Canadian Energy Outlook

2018

horizon 2050

INSTITUT DE L'ÉNERGIE TROTTIER

e3Hub HEC MONTRÉAL Expertise in Energy and Environment

Modelling

ESMIA Energy Super Modelers and International Analysts

Financial support

FONDATION FAMILIALE TROTTIER FAMILY FOUNDATION

Analysis and writing

Institut de l'énergie Trottier - Polytechnique Montréal
- Simon Langlois-Bertrand, PhD
- Normand Mousseau, PhD
- Louis Beaumier, M.A.Sc.

e3 Hub – HEC Montréal
- Olivier Bahn, PhD

Modelling

ESMIA Consultants inc.
- Kathleen Vaillancourt, PhD

Acknowledgments

The authors would like to thank the Trottier Family Foundation for their financial support in producing this report, and for supporting previous initiatives related to energy and climate change, some of which have directly inspired this work.

Disclaimer

Citation

Langlois-Bertrand Simon, Vaillancourt Kathleen, Bahn Olivier, Beaumier Louis, Mousseau Normand, 2018. Canadian Energy Outlook. Institut de l'énergie Trottier and e3 Hub
[Web] http://iet.polymtl.ca/energy-outlook/ (page visited day/month/year)

Version 02/11/2018

About the Institut de l'énergie Trottier (IET)

The *Institut de l'énergie Trottier* (IET) was created in 2013 thanks to a generous donation from the Trottier Family Foundation. Its mission is to train a new generation of engineers and scientists with a systemic and trans-disciplinary understanding of energy issues, to support the search for sustainable solutions to help achieve the necessary transition, to disseminate knowledge, and to contribute to discussions of energy issues.

Based at Polytechnique Montréal, the IET team includes professor-researchers from HEC, Polytechnique and Université de Montréal. This diversity of expertise allows IET to assemble work teams that are trans-disciplinary, an aspect that is vital to a systemic understanding of energy issues in the context of combating climate change.

About the e3 Hub

e3 Hub is a multidisciplinary platform whose mandate is to identify and transfer knowledge and best practices in energy management to various audiences. This mandate is based on several strategic axes, in particular the study of best practices in energy efficiency within companies, and the realization of economic analyses to understand the different issues related to the production and the consumption of energy.

Based at HEC Montréal, e3 Hub not only draws on the School's academic resources, but also develops partnerships with various organizations to carry out its mission. It is also a platform for networking, where academics and practitioners can share their knowledge and learn from each other.

About ESMIA Consultants inc.

ESMIA offers expert services in the development and application of 3E optimization models (Energy-Economy-Environment) for strategic decision making at local, regional, national and global scales. Specialized in the development of integrated energy models, the ESMIA consultants have been providing a full range of support services for clients who want to develop their own model or learn how to use existing models. They have participated in the development of numerous models for prestigious public and private organizations worldwide. ESMIA consultants also provide consulting services for the analysis of complex and long-term energy-related issues, including the energy transition to a low-carbon economy, the impact of emerging technologies and climate policies. ESMIA benefits for this purpose from its own North American model.

Table of contents

Figures and tables list

Figures

Tables

1

Why an Energy Outlook?

Since the beginning of the industrial revolution, energy has been at the core of economic development, supporting the natural resources, agricultural, industrial and manufacturing sectors, as well as providing services essential to move people and goods, heat buildings and ensure the efficient operation of society as a whole.

With the competitive exploitation of non-conventional fossil fuels, such as shale oil and gas, the rapid cost reduction of intermittent renewable energy sources and worldwide efforts to reduce GHG emissions – produced in Canada at more than 80% by the energy sector – energy issues have never been more important, at least since the oil crises of the 1970s, to further understanding of what the current and expected developments mean for Canada's future and help enlighten policy and investment decisions.

Similarly to most developed countries, for some 30 years, Natural Resources Canada has produced an Energy Outlook that has attempted to look at the impact of current and expected energy-related conditions on possible futures for the country. This tradition was abandoned 12 years ago, in 2006, two years before the shale gas and oil shattered the North American and world energy markets. According to the NRC Outlook, oil prices were expected to double by 2020, and natural gas prices to triple; the defunct Mackenzie Delta gas pipeline was, expected for 2011 and most Canadian nuclear plants were to be refurbished. Twelve years is a very long time in the energy world.

In parallel, since 1967, the National Energy Board has been producing an Energy Futures report that projects long-term production and demand, historically focusing fairly narrowly on supply and distribution in support of its own mandate. However, in its last report, published in 2017, the NEB Energy Futures considers the impact of carbon pricing on demand for the first time.

More recently, a few non-profit initiatives also examined Canada's future. Supported by the Trottier Family Foundation, the Trottier Energy Futures Project (TEFP 2016), published in 2016, focused on the impact of various GHG reduction scenarios on the 2050 horizon. In May 2018 David Hughes, supported by the Corporate Mapping Institute and the Social Science and Humanities Research Council of Canada, proposed an analysis of Canada's current energy and GHG reduction situation. Entitled "Canada's Energy Outlook" (Hughes 2018), this analysis focuses on the current state of energy in the country and does not model any scenario.

This Outlook complements and expands these efforts. In order to do so, it adopts a traditional form: building on various scenarios, it projects Canada's energy production and consumption into the next decades. Although based on NEB's demand scenario, to allow for a better comparison with the NEB Energy Futures report, it focuses more directly on the transformation that is taking place across Canada's energy sector, its impact on the general economy and its dependence on various provincial and federal GHG emission reduction targets and objectives. Produced by independent researchers, it adopts a critical voice to analyze the trends occurring across the country, the political choices that need to be made and the considerable gap between promises, objectives and targets, on the one hand, and the reality observed as well as the coherence of the measures implemented, on the other.

1.1 Objectives of this Outlook

Canada's energy future is far from being written. This Outlook aims to promote a better understanding of what is happening today and how we can forge tomorrow's Canada. To this end, the scenarios presented produce results that are discussed with several overarching objectives in mind:

1. A first objective is to identify possible pathways to reach medium- and long-term GHG emission reduction targets. Identifying and discussing these pathways, which cut across all parts of Canada's energy system, is essential to understand the implications of the energy transition for the decades to come, what choices they require Canadians to contemplate, and what potential they hold for improving the quality of life in conjunction with the transition.

2. The second aim of the report is to ensure a thorough discussion of cross-provincial variations within these pathways. Keeping

provincial variation in mind is crucial for at least two reasons in this context:

a. Certainly the importance of political efforts to bring about emission reductions varies quite substantially across provinces, based on differences in the structure and importance of economic sectors, the size of the population and its spread among rural and urban regions, as well as the preferences, values and ideologies that prevail in their population and political class.

b. Furthermore, these differences occur in the context of a federation, where a significant portion of jurisdiction for energy matters lies with the provinces. This situation complicates national initiatives to coordinate efforts to reduce emissions and transform the economy, but it also points to the possibility that thinking in national terms may lead to a more efficient distribution of the transition costs, especially in the most aggressive scenarios.

3. Finally, this Outlook provides a special focus on the transportation sector, where challenges to reducing emissions and problems in transforming the sector's energy profile go hand in hand. This constitutes the special theme for this issue.

1.2 Overview

In order to establish the bases for discussing the future of energy in Canada and achieving the objectives outlined above, this Outlook begins with a description of the current state of energy in the country. Chapter 2 provides a profile of the Canadian energy system, along with recent trends in production, consumption patterns in different sectors, and energy efficiency. Chapter 3 then discusses Canada's GHG profile and describes the main political developments in terms of reducing emissions, including key medium-term and long-term targets.

After presenting the different scenarios used throughout the rest of the Outlook, Chapter 4 begins the discussion of energy demand projections, divided into the main sectors, with a separate discussion provided for heating. Chapter 5 follows with an analysis of the projections for energy production, which has special importance in Canada given the size of the sector, its growth prospects for the near future, and its crucial role in the current GHG emissions profile.

Chapter 6 focuses on electricity, with a description of differences across the provinces. The electrification of various activities in all sectors is crucial to any discussion of long-term GHG emission reductions, as it often represents an essential step in more aggressive efforts to stem emissions. This central role in the energy transition, however, comes with a broad variety of costs and problems, and our results provide a few ideas on where to focus efforts and how to understand challenges to come.

Chapter 7 and 8 provide a detailed analysis of the impact of the transformation derived from each scenario. Chapter 7 focuses on GHG reductions and costs, while Chapter 8 examines variations across the provinces.

Chapter 9 presents a special focus on transportation. A low demand scenario is also examined, illustrating the impact of changes in assumptions with regard to energy demand trends for the next three decades in transport.

Chapter 10 concludes by putting in perspective the key takeaways from the results within the current Canadian political context.

1.3 Limitations of and omissions from this Outlook

Modelling exercises such as those presented in this document have a number of limitations that derive from the simplifications required and the uncertainty inherent in forward-looking initiatives. Dealing with these limitations requires making careful assumptions; while the more specific of these are presented in Chapter 4, a few key points are set out below.

In this Outlook, we have assumed that the share of reductions in both energy-related emissions and emissions from other sources would be similar.

This is a reasonable proposition in Canada, where the proportion of energy-related emissions is currently over 80%, with the rest of emissions coming from industrial processes (7%), waste (3%) and agriculture (8%). Nevertheless, in many respects, reductions in these sectors are likely to follow a different trajectory, adding or releasing pressure on the energy sector. For example, the development of new low-carbon industrial processes, such as announced recently for aluminum smelting, can lead to stepwise GHG reductions in some sectors.

This development also highlights one important source of uncertainty, which is the likelihood of the advent of disruptive technologies that could be game changers in some sectors, affecting the pace of some of the results. This uncertainty is typical in this kind of modeling and must certainly be kept in mind when interpreting the results.

Focusing on energy issues, this Outlook has also left aside the important issue of adaptation to climate change that will affect energy consumption/ production and the choice of investments in infrastructure. Certainly the energy transition is as much about technological and economic development as it is about reducing the risks and costs associated with accelerated climate change caused by rising greenhouse gas levels in the atmosphere.

Finally, it must be noted that our discussion to a certain extent downplays the issue of displaced emissions. Not all technologies required for the extensive transformation of energy services following the different scenarios will be produced in Canada, and we do not evaluate the impact that this shift will have on global GHG emissions. Although we do not take this issue lightly, this shortcoming is inevitable given our Canadian focus, as well as beyond the scope of our analysis and many others with a national focus.

Despite these caveats, modelling allows the identification of general trends, which we believe to be fundamental in setting the bases for a discussion of pathways for the Canadian energy system. We return to these issues in the concluding chapter in light of our results.

2

The starting point: Canada's energy system in 2018

This chapter provides a snapshot of Canada's energy system, including an overview of consumption, production, transformation, trade and efficiency, as well as its contribution to the Canadian economy. In addition to presenting recent data on each of these issues, this portrait serves to highlight some of the key energy challenges in the Canadian context.

The starting point:
Canada's energy system in 2018

Highlights

Canada is among the world's most important energy producers and exporters, with significant fossil fuel and uranium ore extraction sectors.

81% of Canada's electricity production is from low-carbon sources; the electricity energy mix varies greatly between provinces.

Over the past 20 years, natural gas imports have increased by a factor of more than 16, and crude oil exports have almost tripled.

Canadians have one of the world's highest per capita energy consumption levels, with large provincial variations being explained by industrial sector structural differences.

Contrary to almost all other sectors, energy consumption in the transport sector continues to increase – even on a per capita basis.

Wind and solar electricity generation has allowed private actors to penetrate a traditionally public sector.

Worldwide oil prices, energy access to markets and GHG reduction targets are shaping current energy debates in Canada.

The starting point: Canada's energy system in 2018

2.1 Recent developments in Canada's energy sector

Several events have contributed to reconfiguring energy issues over the past year. In particular, pipeline development has proceeded through the advancement of several projects, although not without substantial opposition from the public and some provincial governments; carbon pricing initiatives have continued to expand in some areas of the country; and uranium production has been hit by the suspension of activities at several sites. This section provides an overview of these and other major developments that marked the year in the energy sector.

The first category of developments applies to pipelines. The year 2017 began with the newly elected U.S. President's executive order to approve the Keystone XL pipeline, reversing the previous President's policy. The pipeline is still facing significant opposition, including possible challenges in Nebraska, despite the state's approval of an alternative route in November. The project would deliver up to 830,000 barrels a day of crude oil from Alberta to Nebraska, connecting with the U.S. pipeline network and ultimately reaching the Gulf Coast hub of refineries and export terminals.

Kinder Morgan's Trans Mountain expansion across British Columbia is a second pipeline project that has drawn attention since 2017 . Although the project was approved by the federal government and is supported by Alberta, in 2017 British Columbia's newly elected government signalled that it would take steps to limit the flow of oil through the pipeline or prevent the expansion altogether. These intentions morphed into concrete action in January 2018, when British Columbia proposed new regulatory restrictions on the transport of bitumen, which would affect the Trans Mountain project. The move triggered a strong reaction from Alberta, and Kinder Morgan publicly stated that this political uncertainty made it more hesitant to forge ahead with the project. These developments led the Federal Government to announce in May its purchase of the pipeline and the expansion project, with the intention of selling it later to a third-party buyer, although none had been found at the time of writing.

Furthermore, Enbridge's project to replace the existing Line 3, improving safety and expanding capacity, was approved in 2016. However, in December of 2017, a Minnesota court delayed the approval because of deficiencies in the environmental impact statement.

Finally, TransCanada's Energy East and Eastern Mainline projects, which would have resulted in the transport of 1.1 million barrels a day from Alberta to Eastern Canada, were cancelled in the fall of 2017. Although the projects faced intense criticism, notably in Quebec, TransCanada cited the new conditions imposed by the National Energy Board, which included the review of indirect GHG emissions, as the basis for its decision.

Overall, these developments highlight the substantial efforts deployed by the Canadian oil and gas industry to find ways to expand its export capacity. Oil exports, which have increased 182% over the past 20 years, have proceeded to occupy most of the pipeline capacity, even of newer infrastructure, requiring several new projects or expansions. Recent events surrounding these projects also show the increased importance of strong local opposition to pipelines, both domestically and abroad. Parallel to all these developments, the federal government presented a new approval process that has yet to be approved.

