenergy	14	14	14	16	16	18	21	5	6	1.3
Other renewables	0	3	3	4	5	7	8	1	2	3.4
Power generation	**89**	**97**	**99**	**96**	**98**	**105**	**113**	**100**	**100**	**0.4**
Coal	27	16	15	12	8	4	1	15	1	-7.7
Oil	3	2	2	1	1	0	0	2	0	-5.0
Gas	7	15	16	18	23	31	35	16	31	2.4
Nuclear	19	26	27	21	21	21	22	27	19	-0.6
Hydro	31	33	33	37	38	39	41	34	36	0.6
Bioenergy	2	3	3	4	4	5	6	3	5	1.6
Other renewables	0	3	3	4	5	6	8	3	7	3.2
Other energy sector	**26**	**38**	**37**	**55**	**63**	**90**	**104**	**100**	**100**	**3.1**
Electricity	*8*	*9*	*10*	*10*	*10*	*12*	*13*	26	12	*0.9*
TFC	**192**	**193**	**193**	**203**	**205**	**212**	**220**	**100**	**100**	**0.4**
Coal	4	3	2	2	2	2	2	1	1	-0.3
Oil	80	89	90	90	88	84	83	46	38	-0.2
Gas	53	47	45	50	52	56	59	23	27	0.8
Electricity	41	43	44	47	49	54	58	23	27	0.8
Heat	1	1	1	1	1	1	1	0	0	0.6
Bioenergy	12	11	11	12	12	14	16	6	7	1.1
Other renewables	-	0	0	0	0	0	0	0	0	7.3
Industry	**56**	**45**	**44**	**48**	**48**	**49**	**50**	**100**	**100**	**0.4**
Coal	3	2	2	2	2	2	2	5	4	-0.3
Oil	7	7	7	6	6	5	5	15	10	-1.0
Gas	19	15	14	16	17	17	18	32	35	0.7
Electricity	17	14	15	16	16	16	16	33	33	0.3
Heat	1	1	1	1	1	1	1	1	1	0.2
Bioenergy	8	6	6	6	7	8	9	13	17	1.1
Other renewables	-	-	-	0	0	0	0	-	0	n.a.
Transport	**52**	**61**	**61**	**62**	**60**	**59**	**61**	**100**	**100**	**-0.0**
Oil	47	56	56	56	53	50	50	91	83	-0.3
Electricity	0	0	0	0	1	1	1	1	2	3.4
Biofuels	0	2	2	2	2	2	2	3	3	-0.2
Other fuels	5	4	3	4	5	6	8	6	12	2.4
Buildings	**60**	**62**	**61**	**64**	**67**	**72**	**77**	**100**	**100**	**0.7**
Coal	0	0	0	0	0	0	0	0	0	-4.5
Oil	9	6	6	5	5	4	4	9	5	-1.0
Gas	25	26	24	26	27	28	29	40	38	0.5
Electricity	23	27	28	30	31	35	38	46	50	0.9
Heat	0	0	0	0	0	0	0	0	0	3.5
Bioenergy	4	3	3	3	4	4	5	5	6	1.3
Traditional biomass	-	-	-	-	-	-	-	-	-	*n.a.*
Other renewables	-	0	0	0	0	0	0	0	0	5.0
Other	**24**	**25**	**25**	**29**	**30**	**31**	**32**	**100**	**100**	**0.7**
Petrochemical feedstock	*13*	*11*	*11*	*13*	*14*	*14*	*14*	*18*	*18*	*0.7*

Notes: CAAGR = compound average annual growth rate. Data marked as 2016e are estimates derived from IEA analysis in 2017.

Annex A.2 • Canadian energy demand: New Policies Scenario and Energy Efficiency Case