A second category of developments relates to carbon pricing. First, a California appeals court confirmed the legality of the Western Climate Initiative's carbon market between the U.S. state and Quebec. The decision was followed by a supermajority legislative approval in the California state assembly extending the system until 2030, ending uncertainty over the future of the cap-and-trade system. California's GHG emissions reductions target for 2030 has also been raised to 40%, while Ontario and Quebec 2030 targets stand at 37% and 37.5% respectively. The auctions following California's announcement, held in August, November and February, saw all allowances sold, and at a price above the minimum for the first time since 2015. The province of Ontario also linked its carbon market to this system, starting on January 1, 2018. This participation was short lived as the newly elected government announced Ontario's withdrawal less than six month later.

Other notable developments with regard to carbon pricing occurred in Alberta, which reformed its carbon pricing system, and in British Columbia, where the revenue-neutral characteristic of its carbon tax was abandoned by the new government. New announcements were also made across the country to conform to the federal government's carbon pricing framework. Chapter 3 describes all these developments and policies.

As concerns the electricity sector, Ontario's participation in the carbon market came after announcements of greater integration of Quebec and Ontarios' electricity systems. This included an agreement concluded in 2016, under which Ontario receives 2 TWh of electricity annually from Hydro-Québec, while Ontario provides a 500 MW surplus capacity during Quebec's peak demand periods in the winter. The agreement is mainly aimed at helping fill gaps in Ontario's supply left by the refurbishment of its nuclear reactors until 2023, and negotiations to expand electricity trade held since have not been successful. Hydro-Québec also announced the completion of the Romaine-3 hydroelectric power plant in 2017, part of a complex of four plants to be completed in 2020.

As regards nuclear energy, the uranium mining industry has been hit by continuously low prices at the international level, leading to the suspension of operations at several sites. In late 2017, in particular, a 10-month suspension of production was announced for the McArthur River mine, the largest uranium production operation in the world, which normally supplies over 40% of Canadian production.

Finally, 2017 kicked off with the launch by Natural Resources Canada – which is responsible for the energy transition at the national level – of Generation Energy, an online consultation that ended with a large gathering in Winnipeg, led by Minister Jim Carr, in October 2017. While the consultation was a success, reaching more than 380,000 Canadians according to the report presented by Minister Carr, no clear path of action to drive the promise energy transition has followed this large scale effort.

These developments affect different parts of the Canadian energy system. The next sections provide a more detailed look at the various dimensions of this system to further understanding of the impact – and in some cases, the causes – of these events and announcements.

2.2 Canadian characteristics

2.2.1 Production

The Canadian energy system stands out when compared to that of other countries around the world. On the production side, the first notable element is the importance of domestic resources (Table 2.1), which include crude oil (3rd in the world for reserves), natural gas (4th producer in the world), uranium (3rd world reserves) and hydroelectric power (2nd in the world in terms of electricity generated). Overall, Canada is one of the world's leading energy producers (6th) and net exporters (5th) (NRCAN 2018). As a result, the energy sector employs more than 127,000 people and accounts for close to 7% of the country's gross domestic product (GDP).

2.2.2 Consumption

Canada also stands out when it comes to energy consumption, being 8th in the world for overall consumption and having one of the highest global consumption levels on a per capita basis (more details in Section 2.2.4 below). More specifically, Canada's per capita energy use is higher than all other OECD countries, with the exception of Iceland, which has a much smaller economy.

Table 2.1 – Energy in Canada: world ranking for reserves/capacity, production, and exports

Energy Resource	Proved Reserve /Capacity	Production	Exports
Crude Oil	3	4	3
Uranium	3	2	2
Hydroelectricity	4	2	-
Electricity	7	6	3
Coal	15	12	8
Natural Gas	17	4	4

Source: NRCAN 2018

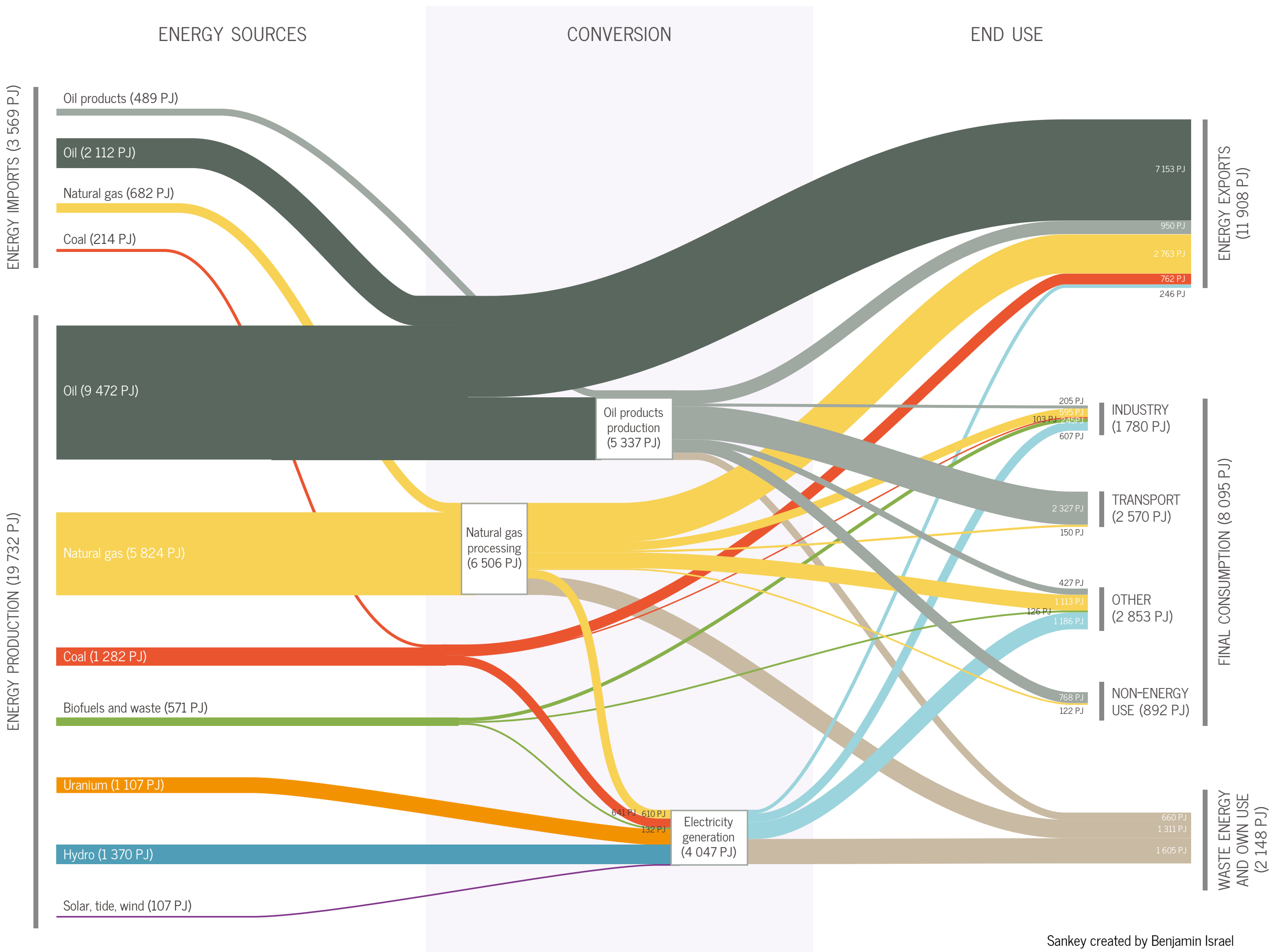
Source: Statistics Canada (2018a)

On a per capita basis, the sources of this consumption present similarities across most provinces, notably in the transport, commercial and residential sectors. However, the share of the industrial sector in final energy consumption varies significantly across provinces. These similarities and differences are discussed in Section 2.3. Figure 2.1 shows a Sankey diagram illustrating the different energy flows from a national perspective.

2.2.3 Renewable sources

In 2015, 81 % of Canada's electricity production was low carbon emitting. Fifteen per cent of the total production came from nuclear reactors and 66%, from renewable sources, mainly from the hydroelectric sector (60% of total generation). Wind energy stood at 4%, with biomass (2%) and solar (0.5%) producing most of the rest (NEB 2017). This gives Canada the world's 6th highest share of renewables in electricity generation. With the exception of Brazil, which counts on a share of hydroelectricity similar to Canada's, all other

Figure 2.1 – Supply, transformation and consumption of energy in Canada



Source : IEA 2018

Notes : Energy Flows less than 100 PJ are not displayed. Totals may not add up due to rounding. Final consumption captured under "Other" includes residential, commercial and public services, agriculture and forestry, fishing and non-specified.

countries with larger shares of renewable sources in electricity generation are much smaller in terms of population and territory – namely, Norway, New Zealand, Austria and Denmark. Within Canada, provinces differ significantly in the energy mix necessary for the production of electricity, as well as in the importance of natural gas usage.

2.2.4 Provinces

Another particular feature of the Canadian energy system is that jurisdiction for energy matters rests largely with the provinces. Historically, this has led provinces to dominate energy decisions in many areas, generating clustered provincial energy systems. Accordingly, interprovincial energy trade is relatively limited, despite the importance of domestic production as described above. This is visible in the electricity sector, where provincial grids have been largely targeted toward exports to neighbouring U.S. states, with much less effort being focused on exporting to adjacent provinces. A regional disconnect has also existed in oil and natural gas over the past decades, with Central and Eastern Canada traditionally importing from abroad, while the bulk of oil sands production went to United States refineries.

There has been movement on both these fronts over recent years. In terms of electricity, a small increase in electricity traded between Ontario and Quebec has resulted in particular from a new openness to trade and increased cooperation. As for oil supply, Quebec and Ontario have seen a change in their sources of supply, favouring American and Canadian production to the detriment of overseas countries like Nigeria and Algeria, primarily due to a decrease in the price of Alberta crude oil relative to the Brent variety.

2.2.5 The economy

Overall, Canada's energy system occupies a strong place in the country's economy, given the importance of energy production and the country's large consumption levels. Variation in the provinces' energy profiles are key to this portrait: more specifically, oil production is concentrated in Alberta and Saskatchewan, uranium is mined in Saskatchewan, the production and use of hydroelectricity vary quite substantially across provinces, and the same holds true for other renewable sources, as the sections below indicate. Actions and policy aiming to modify energy consumption or to reduce GHG emissions must proceed through sectors with strong regional constituencies, adding political difficulties to economic challenges. This is further complicated by the historical lack of cooperation among provinces on energy matters, which contributes to the physical and political challenges for deeper integration.

Nevertheless, these features do not eliminate the presence of strong national trends, such as the overwhelming importance of oil in the transport sector, recent policy efforts to measure and reduce GHG emissions, and strong ties with the United States as the primary customer for energy exports. This chapter reviews the differences and similarities that make up the Canadian energy system: the following sections present numbers on different aspects of energy in the Canadian context, including the past evolution of key indicators.

2.3 Energy system overview

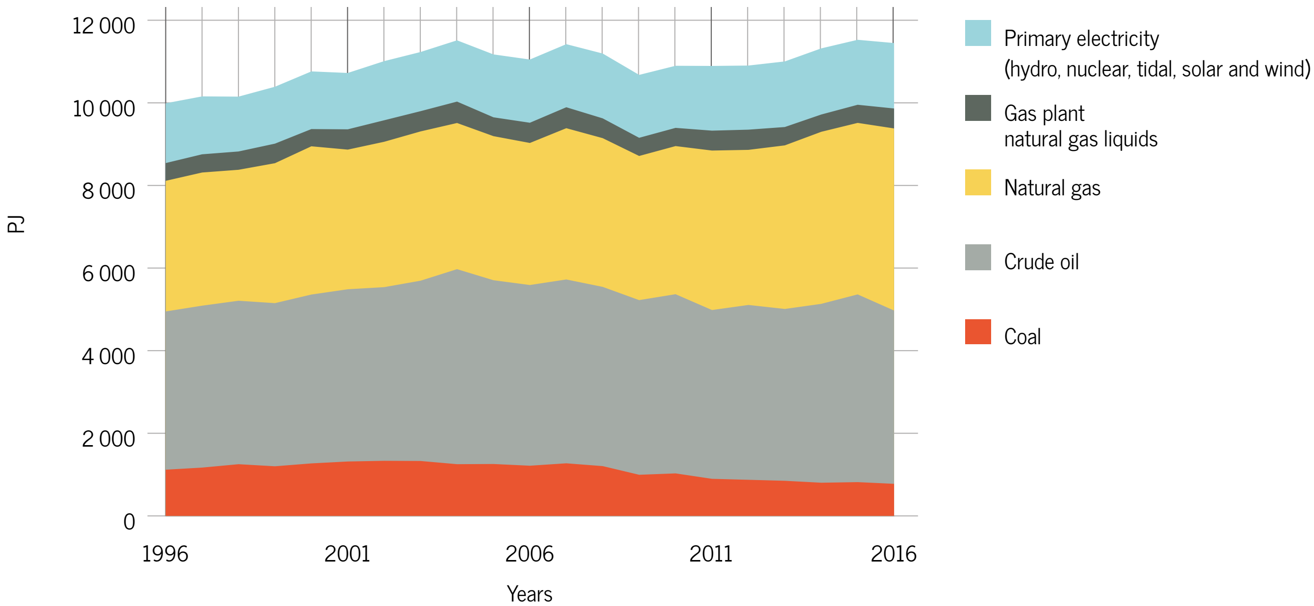
2.3.1 Supply and consumption[1]

Natural gas and oil represent the largest shares of Canada's energy supply, while primary electricity (mostly from nuclear and hydroelectric sources) and coal provide the rest. As Figure 2.2 shows, in terms of fuel categories, the main change over the past 20 years has been the decreasing share of coal, driven by its phase-out in Ontario's electricity generation, and the corresponding increase in natural gas. While renewables have been playing an increasing role in recent years, they remain a small share of the total. As a result, the proportion of the energy supply from fossil fuels is similar to what it was 20 years ago, although the overall supply is larger today.

Looking more closely at the composition of the fuel mix, another clear trend has been the progressive shift in the main types of crude oil. In 1990, refinery supply was made up of 75% light conventional crude oil and another 13% of heavy convention crude oil, while only 11% came from the synthetic variety extracted from oil sands deposits. In 2016, by contrast, oil sands supplied 28% of crude oil used

[1] To ensure consistency in the discussions found in this chapter, we try to provide data for the 20-year period going from 1996 to 2016. Unless specified otherwise, data availability explains the use of different years in some tables and figures.

Figure 2.2 – Domestic primary energy supply, 1996-2016



Source: Statistics Canada 2018a

by refineries, with heavy conventional remaining at 13% but light conventional falling to 54% (Statistics Canada 2018b). In other words, although the share of crude oil in domestic primary supply mainly remained constant overall in the period from 1996 to 2016, this should not mask the fact that Western Canada's oil sands have grown in importance as a source of crude oil for Canadian refineries.

Table 2.2 shows that the industrial and transportation sectors each make up a similar share of the country's energy use, while the rest of final demand is split among the residential, commercial and – to a lesser extent – agricultural sectors. Importantly, however, Table 2.1 also shows that non-energy use and producer consumption represent almost a quarter of the energy products available for use, highlighting the importance of energy production and refining sectors in the Canadian economy. The importance of producer consumption, largely associated with GHG-intensive activities, implies the necessity to factor in the essential role of this sector if efforts to reduce GHG emissions are to be effective.

Figure 2.3 provides a closer look at the industrial sector and shows the breakdown according to different industries. The sector's total consumption increased by 17% between 1996 and 2015. The mining sector (including oil and gas) corresponds to both the largest category (37.7% of total) and the steepest increase over the period (+185%). In several other industries, energy use decreased in the same period, notably in the iron and steel (-19%), petroleum refining (-13%), pulp and paper (-11%), and other manufacturing (-16%) sectors. The changes and importance of the mining sector can be explained by its rapid expansion over the period, especially in oil and gas extraction. This underlines the central role played by these activities in the economy of some provinces and their overall weight in the Canadian economy as a whole. The decrease observed in several other industries derives mainly from a mix of efficiency improvements and closures in the sector.

The profile of the national industrial sector is also characterized by electricity occupying only a 20.1% share of the total. Natural gas dominates energy use in this sector (42.6%) and other fuels, notably still gas and petroleum coke (13.3%), wood waste and pulping liquor (11%), and diesel fuel oil, light fuel oil and kerosene (6%), represent a smaller but non-negligible share (OEE 2018).

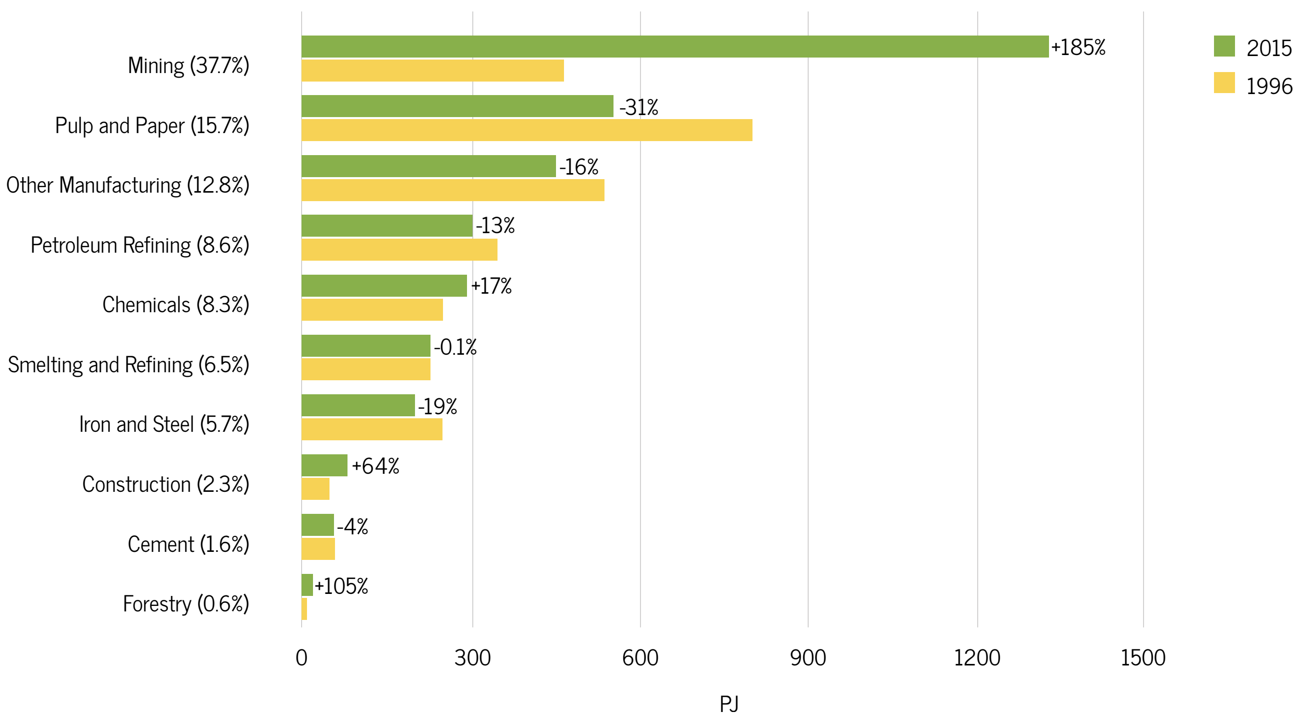
Table 2.2 – Net supply of energy – primary and secondary – by sector

Category	1996 (PJ)	2001 (PJ)	2006 (PJ)	2011 (PJ)	2016 (PJ)	Share (2016)
Total	8 746	9 139	9 881	10 201	10 691	100.0%
Producer consumption	1 056	1 290	1 358	1 280	1 431	13.4%
Non-energy use	875	948	1 071	1 089	1 039	9.7%
Total final demand	6 902	7 089	7 352	7 820	7 953	74.4%
Industrial	2 158	2 147	2 286	2 456	2 599	24.3%
Transportation	2 117	2 249	2 498	2 608	2 674	25.0%
Agriculture	222	223	230	272	299	2.8%
Residential	1 336	1 246	1 281	1 401	1 286	12.0%
Commercial, inst. and publ. admin.	1 010	1 124	1 057	1 084	1 095	10.2%

Source: Statistics Canada 2018a

Note: due to statistical differences, total final demand, producer consumption and non-energy use do not add up to the total

Figure 2.3 – Industrial energy use by industry (1996 and 2015)



Source : OEE 2018

Note: percentages shown in the vertical axis represent the share of total energy use in the sector (total is not 100% due to rounding).

The national commercial and institutional sector presents a very different energy profile, with 50.8% of energy use coming from natural gas in 2015, and 42.1% from electricity sources. The rest came from light fuel oil and kerosene (3.2%), as well as coal, propane and other fuels (OEE 2018).

Figure 2.4 presents energy consumption in this sector by end-use, including space and water heating, lighting, auxiliary equipment, auxiliary motors, space cooling, and street lighting. The figure also shows the evolution from 1996 to 2015. All areas except auxiliary motors have increased demand, most notably auxiliary equipment (+122.4%) and space cooling (+102.3%). Between 1996 and 2015, the total increase for the Canadian commercial and institutional sector was 20.6%, a much smaller figure than it would have been without efficiency improvements (NRCAN 2018). This profile makes the commercial sector less reliant on GHG-intensive sources of energy and highlights the importance of space heating activities, as well as the increasing importance of auxiliary equipment.

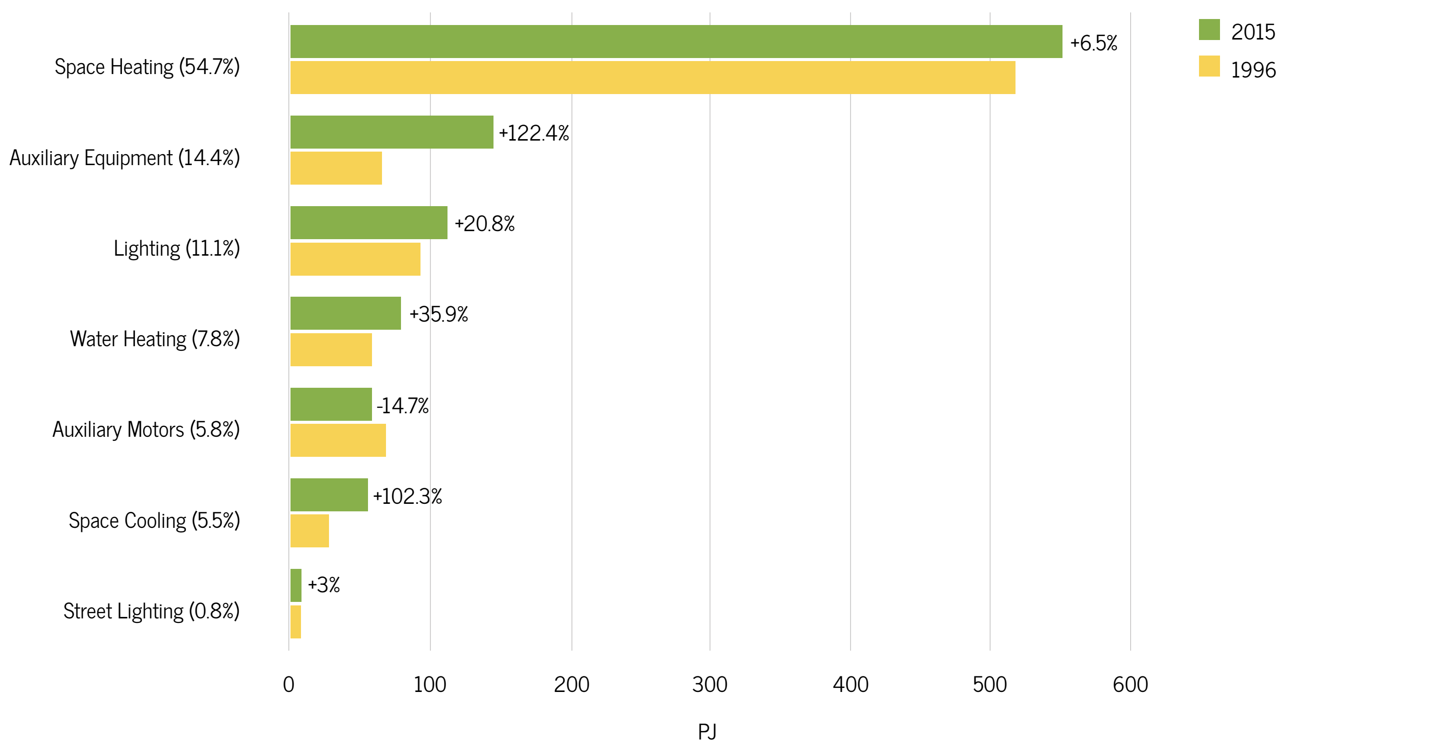
In the transport sector, consumption continues to be dominated by gasoline (56%) and diesel (31%), with aviation turbo fuel (10%) being the only other category of fuel with a share over 5% of total energy use for the sector. The share of diesel is higher in freight transport (66%), a category that has also seen a steeper increase in energy use (45%) compared with passenger transport (15%) over the 1996-2015 period. Although off-road transport more than doubled its energy use, it represents only 4% of energy consumption for the overall transport sector (OEE 2018).

Despite improvements in energy intensity, passenger transport resulted in 761,751 million passenger-kilometres in 2015, a 38.6% increase from 1996. Even on a per capita basis, passenger transport went up by 14.6%, reaching 21,200 passenger-kilometres per person in 2015.

Freight transport, which has seen very limited improvements in energy intensity over the same period, presents larger increases. Tonne-kilometres transported went up by 46.3% to 971,527, an increase that amounts to 20.9% on a per capita basis (OEE 2018).

These numbers show that improvements in energy intensity for passenger transport have been

Figure 2.4 – Commercial and institutional energy use by end-use (1996 and 2015)



Source : OEE 2018

offset by the increase in the number of kilometres travelled by individuals. In the freight category, the situation is even more problematic, as a similar increase in tonne-kilometres transported has not been accompanied by parallel improvements in fuel efficiency. This evolution underlines the challenges facing the Canadian transport sector, where geography and historically low energy prices in particular have led to an urban structure heavily dependent on transport.

Finally, the residential sector's energy consumption (Figure 2.5) comes mainly from space heating (61%), with the rest consisting mostly of water heating (24%) and appliance use (11%). Natural gas is the main source for both space heating (42%) and water heating (77%), with electricity in second place. Electricity is also the dominant source in other end-uses (appliances and lighting in particular).

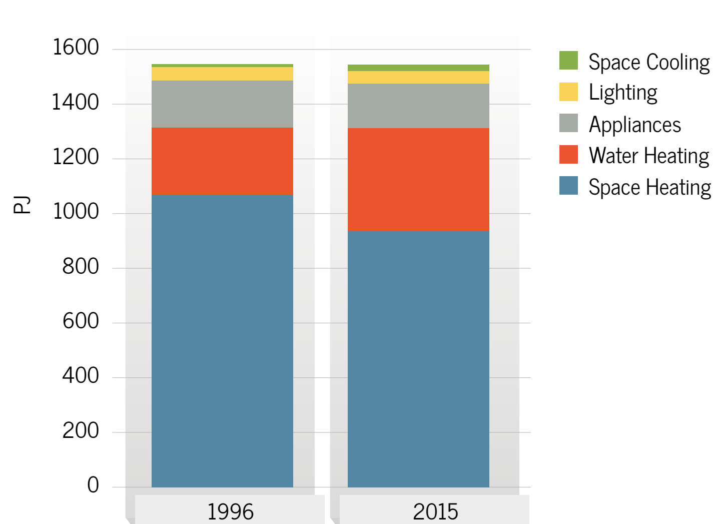
Overall residential consumption mainly remained constant between 1996 and 2015, decreasing by 17% on a per capita basis. Appliances and water heating increased their share of the total, chiefly offset by a decrease in the share of space heating. While space cooling increased by 131%, it remains a very small portion of total consumption.

2.3.1.1 Provincial variation

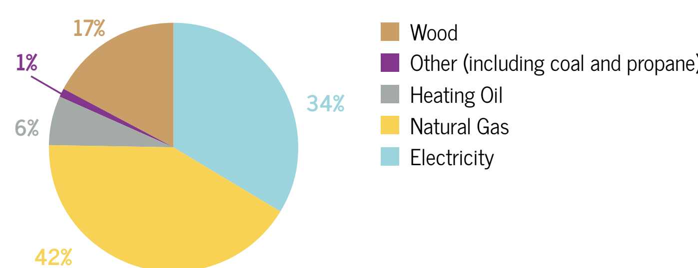
Turning to provincial differences, Figure 2.6 presents energy use characteristics across provinces based on sector, ranked by total energy use. In terms of overall consumption, Ontario, Quebec, British Columbia and Alberta top the list, with Alberta's position largely explained by its oil and gas industry. Accordingly, the industrial sector represents over half the province's final energy consumption, in comparison to slightly over one-third (33%) for Canada as a whole. Nova Scotia, Newfoundland and Labrador, and Prince Edward Island have the smallest share of energy use in the industrial sector.