	Energy demand (Mtoe)						Shares (%)		CAAGR (%)	
	2030	2040	2050	2030	2040	2050	2050		2016e-2050	
	New Policies Scenario			Energy Efficiency Case			NPS	EEC	NPS	EEC
TPED	**286**	**307**	**321**	**261**	**262**	**258**	**100**	**100**	**0.5**	**-0.2**
Coal	3	3	3	3	2	2	1	1	-5.5	-6.0
Oil	93	88	84	84	72	64	26	25	-0.4	-1.2
Gas	110	131	141	96	106	106	44	41	1.5	0.7
Nuclear	21	21	22	21	21	22	7	8	-0.6	-0.6
Hydro	38	38	39	37	38	39	12	15	0.4	0.4
Bioenergy	18	20	23	16	16	17	7	7	1.5	0.6
Other renewables	5	7	9	5	7	9	3	3	3.7	3.5
Power generation	**91**	**99**	**106**	**85**	**89**	**95**	**100**	**100**	**0.2**	**-0.1**
Coal	0	0	0	0	0	0	0	0	-12.1	-
Oil	1	0	0	1	0	0	0	0	-4.9	-5.5
Gas	23	28	31	18	20	21	29	22	2.0	0.8
Nuclear	21	21	22	21	21	22	21	23	-0.6	-0.6
Hydro	38	38	39	37	38	39	37	41	0.4	0.4
Bioenergy	4	5	6	4	5	6	5	6	1.6	1.6
Other renewables	5	7	8	5	7	8	8	8	3.5	3.3
Other energy sector	**57**	**74**	**80**	**55**	**72**	**77**	**100**	**100**	**2.3**	**2.1**
Electricity	*10*	*11*	*11*	*9*	*9*	*10*	*14*	*13*	*0.5*	*0.0*
TFC	**197**	**198**	**203**	**177**	**158**	**148**	**100**	**100**	**0.1**	**-0.8**
Coal	2	2	2	2	2	2	1	1	-0.5	-1.0
Oil	82	74	71	73	59	51	35	35	-0.7	-1.6
Gas	51	53	55	43	37	31	27	21	0.6	-1.1
Electricity	48	52	56	46	48	51	28	35	0.7	0.4
Heat	1	1	1	1	1	1	0	0	0.4	0.1
Bioenergy	14	16	18	12	12	12	9	8	1.5	0.2
Other renewables	0	1	1	0	0	1	0	0	9.0	7.7
Industry	**47**	**47**	**48**	**43**	**39**	**38**	**100**	**100**	**0.2**	**-0.5**
Coal	2	2	2	2	2	1	4	4	-0.5	-1.1
Oil	6	5	5	5	4	3	10	9	-1.1	-2.1
Gas	17	17	17	15	14	13	35	35	0.5	-0.3
Electricity	16	16	16	14	13	13	33	36	0.2	-0.3
Heat	1	1	1	1	1	1	1	1	0.0	-0.5
Bioenergy	7	7	8	6	6	6	16	15	0.9	-0.0
Other renewables	0	0	0	0	0	0	1	0	n.a.	n.a.
Transport	**57**	**53**	**53**	**50**	**40**	**35**	**100**	**100**	**-0.4**	**-1.7**
Oil	48	42	40	42	31	25	76	73	-1.0	-2.3
Electricity	1	1	2	2	4	5	4	15	4.4	7.4
Biofuels	3	4	4	2	2	2	7	6	2.3	0.3
Other fuels	5	6	7	3	3	2	13	7	2.1	-1.1
Buildings	**64**	**68**	**71**	**55**	**50**	**47**	**100**	**100**	**0.4**	**-0.8**
Coal	0	0	0	0	-	-	0	-	-7.3	-
Oil	4	3	2	3	1	0	3	0	-2.4	-9.6
Gas	25	26	26	21	16	12	37	25	0.2	-2.1
Electricity	30	33	36	28	30	31	51	66	0.7	0.3
Heat	0	0	0	0	0	0	0	0	3.4	3.9
Bioenergy	4	5	5	3	3	3	7	7	1.6	0.3
Traditional biomass	-	-	-	-	-	-	-	-	*n.a.*	*n.a.*
Other renewables	0	0	1	0	0	0	1	1	7.6	6.3
Other	**29**	**30**	**31**	**28**	**29**	**29**	**100**	**100**	**0.6**	**0.4**
Petrochem.	*14*	*14*	*14*	*14*	*14*	*14*	*20*	*30*	*0.7*	*0.7*

Annex A.3 • Canadian gross electricity generation, electrical capacity and CO_2 emissions from fossil fuel combustion: Current Policies Scenario