Figure 2.5 – Residential energy use by end-use (1996 and 2015)

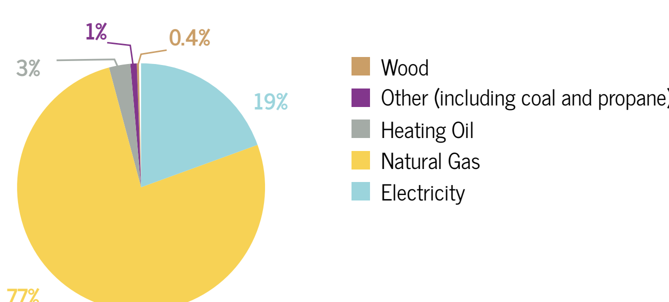
Residential consumption by end-use



Sources of energy for space heating (2015)

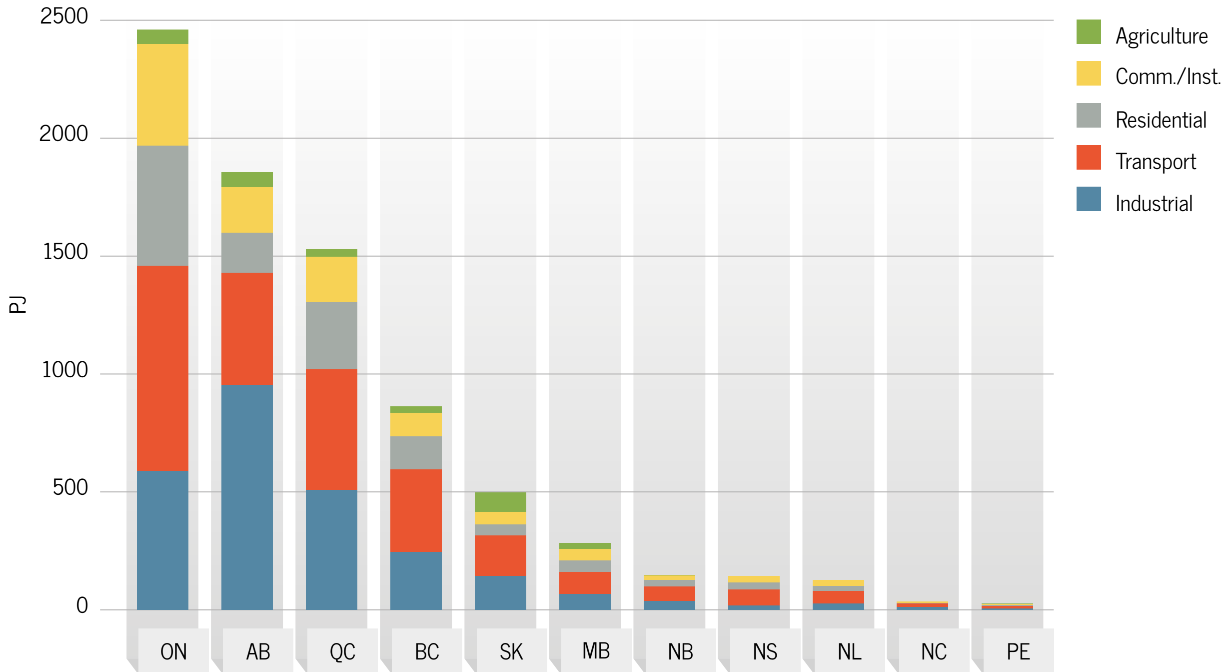


Sources of energy fo water heating (2015)



Source : OEE 2018

Figure 2.6 – Total final energy consumption, by province and sector (2016)

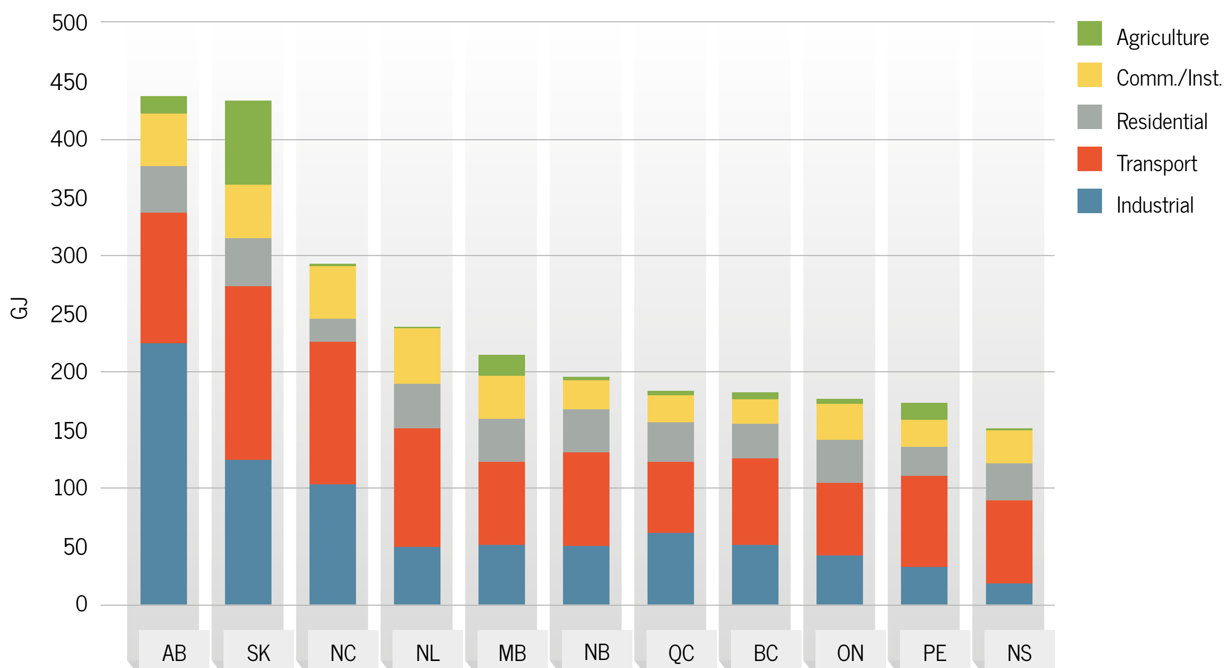


Source : Statistics Canada 2018a

Notes: - NC (Northern Canada) includes the Nunavut, Yukon, Northwest Territories.

- The Commercial/Institutional sector includes public administration.

Figure 2.7 – Total per capita final energy consumption, by province and sector (2016)



Source : Statistics Canada (2018a, 2018c)

Sectoral variations across provinces are smaller as concerns the transport, commercial and institutional and residential sectors, while the size of the agriculture sector is typically small but stands out in Saskatchewan.

Figure 2.7 illustrates the distribution of consumption by province and sector on a per capita basis. With the exception of Saskatchewan's consumption in the agricultural sector, which here again differs markedly from other provinces, the variation in per capita use across provinces is mainly explained by energy use in the industrial sector. Alberta and Saskatchewan clearly stand out, with consumption in their industrial sector fuelled by oil and gas production. The total per capita consumption is much more similar across other provinces, highlighting smaller variations in per capita energy use in the transport, residential, and commercial sectors.

In addition to contributing to widely different shares of total consumption from province to province, the industrial sector's overall energy use highlights the necessity of making it central to national efforts to reduce GHG emissions. However, this sectors' energy consumption does not provide a full picture of the sector's impact on energy-related economic activity in the country. We now turn to an overview of energy production's main features Canada-wide.

2.3.2 Production, transformation and trade

As explained in Section 2.2.1, Canada is a major energy producer on the world scene. This production covers a broad variety of sources and comprises a large number of operations both in fossil fuels and in non-emitting sources.

Table 2.3 shows the magnitude of this production with regard to fossil fuels. Crude oil and natural gas dominate, while coal production represents around 7.5% of fossil fuels produced. Moreover, oil production has almost doubled since 1996, while increases in natural gas production have been more modest, and coal output decreased by 27%. In recent years, Canadian production has also provided 23% of the world's uranium, or about 14 kt. However, as low prices resulted in the suspension of uranium mining in 2016 and 2017, these numbers are likely to be very different in the short term.

Table 2.3 – Fossil fuel production (2016)

Fuel	1996 (PJ)	2016 (PJ)
Crude oil	4 555	8 879
Natural gas	6 177	6 896
Coal	1 832	1 331
Gas plant natural gas liquids	595	762

Source: Statistics Canada (2018a)

Canada is home to 15 oil refineries (Table 2.4) that transform crude oil into a variety of refined petroleum products, over half of which consists of gasoline (35%) and diesel fuel (25%) used mainly in the transport sector. These fuels are then distributed through a network of 12,000 retail and commercial sites (Canadian Fuels Association 2018).

Table 2.4 – Refining capacity, by installation and province (2016)

Refinery installation	Province	Capacity (kb/d)	Total by province
Husky	British Columbia	12	69
Chevron	British Columbia	57	
Suncor	Alberta	142	429
Imperial	Alberta	187	
Shell	Alberta	100	
Federated Co-op	Saskatchewan	130	130
Imperial	Ontario	121	409
Shell	Ontario	75	
Suncor	Ontario	85	
Petro-Canada Lubricants	Ontario	16	
Imperial	Ontario	112	
Valero	Quebec	265	402
Suncor	Quebec	137	
Irving Oil	New Brunswick	318	318
North Atlantic Refining	Newfoundland and Labrador	130	130
Total for Canada:			1 887

Source : Canadian Fuels Association 2018

Note: the Alberta's North West Redwater refinery will add to this capacity once it is fully operational in 2018.

Some 13% of refinery production goes to non-energy products such as petrochemical feedstocks, as well as a variety of other fuels used in specialized applications, mainly in the industrial sector (e.g., kerosene and stove oil, still gas and petroleum coke). This overall distribution of fuel output at Canadian refineries has mainly remained constant since 1996.

In the electricity sector, hydroelectricity contributes over half of electricity generation. Table 2.5 presents Canadian electricity generation by source. Renewable energy sources make up a total of 64% of the electricity mix, while nuclear is close to 15%. Thermal generation, primarily from coal and natural gas, completes the mix. Coal presents the most significant change since 2005, losing nearly half of its share due to power plant closures in Ontario. Renewable sources other than hydroelectricity, especially wind, have been expanding rapidly over the past decade as a result of support policies across the country, particularly in Ontario and Quebec. Net renewable electricity generation has increased 12% since 2010, driven by wind and solar (NRCAN 2018).

Table 2.5 – Electricity generation by source

Type of electricity generation	2005 (GWh)	2016 (GWh)	2005 (%)	2016 (%)
Total	604 370	648 245		100.00
Hydraulic turbine	358 446	383 374	59.31	59.14
Tidal power turbine	28	18	0.00	0.00
Wind power turbine	1 552	30 462	0.26	4.70
Solar	N/A	1 981	0.00	0.31
Other types of electricity generation	N/A	135	0.00	0.02
Total hydro, tidal, wind, solar and other generation	360 026	415 970	59.57	64.17
Conventional steam turbine	130 320	..	21.56	..
Nuclear steam turbine	86 830	95 418	14.37	14.72
Internal combustion turbine	1 301	..	0.22	..
Combustion turbine	25 893	..	4.28	..
Total thermal generation	244 344	232 275	40.43	35.83
Thermal generation by fuel type:			Share of total electricity generation	
Uranium	86 830	95 418	14.37	14.72
Coal	93 892	58 036	15.54	8.95
Natural gas	29 769	41 377	4.93	6.38
Oil (petroleum coke and petroleum products)	14 341	5 774	2.37	0.89
Wood	1 781	2 221	0.29	0.34
Other fuels	17 731	29 449	2.93	4.54

Source : Statistics Canada 2018d, 2018e

Note : comparisons over time for wind must be done with care (see note 11 of CANSIM 127-0006). Statistical discrepancies between the two tables end up in the "other fuels" category because of differences between the reported totals for thermal non-nuclear by fuel type and the sum of 'conventional steam turbine', 'combustion turbine', and 'internal combustion turbine'.

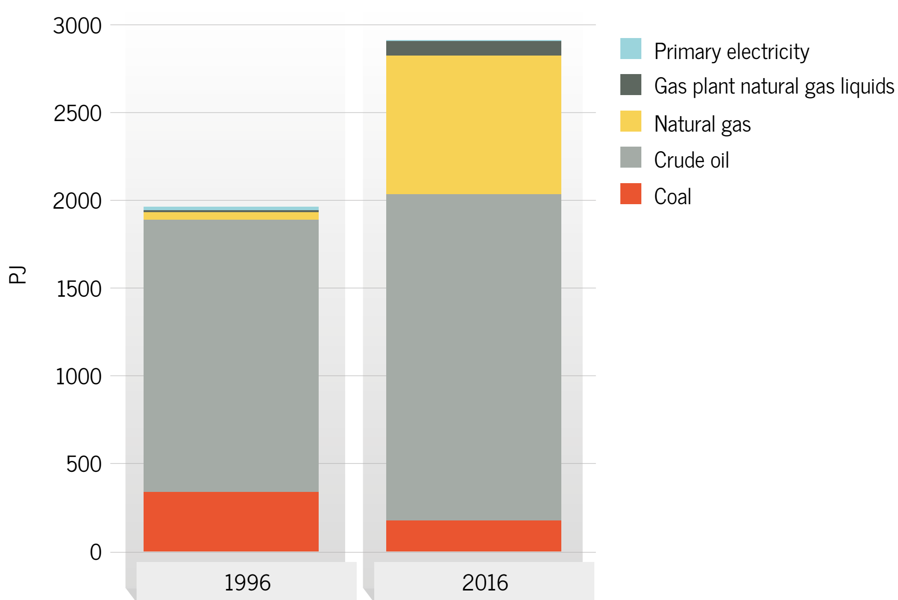
By and large, electricity generation remains a public enterprise across the country, with 65% of installed capacity belonging to state-owned utilities. This share of public ownership climbs to 88% of installed capacity for hydroelectric generation. By contrast, 55% of installed capacity for nuclear electricity generation is public, and this share is at 38% for non-nuclear thermal generation. Wind and solar energy producers are mainly private actors, at 89% and 63% of installed capacity respectively. As a result, the expansion of wind and solar energy has enabled private actors to penetrate the traditionally public sector, often with much smaller operations in comparison to large centralized power plants.

Renewable energy production also includes solid biomass (wood waste, pellets, etc.), which stood at 493,000 TJ in 2015. These fuels, primarily used for heat production, contribute only a very small share of electricity production. Additionally, Canada produces a significant quantity of ethanol (1,700 million litters) and biodiesel (430 million litres), driven in part by the provincial and federal mandates for gasoline and diesel blends, which are required to contain from 2% to 8.5% renewable fuels.[2]

Canada also trades large quantities of energy for most of the sources detailed above. While the country has produced a large quantity of oil and natural gas over the past decades, geographic variation in supply has led to its importing a significant quantity of each of these fuels in Eastern Canada, while the main extraction centers in the Western provinces export a large part of their production. Most of the imports come from the United States (65% of energy imports). These imports constitute 27% of Canadian consumption of crude oil, 19% of natural gas consumption, 17% of coal consumption and 9% of petroleum products used in Canada (NRCAN 2018).

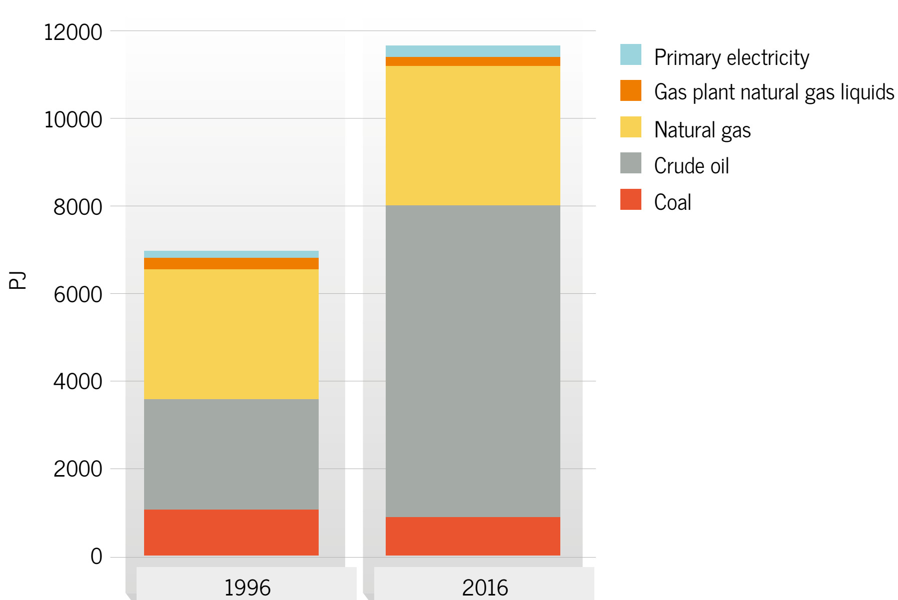
Overall imports (Figure 2.8) have increased substantially (48%) in the past 20 years, a trend mainly associated with natural gas imports increasing by a factor of more than 16, while crude oil also contributes with a 20% increase. This illustrates a drastic change, as natural gas imports, which were marginal in 1996, rose to close to 800 PJ in 2016. This expansion in overall imports, along with a 50% reduction in the quantity of coal imported, also explains coal's decreased share.

Figure 2.8 – Primary energy imports



Source: NRCAN 2018; Statistics Canada 2018
Note: 2016 number for coal is an estimation

Figure 2.9 – Primary energy exports



Source: NRCAN 2018; Statistics Canada 2018
Note: 2016 number for coal is an estimation

[2] The federal mandate requires at volume of 5% for ethanol and 2% for biodiesel, but some provinces have put in place mandates necessitating higher shares. Details on provincial mandates can be found in chapter 3.

The overall picture for primary energy exports is quite different. Although exports, like imports, have increased significantly in the past 20 years (+67%), the shares of each energy product in primary exports has changed significantly, as Figure 2.9 shows. Most of this evolution, however, can be attributed to a 182% increase in the quantity of crude oil exported, which is largely responsible for the overall increase in exports. To a much lesser extent, a 16% decrease in coal exports also explains this fuel's smaller share. In other words, natural gas exports remained roughly similar between 1996 and 2016, and the changes in natural gas liquids and primary electricity are very small in contrast to overall energy exports.

In the case of biofuels, the domestic production of ethanol is far from sufficient to meet demand, and, as a result, all production and a sizeable quantity of imports are needed. The picture is different for biodiesel (Table 2.6), where net trade is small and exports and imports largely reflect geographic drivers for demand. The lower mandates for blending biodiesel into diesel fuel also help explain this situation.

Table 2.6 – Production and trade of biofuels in Canada (2016)

	Ethanol (million litres)	Biodiesel (million litres)
Production	1700	430
Imports	1102	374
Exports	0	422
Domestic consumption	2802	382

Source: NRCAN 2018

Finally, electricity trade, which is better understood from a provincial perspective, is discussed below.

2.3.2.1 Provincial variations

Alberta is home to the bulk of Canadian fossil fuel production. In crude oil extraction, the province's output has more than doubled since 2001. Saskatchewan's and Newfoundland's production has also come to represent a large share, while about half of the rest of Canadian production comes from British Columbia (Table 2.7).

Table 2.7 – Crude oil production, by province

	1996 (PJ)	2001 (PJ)	2006 (PJ)	2011 (PJ)	2016 (PJ)
Alberta	3549	3284	4063	5076	7068
Saskatchewan	828	952	953	987	1059
Newfoundland and Labrador	0	336	N/A	N/A	481
British Columbia	102	103	90	84	140
Other	77	101	N/A	N/A	131
Canada	4555	4777	5905	6890	8879

Source: Statistics Canada 2018a

Table 2.8 – Natural gas production, by province

	1996 (PJ)	2001 (PJ)	2006 (PJ)	2011 (PJ)	2016 (PJ)
Alberta	5116	5594	5491	4191	4849
British Columbia	758	1008	1159	1511	1738
Saskatchewan	291	314	363	236	201
Other	11	281	192	144	108
Canada	6177	7196	7205	6082	6896

Source: Statistics Canada 2018a

Alberta also dominates natural gas production, even though it saw its output decrease between 2001 and 2011 (Table 2.8). British Columbia is comfortably in second place for gas production, while Saskatchewan, with a much smaller production, ranks third. Despite a 129% increase in production from British Columbia from 1996 to 2016, overall Canadian production decreased. This is a result of the rapid expansion of shale gas in the United States after 2006, leading to a deep price fall as conventional resources depleted in both Alberta and Saskatchewan.

Some 85% of coal production comes from Alberta and British Columbia (NRCAN 2018). Specific production numbers for each province are confidential, but Alberta produced 41% of the total in 2015. Natural gas liquids production, which reached 761,776 TJ in 2016, came predominantly from Alberta (69%) and Ontario (18%).

Provinces also show important variations in their electricity mix. Quebec and Manitoba are almost entirely supplied by hydroelectricity with some wind energy as well, while Prince Edward Island's generation is almost entirely from wind. Ontario and New Brunswick are the only two provinces with nuclear generation, and coal is used in five provinces – Nova Scotia, New Brunswick, Alberta and Saskatchewan, as well as minimally in Manitoba. Given that the electricity sector is a favourite target for GHG emission reduction policies; this provides provinces with widely differing opportunities, as hydroelectric and other renewable energy potential, plus the presence or absence of coal-fired generation, greatly affects the options available to each province.

In addition, interprovincial electricity transfers and trade with the United States vary significantly from province to province (Table 2.9). Quebec is by far the largest electricity trader. Its first place in terms of electricity transfers into the province is due the Churchill Falls imports from Newfoundland and Labrador. Quebec is also by far the greatest exporter of electricity to the United States, and is second only to Newfoundland and Labrador for deliveries across provincial borders.

Ontario is the second largest recipient of electricity produced outside its borders. Interprovincial receipts, which represent imports from other Canadian provinces, constitute the bulk of this electricity. On the export front, Ontario is also in second place for exports to the United States. Manitoba, British Columbia and New

Table 2.9 – Electricity, interprovincial transfers and U.S. trade (2016)

	Imports from U.S. (GWh)	Interprov. receipts (GWh)	Total receipts (GWh)	Exports to the U.S. (GWh)	Interprov. Deliveries (GWh)	Total deliveries (GWh)
Quebec	13	30 807	30 820	31 382	12 025	43 406
Newfoundland and Labrador	-	26	26	-	29 011	29 011
Ontario	706	7 516	8 222	19 328	2 902	22 230
Manitoba	67	1 116	1 183	10 655	893	11 548
British Columbia	1 145	556	1 701	6 789	283	7 072
New Brunswick	148	5 458	5 605	4 900	1 415	6 315
Alberta	138	297	435	110	746	856
Prince Edward Island	-	982	982	-	274	274
Saskatchewan	18	408	426	196	14	211
Nova Scotia	-	406	406	-	28	28
Canada	2 233	-	2 233	73 361	-	73 361

Source: Statistics Canada 2018f

Brunswick also export a large quantity of the electricity they produce to the United States.

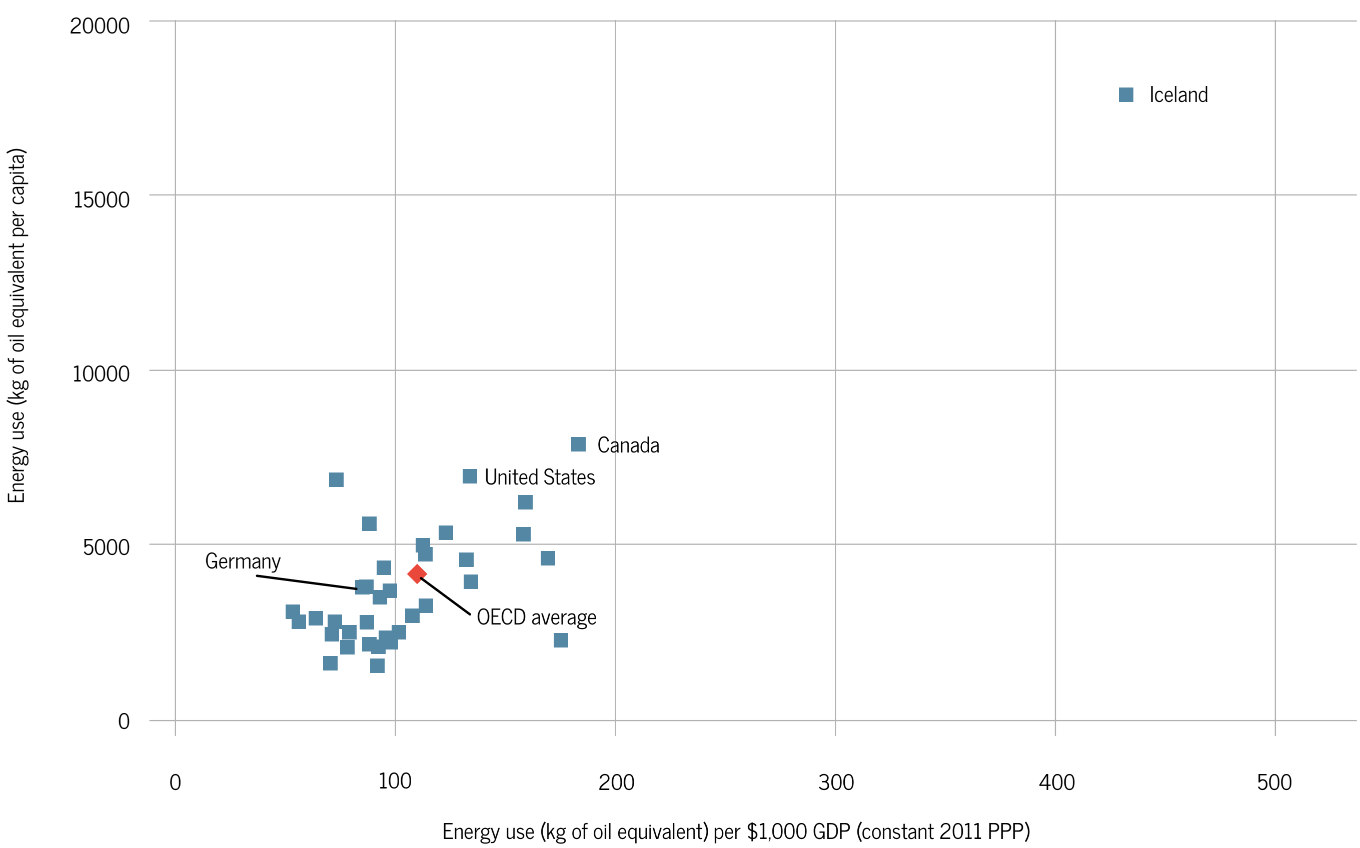
Overall, Canada exported 73.3 millions of MWh to the United States in 2016, for a total of $3 billion worth of sales. Fifty-four percent of this amount was received by Quebec, despite a smaller share of electricity traded in terms of quantity (43%). This suggests that Hydro-Québec manages to seize more profitable trading opportunities than its counterparts in other provinces. The recent agreement to build a transmission line to participate in Massachusetts' supply should enhance this position.

Overall, the Canadian energy production sector is characterized by a large, geographically concentrated oil and gas sector, as well as by varying provincial electricity mixes and trading profiles. Developments over the past 20 years have seen oil extraction expand significantly, and these activities have come to represent a dominating share of Canadian energy production and trade. This partly explains the developments in pipeline construction described in Section 2.1 – along with increased public opposition. Additionally, electricity trade with U.S. states looking to expand their supply from non-emitting sources, notably within Hydro-Québec's reach, has created potential for an expansion of these exports, although to a much lesser extent than for crude oil.

2.3.3 Energy efficiency

Canada is among the world's largest energy users on a per capita basis, surpassing all OECD countries with the exception of Iceland.[3] As Figure 2.10 shows,

Figure 2.10 – OECD members energy use and intensity (2014)



Source: WDI 2018

[3] The expansion of energy-intensive industries, such as aluminum, in Iceland, along with its very small population, explains its outlier energy profile.

Canada's per capita energy use in 2014 was greater than that of the United States, twice as large as that of Germany, and almost twice as large as the OECD average. This position can be partly explained by Canada's larger consumption in the industrial and transport sector. The colder climate also plays a role in this profile. Figure 2.10 also shows that the energy required to produce $1,000 of GDP is more significant than in comparable economies. As a result, Canada ends up in the upper right extremity of the chart for the main group of countries.