	Electricity generation (TWh)							Shares (%)		CAAGR (%)
	2000	2015	2016e	2025	2030	2040	2050	2016e	2050	2016e-2050
Total generation	**606**	**665**	**681**	**727**	**754**	**823**	**886**	**100**	**100**	**0.8**
Coal	118	66	65	53	34	17	5	10	1	-7.3
Oil	15	8	8	4	3	1	2	1	0	-4.9
Gas	33	67	73	101	130	184	215	11	24	3.2
Nuclear	73	101	102	79	79	79	84	15	9	-0.6
Renewables	367	423	433	491	508	542	581	64	66	0.9
Hydro	359	381	389	429	439	454	474	57	53	0.6
Bioenergy	8	13	13	15	16	17	21	2	2	1.3
Wind	0	26	27	41	46	60	73	4	8	3.0
Solar PV	0	3	3	6	6	7	9	0	1	3.0
Marine	0	0	0	0	1	3	4	0	1	18.7

	Electrical capacity (GW)						Shares (%)		CAAGR (%)
	2015	2016	2025	2030	2040	2050	2016	2050	2016-2050
Total capacity	**146**	**147**	**163**	**169**	**185**	**202**	**100**	**100**	**0.9**
Coal	9	9	9	6	4	3	6	1	-3.7
Oil	5	5	3	3	2	2	4	1	-2.9
Gas	21	21	31	38	51	60	14	30	3.2
Nuclear	14	14	11	11	11	11	10	6	-0.7
Renewables	96	97	108	111	117	126	66	62	0.8
Hydro	79	80	83	84	86	90	54	44	0.4
Bioenergy	3	3	4	4	4	4	2	2	0.7
Wind	11	12	17	18	20	24	8	12	2.1
Solar PV	3	3	5	5	6	7	2	3	2.8
Marine	0	0	0	0	1	1	0	1	13.0

	CO_2 emissions (Mt)							Shares (%)		CAAGR (%)
	2000	2015	2016e	2025	2030	2040	2050	2016e	2050	2016e-2050
Total CO_2	**516**	**548**	**541**	**563**	**559**	**600**	**636**	**100**	**100**	**0.5**
Coal	126	74	72	58	41	23	13	13	2	-5.0
Oil	227	262	263	267	259	254	258	49	41	-0.0
Gas	163	212	206	238	260	323	365	38	57	1.7
Power	**135**	**103**	**105**	**93**	**85**	**87**	**87**	**100**	**100**	**-0.5**
Coal	109	62	61	47	30	14	3	58	4	-8.2
Oil	9	6	7	3	2	1	1	6	1	-5.0
Gas	17	34	37	42	53	73	83	35	95	2.4
TFC	**327**	**328**	**322**	**330**	**325**	**322**	**326**	**100**	**100**	**0.0**
Coal	17	12	11	11	11	10	9	3	3	-0.4
Oil	194	212	212	210	201	190	187	66	57	-0.4
Transport	*139*	*165*	*166*	*166*	*159*	*150*	*150*	*52*	*46*	*-0.3*
Gas	116	104	99	109	114	122	130	31	40	0.8

Annex A.4 • Canadian gross electricity generation, electrical capacity and CO_2 emissions from fossil fuel combustion: New Policies Scenario and Energy Efficiency Case

	Electricity generation (TWh)						Shares (%)		CAAGR (%)	
	2030	2040	2050	2030	2040	2050	2050		2016e-2050	
	New Policies Scenario			Energy Efficiency Case			NPS	EEC	NPS	EEC
Total generation	**733**	**787**	**839**	**694**	**726**	**768**	**100**	**10**	**0.6**	**0.4**
Coal	1	1	1	1	1	1	0	0	-12.0	-
Oil	3	2	2	3	1	1	0	0	-4.8	-5.3
Gas	141	170	187	110	117	125	22	16	2.8	1.6
Nuclear	79	79	84	79	79	84	10	11	-0.6	-0.6
Renewables	509	536	566	501	528	558	67	73	0.8	0.7
Hydro	437	444	452	430	436	449	54	58	0.4	0.4
Bioenergy	16	17	21	16	17	21	2	3	1.3	1.3
Wind	49	64	79	49	64	74	9	10	3.2	3.0
Solar PV	6	8	9	6	8	9	1	1	3.2	3.0
Marine	1	3	5	1	3	5	1	1	18.8	18.8

	Electrical capacity (GW)						Shares (%)		CAAGR (%)	
	2030	2040	2050	2030	2040	2050	2050		2016-2050	
	New Policies Scenario			Energy Efficiency Case			NPS	EEC	NPS	EEC
Total capacity	**170**	**186**	**202**	**163**	**175**	**188**	**100**	**10**	**0.9**	**0.7**
Coal	1	0	0	1	0	0	0	0	-12.0	-
Oil	3	2	2	3	2	2	1	1	-2.7	-3.3
Gas	43	57	64	38	47	53	32	28	3.4	2.8
Nuclear	11	11	11	11	11	11	6	6	-0.7	-0.7
Renewables	111	117	124	110	115	122	62	65	0.7	0.7
Hydro	83	84	86	82	83	85	42	45	0.2	0.2
Bioenergy	4	4	4	4	4	4	2	2	0.7	0.7
Wind	19	21	26	19	21	24	13	13	2.3	2.1
Solar PV	5	6	7	5	6	7	4	4	2.9	2.7
Marine	0	1	1	0	1	1	1	1	13.0	13.0

	CO_2 emissions (Mt)						Shares (%)		CAAGR (%)	
	2030	2040	2050	2030	2040	2050	2050		2016e-2050	
	New Policies Scenario			Energy Efficiency Case			NPS	EEC	NPS	EEC
Total CO_2	**495**	**509**	**523**	**438**	**404**	**379**	**100**	**10**	**-0.1**	**-1.0**
Coal	11	9	9	10	8	7	2	2	-6.1	-6.6
Oil	235	212	203	211	168	146	39	38	-0.8	-1.7
Gas	249	287	311	218	228	226	59	60	1.2	0.3
Power generation	**56**	**68**	**74**	**44**	**47**	**49**	**100**	**10**	**-1.0**	**-2.2**
Coal	0	0	0	0	0	0	0	0	-17.8	-
Oil	2	1	1	2	1	1	2	2	-4.9	-5.5
Gas	54	66	73	42	46	48	98	98	2.0	0.8
TFC	**303**	**284**	**278**	**260**	**202**	**165**	**100**	**10**	**-0.4**	**-1.9**
Coal	11	9	9	10	8	7	3	4	-0.7	-1.3
Oil	183	159	149	158	116	93	54	56	-1.0	-2.4
Transport	*144*	*126*	*120*	*126*	*93*	*76*	*43*	*46*	*-1.0*	*-2.3*
Gas	110	115	120	93	78	65	43	39	0.6	-1.2

Annex B.1 • Selected policy assumptions in the Current Policies Scenario* by main sector

Sector	Assumption
Cross-cutting	● CO_2 price rises slowly to around USD 40/tCO_2 by 2050 (i.e. below the price set out in the Pan-Canadian Framework for 2022). ● Energy Innovators Initiative (EII) provides products and services to help organisations plan, finance and implement comprehensive energy efficiency improvements. ● Accelerated Capital Cost Allowance (CCA) allows investors up to 50% accelerated write-off of certain efficient or renewables-based energy supply equipment. ● At provincial level, initiatives target climate change, for example the Nova Scotia Greenhouse Gas Emissions Regulation to reduce GHG emissions by 24% by 2020 compared with 1990.
Buildings	● National Energy Code for Buildings 2015 (the model code) is adopted (or adapted and adopted) by provinces and territories as of mid-2017. ● MEPS established in 47 product categories, including major household appliances, home electronics, water heaters, heating and air conditioning equipment, etc. ● ENERGY STAR labelling programme certifies that products meet strict technical specifications for energy performance. Voluntary building energy performance labelling programmes are adopted, such as ENERGY STAR for homes, EnerGuide and R2000. ● Provincial schemes support renewable heat or heat pump deployment (e.g. rebates and tax refunds in British Columbia, Chauffez Vert programme in Quebec, grants in Prince Edward Island and Northwest Territories).
Industry	● Canadian Industry Program for Energy Conservation promotes voluntary action and peer-to-peer support to reduce industrial energy intensity. ● Energy Efficiency for Industry programme funds process integration and up to 50% of costs for energy management projects, including implementation of ISO 50001. ● Industrial energy management voluntary standards set minimum energy performance requirements and certify energy efficiency. ● Provincial grants and incentives support use of renewable heat (Northwest Territories, Programmes de biomasse forestière résiduelle and ÉcoPerformance in Quebec, etc.). ● Industrial Conservation Initiative (ICI) in Ontario imposes a capacity charge on large consumers, based on their annual consumption during peak demand hours instead of overall consumption.
Transport	● Passenger Automobile and Light Truck Greenhouse Gas Emission Regulations are imposed: for passenger cars, average footprint curve improvement of 5% per year until model year (MY) 2025; for light-duty trucks, average improvement of 3.5% until MY 2021 and 5% improvement until MY 2025. ● Heavy-Duty Vehicle and Engine Greenhouse Gas Emission Regulations are imposed: GHG emissions from 2018 MY heavy-duty vehicles to be reduced by up to 23%, and new regulations build on these reductions for post-2018 MY heavy-duty vehicles. ● Electric Vehicle and Alternative Fuel Infrastructure Deployment Initiative enables adoption of energy-efficient EVs. ● Voluntary agreements and action plans to improve train and aviation energy efficiency. ● Federal government support for fuel switching in the rail, aviation, marine and off-road sectors; investment in public-transit upgrades and expansions and in more efficient trade and transportation corridors, including transportation hubs and ports.
Power	● Reduction of CO_2 emissions from coal-fired electricity generation, by setting emissions performance standard of 420 tCO_2/GWh for new coal-fired electricity generation units and units that have reached the end of their useful life. ● Phase-out of all unabated coal-fired power plants by 2030 in New Brunswick and Alberta. ● Quebec to increase overall renewable energy production by 25% by 2030.