The evolution of these indicators shows that energy use per capita decreased only slightly (-5%) over the 1996-2015 period, despite a significant decrease in energy intensity (-29%). This leads to two general observations. The first is that although Canada's energy intensity diminished significantly over the period, it was not enough to catch up with other industrialized economies, as Figure 2.10 illustrates. The second conclusion follows from the fact that energy consumption per capita would be greater without the energy efficiency improvements that occurred during the period. A lower energy intensity generally implies that a smaller quantity of energy is needed to satisfy similar needs, and, as a result, the fact that energy use remained at the same level despite a decrease in intensity implies a larger demand for energy services.

Overall then, this situation is largely due to the rapid expansion of the industrial sector, most notably in oil production. Energy efficiency improvements in some energy-intensive sectors (notably iron, steel, pulp and paper) have been offset by rising demand in the mining and quarrying industries, including first and foremost oil and gas extraction (OECD 2017).

This conclusion is confirmed by looking at variations across provinces (Table 2.10). Not only do most provinces have a lower per capita energy use than Canada as a whole: the only three provinces pegged above the Canadian average are Alberta, Saskatchewan and Newfoundland and Labrador, three provinces that are home to a large oil sector, and in the case of Alberta and Saskatchewan, a large natural gas production sector as well. For Alberta and Saskatchewan, this departure from the Canadian average is remarkably large, representing more than twice the average per capita energy use in the country. Nevertheless, this outstanding role of the oil sector should not mask the fact that even low-consumption provinces by Canadian standards remain at higher levels than most other countries around the world.

Table 2.10 – Total energy use per capita, by province (2016)

	Total energy use per capita (GJ)
Alberta	776
Saskatchewan	639
Newfoundland and Labrador	352
Canada	*294*
Territories	251
New Brunswick	243
Manitoba	238
British Columbia	233
Ontario	210
Quebec	207
Nova Scotia	170
Prince Edward Island	154

Source: Statistics Canada (2018a, 2018c)

The large role played by the fossil fuel extraction sector and the overall high consumption level are key features of the Canadian energy profile. While the relative importance of these industries in Canada compared to many other countries is undeniable, it is essential to obtain a measure of their true weight in the country's economy. The next section presents an overview of this weight.

2.4 Contribution of energy to the Canadian economy

2.4.1 GDP and employment

Table 2.11 presents several indicators describing the energy sector's contribution to the Canadian economy. Factoring in indirect jobs and economic activity, energy contributes $188 billion to the Canadian GDP, representing 9.9 % of the total, though 4.9% of its total employment.

All forms of energy together contribute to 18% of merchandise exports. While these exports went to 144 countries in 2016, 92% of energy exports (by value) targeted the United States market. Furthermore, the United States is the destination of 79% of Canadian crude oil production, 53% of natural gas production, 31% of uranium, 21% of petroleum products and 11% of electricity generated in Canada.

Energy exports from the oil and gas sector dwarf all other categories, totalling $75 billion in 2016 (close to 16% of merchandise exports), with 97% of the total going to the United States. The importance of these exports highlights Canada's key position among the energy trading partners of its neighbour to the south, constituting 41% of the United States' crude oil imports, 97% of its natural gas imports, 25% of its uranium imports and 25% of its petroleum products imports. Canadian energy imports also come predominantly from the U.S. (65% of total), with crude oil and natural gas respectively representing 27% and 19% of Canadian consumption of these fuels (NRCAN 2018).

Direct jobs in the energy sector represented 1.5% of Canadian employment in 2016 (Table 2.12). Over a quarter of this employment was in the crude oil industry, overwhelmingly in Alberta, while a similar share was employed in the electricity sector (NRCAN 2018). This highlights the fact that, despite the very high value of crude oil production and exports, the number of direct jobs created by the sector is relatively small: for the overall energy sector, the 9.9% contribution to GDP (Table 2.11) is twice the share of the sector's employment in the Canadian workforce (4.9%).

2.4.2 Research, development and demonstration (RD&D)

Around 8% of public RD&D spending goes to the energy sector, which is roughly in line with the sector's 9.9% contribution to the country's GDP (OECD 2017). Federal RD&D spending remained constant since 2012 before increasing in 2015-2016. However, provincial spending varied substantially over the same period. From 2011-2012 to 2013-2014, provincial funds more than doubled, with the largest share of this increase going to carbon capture, utilization and storage (CCUS). Since 2013-2014, both CCUS and other RD&D spending were halved at the provincial level, the former due

Table 2.11 – Energy facts (2016)

Direct contribution to GDP	$127 billion	(6.7%)
Indirect contribution to GDP	$61 billion	(3.2%)
Total contribution to GDP	$188 billion	(9.9%)
Direct jobs	271 517	
Indirect jobs	612 905	
Total jobs	884 422	(4.9% of total)
Exports	$85.7 billion	(18% of merchandise exports)
Imports	$35.9 billion	(7% of merchandise imports)

Source: NRCAN 2018

Table 2.12 – Direct jobs and contributions to GDP from the energy sector

Jurisdiction	Direct jobs (2016)[a]	Direct contributions of energy to GDP ($ million, 2016)
Canada	271 517	127 000
Alberta	141 145	68 291
British Columbia	19 465	8 098
Manitoba	6 070	3 383
New Brunswick	4 790	2 159
Newfoundland and Labrador	6 035	5 207
Nova Scotia	2 685	1 113
Ontario	36 710	15 589
Prince Edward Island	265	107
Quebec	24 435	14 956
Saskatchewan	21 185	13 716
Northwest Territories	480	292
Nunavut	255	51
Yukon	235	35

Source: NRCAN 2018

[a] Provincial and territorial figures do not sum up precisely to the national total, due to differences in data methodology

Table 2.13 – Expenditures on total energy RD&D by technology area ($ millions)

	Federal (2015/2016)	Provincial & Territorial (2015/2016)	Industry (2014)
Fossil fuels (incl. CCUS)	92	228	1 392
Renewable and clean energy (incl. nuclear)	243	113	509
Energy end use (incl. energy efficiency)	165	52	186
Total	500	394	2 087

Source: NRCAN 2018

to the completion of the Saskatchewan Boundary Dam CCUS project. The 2015-2016 period is also the first time in several years that federal funds represented the majority of RD&D spending.

Table 2.13 presents the breakdown of this spending according to categories of research for 2015-2016, with 2014 figures provided for industry as more recent data was unavailable. More than 80% of federal spending went to clean energy and energy end-use, while this figure is only 42% for provincial RD&D funds. This is partly due to the importance of CCUS spending at the provincial level, which remains at $184 million for 2015-2016. Finally, industrial actors spent a larger portion of RD&D on fossil fuels, which reflects the size of the Canadian oil and gas industry.

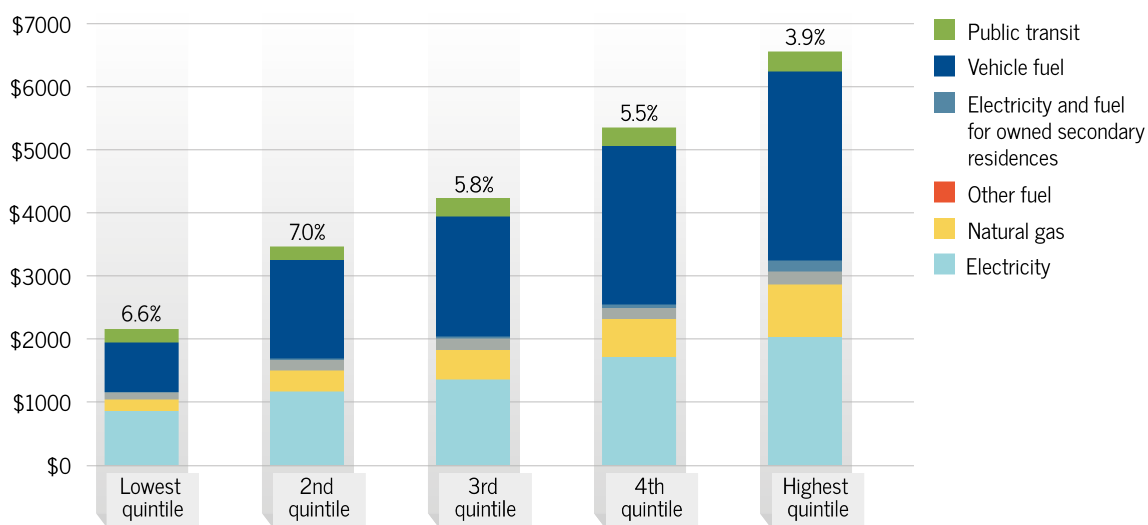
Overall, funding allocated to energy-related RD&D supporting renewable energy and energy efficiency is among the lowest in the OECD, although government investments in clean energy research is planned to double by 2020 under Mission Innovation (OECD 2017).

2.4.3 Household spending on energy services

With respect to household spending on energy, while residential energy use increased by almost 9.5% since 1990, it would have increased by 57% without energy efficiency improvements, which saved 672 PJ of energy and $12 billion in energy costs (NRCAN 2018). In order to more closely examine how these expenses affect Canadian households, Figure 2.11 shows the distribution of energy expenditures according to income quintiles. The average Canadian household spent a little over $4,000 on energy in 2016, and the share of each fuel remains more or less similar across quintiles 2 to 5. Only the lowest quintile has a different distribution, with electricity being more important than for other quintiles, while the opposite is true for vehicle fuel. Around half of energy expenditures for the average household are tied to transport.

Despite a rise in overall household spending of 17% between 2010 and 2016, in the main, energy expenditures remained constant; variation from year to year can primarily be attributed to vehicle fuel. These transport costs are also the only category that increased over the period (+18%), while natural gas, electricity, and other fuel spending decreased.

Figure 2.11 – Annual household energy expenditures, by income quintile (2016)



Source: Statistics Canada 2018g

Note: Electricity, natural gas and other fuels categories represent expenditures linked to households' principal accommodation. Public transit expenses are included as they are linked to daily transport services, which is a similar function than vehicle fuel. Percentages indicate the share of these expenditures in total annual household expenditures.

A closer look at these numbers reveals a few noteworthy facts. First, the share of energy-related expenses in total household expenditures is much lower for richer quintiles than for the first two. This indicates that spending on basic energy services (space and water heating, daily transport needs, and electricity use for appliances and lighting) is a heavier burden for lower income families. Despite a steady and steep increase in total energy expenditures across income quintiles, this burden is almost halved from the two lower-income quintiles to the highest one.

A second insight is that transport services represent both a much greater share and larger absolute values across income levels: vehicle fuel expenses for the richest quintile, for instance, are almost four times those of the first quintile. A difference of this magnitude cannot be explained by different transport service needs. Instead, it more likely stems from the use of a higher number of vehicles per household, less efficient modes of transportation, or both. This is in addition to the fact that flight expenses are not included in these numbers: nonetheless, these expenditures are more than four times larger in the fifth quintile than in the first.

As concerns variations in provincial profiles, one major distinction is related to the natural gas used for household consumption. The share, in terms of expenditures, of natural gas used in main residences is higher in Manitoba (12%), British Columbia (15%), Saskatchewan (17%), Ontario (17%) and Alberta (21%), than in the other five provinces, where households spend less than 2% of their energy expenditures on this function.

This shows that natural gas in the residential sector remains marginal in Quebec, Newfoundland and Labrador, New Brunswick, Nova Scotia, and Prince Edward Island. Although Quebec's commercial sector consumption of natural gas is substantial and almost as large as electricity, this is not the case for Atlantic provinces, where there are very limited natural gas distribution networks.

While Quebec's more limited use of natural gas for residential heating is offset by a more extensive use of electricity, the Atlantic provinces differ from the rest of Canada in their reliance on other fuels (notably heating oil and wood) to heat their homes. The role of these fuels remains marginal for all other provinces (Statistics Canada 2018g).

2.5 Key trends

The Canadian energy system is characterized by the importance and size of its energy sector, and by substantial variations across provinces in both energy consumption and production profiles. First, the contribution of the production sector to the economy is chiefly tied to oil and gas extraction, most particularly oil exports. Even recent increases in electricity trading and production remain marginal compared to the value of oil and gas exports, although the fossil fuel sector sustains a smaller share of the workforce than its contribution to GDP would suggest (see Section 2.4.1).

The geographic concentration of oil and gas production also helps explain a large part of the differences in energy use profiles across provinces. Alberta, notably, comes in second place well before Quebec and British Columbia, despite a smaller population. More generally, on a per capita basis, the structure of provincial industrial sectors is the leading factor explaining why Alberta's and Saskatchewan's energy use is more than twice the level of any other province, with the exception of Newfoundland and Labrador. Given the GHG intensity of these industries, it is clear that efforts to reduce GHG emissions necessitate an approach that focuses on them first and foremost if the federal government's 2030 target of reducing national emissions by 30% is to be met.

Industry is not the only sector that requires special attention. In addition to being the second source of GHG emissions at the national level, the transport sector is either in first or second place in every province (after industries) in terms of energy use. Consumption in both freight and passenger transport, even on a per capita basis, continues to increase rapidly, and household expenditures for energy services show little aversion to spending more on transport when income allows.

Understanding the composition of the Canadian consumption profile is essential to a discussion on transforming the energy system and finding effective avenues for reducing GHG emissions.

The starting point: Canada's energy system in 2018

As the next chapter points out, energy-related emissions represent over 80% of the total. Given that Canadian per capita energy consumption is very high, even outside of considerations linked to oil and gas production, effective policies to change this profile and the quantity of GHG emitted by the Canadian economy must be able to address the root causes of these consumption patterns.

Bolstered by new pipeline projects, oil and gas export activities show little signs of slowing down. Additionally, expenditures and consumption in transport also continue to rise. Consequently, government action to steer the Canadian energy system in a different direction requires strong commitment and carefully designed policies. Chapter 3 describes recent provincial and federal efforts to this effect.

3

Policy focus: accelerating the deployment of GHG reduction strategies

This chapter provides a comprehensive overview of the policies, in place or in development, aimed at reducing greenhouse gas (GHG) emissions at both the provincial and the federal levels. Like much of the rest of the world, the provinces and the federal government have adopted various objectives, targets and strategies with respect to GHG emissions that demonstrate a diversity in approaches and ambitions and underline the challenge of establishing a coherent national program.

Highlights

Most Canadian provinces have adopted GHG emission reduction targets. However:

- Despite the proliferation of action plans and strategies, details on how targets will be reached – including costs, technologies, and pathways – are scant or entirely lacking.
- This makes it difficult to see how these strategies will translate into reality.

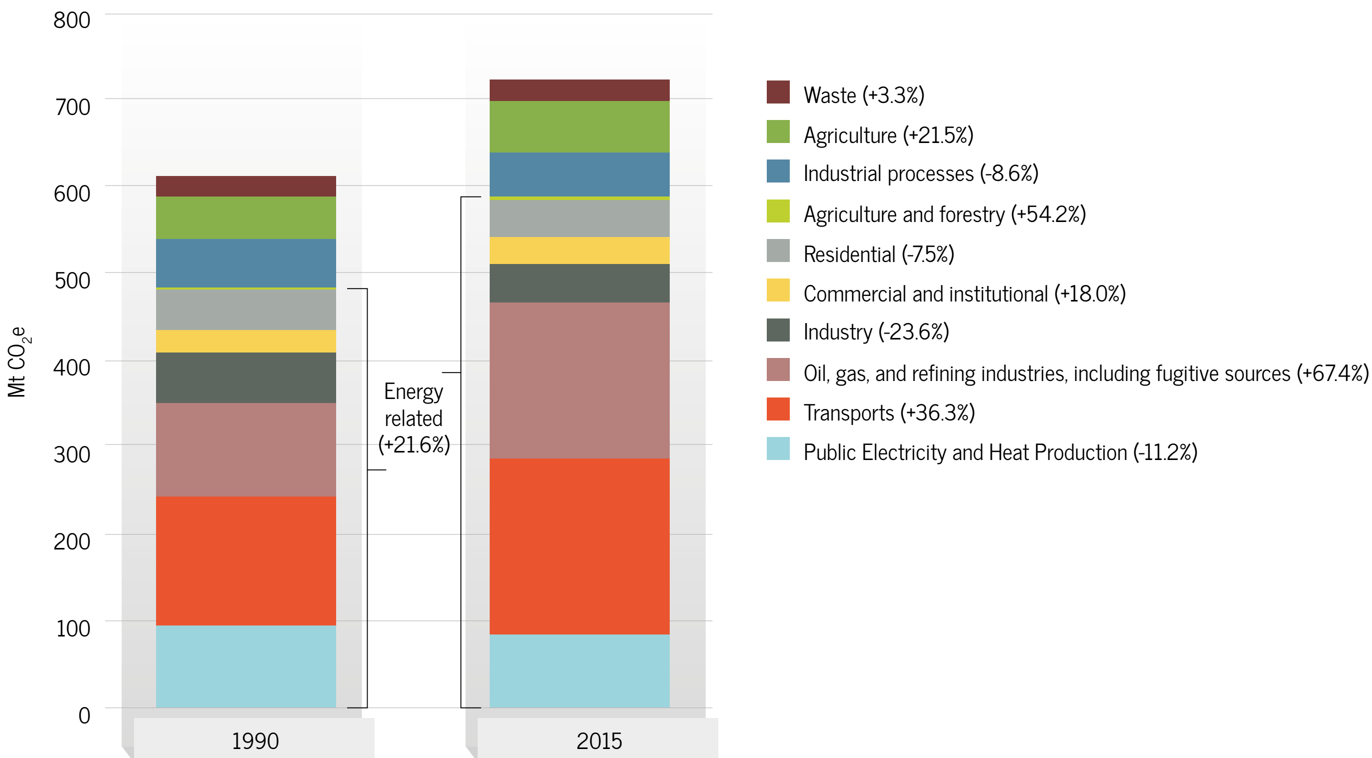
The federal government's efforts – notably through commitments under the Paris Agreement and the Pan-Canadian Framework on Clean Growth and Climate Change (PCF) – have been welcomed by most provinces. Strong disagreements remain, especially on carbon pricing, with Saskatchewan and, since the election of the Progressive Conservatives, with Ontario.

According to the federal plan presented to the UN, 25% of the reduction needed to meet its 2030 target will come from emission allowances purchased from California.

- This is assuming that all current action plans turn into fully implemented policies and work as intended.

Policy focus: accelerating the deployment of GHG reduction strategies

Figure 3.1 – GHG Emissions in Canada by sector



Source: ECCC 2018

Note: Percentages indicate the change between 1990 and 2015.

3.1 Energy-related GHG emissions in Canada

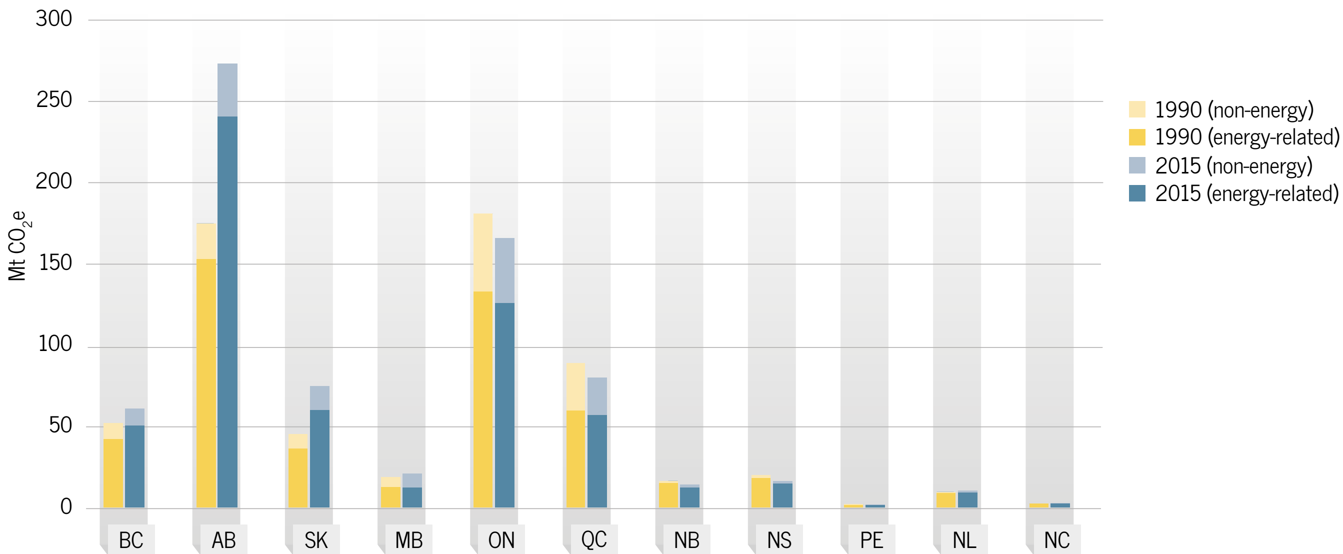
Energy-related emissions make up 81.3% of Canada's total GHG emissions. While total emissions increased by 18% from 1990 to 2015, emissions relating to energy grew more rapidly, climbing by 21.6%. The carbon intensity per dollar of GDP did, however, decrease by 33% (9% on a per capita basis), as transformations in the industrial sector, technological improvements, regulations and more efficient equipment and practices had beneficial impacts (NRCAN 2018a).

Figure 3.1 shows the main sources of emissions in 1990 and 2015. While the electricity and heat production sector, the industrial sector – outside of oil and gas industries – and the residential sector have all reduced their emissions over the 2005-2015 period, this reduction has been more than offset by increases in the transport sector, the commercial and institutional sector, and the oil and gas upstream and refining industries. The latter is now the second single source of emissions after transport. Technological improvements in oil sands production, which reduced emissions per barrel by 12% from 2005 to 2015, only partly tempered this evolution. In the transport sector, freight and passenger transportation each make up about half of emissions (NRCAN 2018a).

The decrease in emissions emanating from the electricity sector can be traced to fuel switching, notably the replacement of coal by natural gas and renewable technologies in Ontario. The recently announced policies to phase out coal at the national level and in Alberta should continue this trend for the medium term, although equivalency agreements allowing other provinces to continue using this source of electricity mean that coal will remain a part of the electricity mix beyond 2030 (Flanagan et al. 2017).

Figure 3.2 shows the breakdown of total emissions by province. Given the importance

Figure 3.2 – GHG Emissions by province and territory, 1990 and 2015



Source: ECCC 2018

Note : Northern Canada includes the Nunavut, Yukon, Northwest Territories.

of the oil and gas sector, Alberta represents by far the largest emissions on a provincial basis. As well, Saskatchewan's emissions are also much larger than its population and economic size would suggest. These two provinces also present the largest increase in GHG emissions over the 1990-2015 period, a direct consequence of increased oil and gas production.

The importance of the evolution of the industrial sector – and, in particular, oil and gas production – should not be understated. Alberta's energy-related emissions increase, for instance, is as large as the overall emissions of Quebec, a much larger province in terms of population and economy. In the case of Saskatchewan, the province's energy-related emissions increase is larger than the combined increase of all other provinces outside of Alberta, even if we disregard provinces that managed to reduce their emissions.

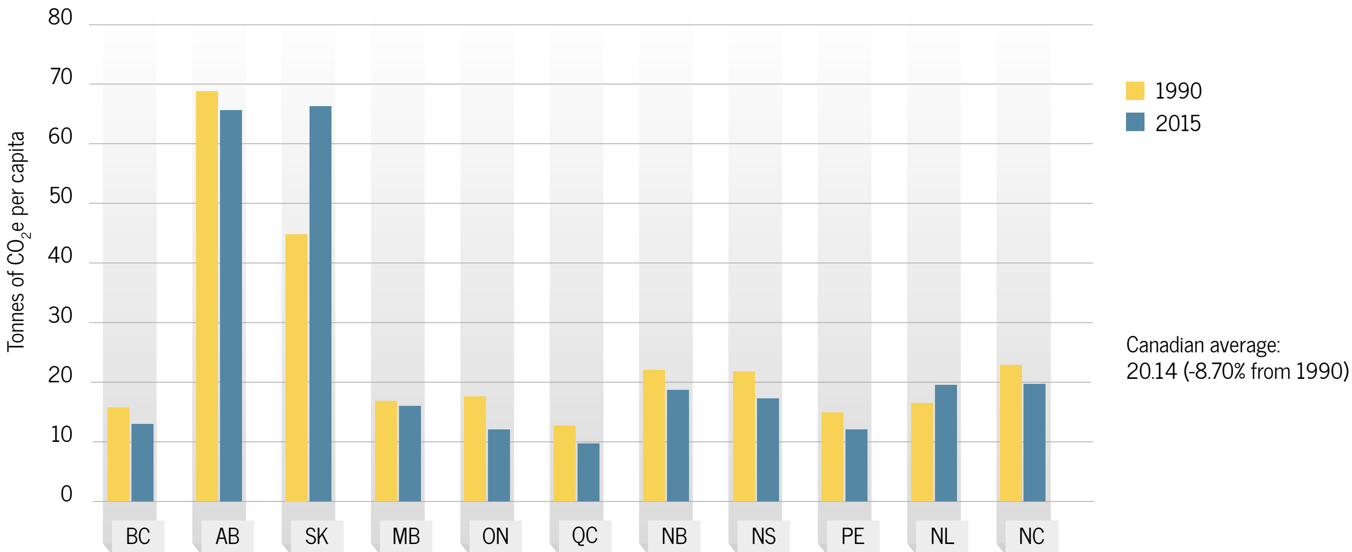
These trends also explain a large part of the wide discrepancy in per capita emissions between Alberta and Saskatchewan on the one hand, and all other provinces on the other (Figure 3.3). Larger per capita figures for the transport sector, as well as a more important presence of fossil fuels in electricity generation, also contribute to this discrepancy.

Building on its oil and gas sector, Canada is one of the few countries operating two carbon capture and storage (CCS) operations. One is the Boundary Dam coal-fired power station in Saskatchewan, where captured carbon is sold to a company for use in oil recovery. The other is the Quest project in Alberta, where the capture operation is applied during the conversion of bitumen extracted from oil sands into higher grade oils (OECD 2017). As a result, the financial viability of both projects, even with massive subsidies, is closely linked to oil extraction operations.

3.2 General overview of policies: targets and objectives

Canada and its provinces have recently announced several policies relating to energy, GHG emissions and carbon pricing. These policies present a long list of objectives and targets that largely revolve around changing energy consumption patterns and behaviour, favouring certain technologies over others, encouraging the production and use of renewable energy, decreasing GHG emissions, and pricing carbon emissions. There is significant overlap, complementarity

Figure 3.3 – Evolution of per capita GHG Emissions in Canada



Source: ECCC 2018

Note: Data for Nunavut and Northwest Territories population is from 1991

and compatibility among these objectives, and most policies highlight more than one.

Table 3.1 summarizes the targets adopted by the federal government and by each province. Targets are specified for the following four categories: reductions in GHG emissions, changes to the energy mix and the share of renewable sources, incentives for the electrification process, and energy efficiency improvements. The column on GHG emissions reductions indicates the year of reference for calculations, in addition to the year when the target must be met.

Since the table merely indicates the current state of announced objectives, it does not discriminate as to whether the target has been legislated or regulated at this point. This distinction in the regulatory or legal status of objectives is important. The announcement of a target in a government press release is not the same as the publication of an official strategic plan specifying the target and listing concrete measures for it to be achieved. This, in turn, is also different from the passage of legislation or the publication of a regulation detailing how the government is moving forward on these measures. As a result, while Table 3.1 presents all targets announced to date, scenarios exclude those at the earliest stages of design and implementation. Details on these exclusions can be found in later chapters.

It should be noted as well that even legislated targets and action plans do not automatically result in the successful achievement of targets. As a result, a look at policy details and implementation so far is essential to provide a sense of the scale of efforts deployed by the federal and provincial governments to achieve these targets.

3.3 Policies at the federal level

The Canadian government has put forward several plans, legislations and proposals affecting energy production and consumption in recent years, a number of which are intended to contribute to the 2030 GHG emission reduction target of 30% from 2005 levels. The most important of these is the Pan-Canadian Framework on Clean Growth and Climate Change (PCF), signed by the federal government, the three territories and eight provinces in 2016, as well as by Manitoba in 2018, leaving only Saskatchewan out at the moment. One of the central components of the PCF is the Pan-Canadian Approach to Pricing Carbon Pollution, which gives the provinces the flexibility to implement an explicit price-based system (e.g., a carbon tax or levy) or a cap-and-trade system. To ensure a minimum price on carbon across the country, the federal government will impose a backstop option in the provinces that choose not to set up their program by 2018, irrespective of whether or not they signed the PCF (Canada 2017a).