* The Current Policies Scenario does not include implementation of the Pan-Canadian Framework on Clean Growth and Climate Change.

Annex B.2 • Selected assumptions in the Energy Efficiency Case by main sector

Sector	Assumption
Cross-cutting	● Introduction of a CO_2 price consistent with the Pan-Canadian Framework by 2022 (CAD 50/tCO_2), then increasing only marginally to 2050.
Buildings	● Adoption of a “net zero energy ready” model building code by 2030 and near 100% compliance of new buildings by 2050. ● Adoption of an increasingly stringent model code for existing buildings beginning in 2022. ● MEPS cover all major appliances and equipment by 2025 and are further enhanced to 2050. ● Building energy management systems installed in all new constructions from 2020. ● Electrification of space and water heating where appropriate.
Industry	● All new equipment efficiency levels match best available technology by 2030. ● Process change and recycling routes further developed when applicable in heavy industry. ● Implementation of process control and energy management systems. ● Adoption of the highest energy efficiency standards for electric motor systems by 2025 and greater adoption of VSDs. ● Electrification of low-temperature heat demand in the chemicals, paper and small industry sectors.
Transport	● Stringent fuel economy standards for both light- and heavy-duty vehicles and adjusted fuel tax to curb rebound effect. ● Incentives for hybrid and electric vehicle adoption. ● Distance pricing for road freight to improve logistics (higher load factors and greater use of heavy-duty trucks for long distances). ● Respect of the most ambitious international efficiency targets for aviation, rail and shipping.
Power	● Enhanced use of highly efficient gas-fired power plants. ● Complete phase-out of traditional coal-fired power by 2030. ● Network infrastructure upgraded to reduce losses.
Other energy supply	● Equipment efficiency in supply sectors matches best available technology by 2030 (oil and gas extraction, refineries and LNG terminals). ● Use of solvent-based technologies in unconventional oil production.

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Acronyms and abbreviations

CCGT	combined-cycle gas turbine
CO_2	carbon dioxide
EEC	Energy Efficiency Case
EV	electric vehicles
GDP	gross domestic product
GHG	greenhouse gas emissions
IEA	International Energy Agency
LNG	liquefied natural gas
MEPS	Minimum Energy Performance Standards
NEB	National Energy Board
NZER	net-zero energy ready
PLDV	passenger light-duty vehicles
PPP	purchasing power parity
SUV	sports utility vehicle
TFC	total final consumption
TPED	total primary energy demand
WEM	World Energy Model

Units of measure

Gt CO_2	gigatonnes of carbon dioxide
km^2	million square kilometres
Mt CO_2	million tonnes of carbon dioxide
mtoe	million tonnes of oil-equivalent
tCO_2	tonnes of carbon dioxide
tkm	tonne-kilometres

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