The Canadian government also announced a plan to phase out coal in electricity generation by 2030. Four provinces currently use coal in electricity generating facilities: Saskatchewan, Alberta, New Brunswick and Nova Scotia.[1] The initiative is intended to help Canada meet its target of deriving 90% of its electricity production from non-emitting sources by 2030 (Canada 2017b). The plan is in accordance with Canada's participation in the Power Past Coal Alliance, formed by a group of countries that have vowed to take action to accelerate clean growth and climate protection through the rapid phase-out of traditional coal power (Canada 2017c). This transition is intended to be supported through the financing of clean energy and modern electricity systems by the Canada Infrastructure Bank (Canada 2016).

In the transport sector, the federal government imposes several taxes on fuel consumption, including a $0.10 tax on gasoline and a $0.04 tax on diesel (including biodiesel). It also imposes an excise tax on the purchase of fuel-inefficient vehicles that, however, does not apply to pick-up trucks or sport-utility vehicles (OECD 2017). In 2016, the federal government announced the development of a Clean Fuel Standard, which would require the lifecycle carbon footprint of fuels to decrease over time in a performance-based approach to favour the use of low-carbon fuels, energy sources and technologies. This includes electricity, hydrogen and renewable fuels such as renewable gas.

With regard to the electrification of transport, Canada participates in the IEA's Clean Energy Ministerial EV30@30 international program, which aims for a 30% sales share for electric vehicles by 2030. Natural Resources Canada has also planned for a $120 million investment in electric vehicle charging infrastructure in 2017. More recently, Transport Minister Marc Garneau announced that a zero-emission vehicle strategy would be presented in 2018 after the completion of a consultation process.

In addition to these announcements, the Greening Government Strategy was presented in late 2017, with the objective of decreasing energy consumption and GHG emissions in government buildings through repairs and retrofits, as well as investments to transform its vehicle fleet to favour electric and hybrid vehicles. The strategy sets targets for GHG emission reductions for government operations at 40% by 2030 (with 2005 as the baseline) and 80% by 2050 (Canada 2018e).

Furthermore, the Federal Sustainable Development Strategy 2016-2019, the third of its kind since the passing of the parent Federal Sustainable Development Act in 2008, establishes goals linked to the United Nations Sustainable Development Goals. First, it sets an objective for federal government buildings to be powered by 100% clean power by 2025. Second, it puts forward the target of developing regulations to reduce methane emissions from the oil and gas sector by 40-45% below the 2012 level by 2025 in partnership with the United States and Mexico. Third, regulation must be developed to regulate HFCs, a GHG used in a broad variety of applications (refrigeration, insulation and air conditioning, in particular), under the Montreal Protocol (Canada 2018f).

Finally, in 2016, Canada joined the United States and Mexico in signing the trilateral Memorandum of Understanding Concerning Climate Change and Energy Collaboration, which is aimed at achieving 50% clean power generation in North America.

Since many of these policies and announcements are very recent, a closer look at the details and actions presented so far is essential for an assessment of the current state of affairs. As for the federal backstop carbon pricing system, which will be enforced in provinces that choose not to have their own program by the end of 2018, details were released by the government at the end of 2017. This system will be comprised of the following two elements: a charge on fossil fuels, paid by fuel producers and distributors, which will start at \$10/tonne of CO_2e in 2018 and rise by \$10 per year to \$50/tonne of CO_2e in 2022; and an output-based pricing system for industrial facilities with high levels of emissions (> 50 000 tCO_2e).

In the output-based pricing system, facilities covered will be evaluated in relation to an emission standard for their activity sector. Facilities emitting less than this standard will be issued surplus credits

[1] Manitoba also has a small generating capacity at the Brandon power plant that only serves for emergency purposes.

Table 3.1 – Federal and provincial objectives[1]

Jurisdiction	GHG Emissions	Energy mix and renewables	Electrification	Efficiency
Federal	≫ -30% by 2030, from 2005 ≫ -80% by 2050, from 2005[2] ≫ -40% by 2030, from 2005, for federal operations (government buildings and fleets) ≫ -40-45% by 2025 methane emissions from the oil and gas sectors, from 2012	≫ Renewable fuels regulation: 5% blend in gasoline, 2% in diesel ≫ Clean Fuel Standard being developed ≫ 90% non-emitting sources for power generation by 2030, 100% in the long term ≫ By 2025, contribute to the North American goal of 50% clean power generation		
Alberta	≫ <100 Mt annual oil sand emissions from 2017 on ≫ -45% by 2025 methane emissions from upstream oil and gas, from 2014 ≫ 0% coal-generated electricity pollution by 2030	≫ Coal phase-out by 2030 ≫ Renewable fuels: 5% of gasoline and 2% of diesel content must be renewable ≫ 30% electricity generated by renewable sources by 2030		
British Columbia	≫ -33% by 2020, from 2007 ≫ -80% by 2050, from 2007	≫ 5% of gasoline and 4% of diesel content must be renewable ≫ -10% in carbon intensity of fuels by 2020 from 2010 levels, -15% by 2030		
Manitoba	≫ -33% by 2030, from 2005 ≫ -50% by 2050, from 2005 ≫ Carbon neutral by 2080	≫ Renewable fuel mandate: 8.5% blend in gasoline, 2% in diesel ≫ Target of 2.3 GW of new hydro and 1 GW of wind power		≫ -22.5% electricity consumption in 15 years ≫ -11.25% gas consumption in 15 years
New Brunswick	≫ -10% by 2020, from 1990 ≫ -35% by 2030, from 1990 ≫ -80% by 2050, from 2001	≫ Regulation under the Electricity Act requires NB Power to achieve 40% of in-province electricity sales being provided from renewable energy by 2020	≫ 2 500 electric vehicles on the road in New Brunswick by 2020 and 20 000 by 2030	
Newfoundland and Labrador	≫ -10% by 2020, from 1990 ≫ -75-85% by 2050, from 2001			≫ Reducing energy consumption by 20% by 2020 from business-as-usual projections.

[1] Sources for this table are found in Appendix A

[2] At this time, this is only a target for governmental operations. However, Canada's Mid-Century Long-Term Low-Greenhouse Gas Development Strategy uses this target in its modeling because it is consistent with the Paris Agreement. In view of this, and to simplify the terminology used throughout this Outlook, we treat it as a long-term target for 2050 for all energy-related emissions.

Jurisdiction	GHG Emissions	Energy mix and renewables	Electrification	Efficiency
Nova Scotia	≫ -10% by 2020, from 1990 ≫ -80% by 2050, from 2009	≫ 40% renewables in the electricity mix by 2020		
Ontario	≫ -15% by 2020, from 1990 ≫ -37% by 2030, from 1990 ≫ -80% by 2050, from 1990	≫ 10 700 MW of wind, solar PV and biomass by 2021 ≫ 20 000 MW of renewable energy capacity by 2025 ≫ Renewable fuel standard: 5% blend in gasoline and 4% in diesel[3]	≫ 5% of EVs in total sales in 2020	
Quebec	≫ -20% by 2020, from 1990 ≫ -37.5% by 2030, from 1990 ≫ between -80% and -95% by 2050, from 1990	≫ -40% 2013 oil product consumption by 2030 ≫ +25% 2013 renewable energy production by 2030 ≫ +50% 2013 bioenergy production by 2030 ≫ Elimination of thermal coal	≫ 3.5% of EV (or PH or hydrogen) for new vehicles sales for 2018, increasing progressively to 22% in 2025 ≫ 100 000 EVs by 2020 ≫ 1 000 000 by 2030	≫ +15% 2013 energy efficiency by 2030
Prince Edward Island	≫ -30% by 2030, from 2005			Achieve savings of 2% per year in the electricity sector
Saskatchewan	≫ -40% by 2030[4], from 2005	≫ 50% renewable energy electricity generation capacity by 2030 ≫ Renewable fuels: 7.5% minimum blend in gasoline and 2% in diesel		
Territories	≫ Northwest Territories: return to 2005 emission level by 2030 ≫ Yukon: various targets for government operations (carbon neutral by 2020) ≫ Nunavut: no formal plan to reduce emissions but targets for government and government-funded buildings			

[3] Legislation has been presented to increase this to 10% ethanol in gasoline starting in 2020.

[4] Not a specific target, but results from the 50% renewable power target.

by the federal government, while those emitting above the standard will be required to either submit credits issued by the government, submit eligible offset credits, or pay a carbon charge (set at the same level as the fuel charge described above).

Covered emission sources will include fuel combustion, industrial processes, flaring, and some venting and fugitive sources, excluding methane venting and fugitive methane emissions from oil and gas facilities. Revenues from the proceeds would be sent back to the jurisdiction of origin (Canada 2018a, 2018b, 2018c). In January 2018, the government presented legislation and regulation proposals to implement this system (Department of Finance Canada 2018). A methodology on developing the standard consistently across sectors is being discussed; the government proposed that standards be set in most cases at 70% of the production-weighted national average of the emission intensity for the sector.

With regard to reductions in methane emissions, the federal government released a technical backgrounder specifying that the first federal requirements come into force in 2020 (2023 for the others). The regulations for achieving this objective, proposed in May 2017, apply to oil and gas facilities that function for the purpose of extraction, processing, and transportation (including storage) (ECCC 2017a).

In December of 2017, the government also published a regulatory framework outlining the details of the Clean Fuel Standard and is now waiting for comments from different stakeholders. A draft legislation proposal should be published by the end of 2018 (Canada 2018d). Amendments were also proposed to update regulations on on-road heavy-duty vehicles and engines for models from 2018 (to be released in 2018).

The publication of each of these specifications represents a step forward in implementing the policies described above. Nevertheless, this progress remains preliminary and several measures have yet to materialize or have already been qualified. The coal phase-out plan, for instance, was followed by equivalency agreements with three provinces to allow for coal-fired electricity generation to continue beyond 2030. Additionally, no funds have been invested for the planned $120 million for electric vehicle charging infrastructure. As a result, the follow-up announcements and actions taken by the federal government in 2018 will be crucial in ensuring that these intentions are translated into concrete actions.

Overall, a large portion of these policies has been enacted or proposed by the current Liberal government, elected in 2015, contrasting with more limited activity in this sphere under the previous Harper government. Prior to this election, several provinces had begun introducing measures containing similar objectives to reduce overall emissions, either by raising the share of renewable electricity or by pricing carbon emissions. So far, these efforts have targeted the electricity sector above all, with some initiatives to price carbon developed prior to the current framework announced by the federal government in 2016.

3.4 Policies in the highest GHG-emitting provinces

3.4.1 British Columbia

British Columbia put in place the first broad-scale tax on carbon emissions in 2008, initially at $10/tonne and increased it by $5/tonne per year until it reached $30/tonne in 2012, when the decision was taken to freeze the level. The tax had the particularity of being legislated as revenue-neutral, which ensured that the government cut taxes for individuals or companies each year for an amount equal to the revenues generated by the carbon tax. The province also acted on carbon pricing through the Greenhouse Gas Industrial Reporting and Control Act (GGIRCA), in place since 2016, which puts a price on GHG emissions for industrial facilities or sectors exceeding a threshold, in addition to the application of the carbon tax.

The carbon tax applies to the purchase or use of fuel, and covers around 70% of the province's emissions. Exemptions include the agriculture sector, fuel exports, aviation and external marine, emissions linked to industrial processing, and fugitive methane emissions from the production and transport of fossil fuels. For motor fuel used in internal combustion engines and for propane, an additional Motor Fuel Tax applies as well (British Columbia 2018c).

The exact rate applied for each fuel depends on its carbon content. For example, the carbon tax rate is 6.67¢/litre for gasoline and 7.67¢ for diesel, to which the Motor Fuel Tax is added. The Motor Fuel Tax for gasoline and diesel is also increased by a regional tax for the South Coast British Columbia Transportation Service region (Vancouver area) and the Victoria Regional Transport Service (Victoria area), pushing the total tax to 33.67¢/litre (British Columbia 2017a).

The government of British Columbia also presented a Climate Leadership Plan in 2016, which highlights 21 action items aimed at reducing GHG emissions. The plan includes, for instance, an expansion of the B.C. low-carbon fuel standard and measures to make buildings ready to be net zero in 2032 (British Columbia 2016). The province has also had the Carbon Neutral Government Regulation in place since 2010, enforcing the carbon neutrality of government and public institutions operations (British Columbia 2018d).

In the transport sector, the government of British Columbia introduced the Clean Energy Vehicle program in 2011, which has provided cash rebates of up to $6 000 for the purchase of electric and hydrogen fuel cell vehicles and investments in charging and hydrogen fuelling infrastructure (British Columbia 2018e).

Finally, BC Hydro offers the eDrive rate to LNG producers in order to encourage the use of hydro-electricity instead of natural gas (BC Hydro 2016).

After the May 2017 provincial election, the new NDP minority government, led by John Horgan and forming a coalition with the Greens, released a budget update in September 2017. The update committed to extend and expand the Clean Energy Vehicle program and maintain a system of purchase incentives. More importantly, however, the update included both the elimination of the revenue neutrality of the carbon tax as well as an increase in the rate by $5/tonne per year from 2018 to reach $50/tonne in 2021 (British Columbia 2017b).

This is a major development, as revenue neutrality is a central feature of British Columbia's carbon tax. It has led to a reduction of 5% in the first two personal income tax rates, a low-income climate action tax credit, a northern and rural homeowner benefit of up to $200, reductions in the general corporate income tax rate, reductions in the small business corporate income tax rate, and an industrial property tax credit (British Columbia 2018a, 2018b). Consequently, its elimination represents a significant departure from the original program.

Moreover, the effectiveness of the tax has been limited since its implementation. After the introduction of the tax in 2008, British Columbia's GHG emissions decreased in the following year, but they went back up and have mainly remained constant since (ECCC 2018). As a result, a $30/tonne tax with broad coverage was not enough to reduce the province's emissions. It remains to be seen whether the additional measures since put in place, especially the increase in the tax rate planned for the coming years, will produce results that help the province reduce its emissions to meet its target of 33% below 2007 levels by 2020.

3.4.2 Alberta

In Alberta, several of the key policies related to energy and GHG emission reductions are part of the Climate Leadership Plan, released by the government in 2015. The plan includes a phase-out of coal in electricity generation by 2030, a target stating that 30% of electricity produced in the province must come from renewable energy sources (Alberta 2018b), a legislated annual limit of 100 Mt on GHG emissions from the oil sand sector (Alberta 2018c), and a reduction target of 45% by 2025 for methane emissions. The plan also led to the creation of Energy Efficiency Alberta, a new organization supporting energy efficiency and conservation measures.

Several measures have been put in place to achieve these targets. The Renewable Electricity Program is intended to contribute to the coal phase-out and the 30% renewable electricity target, by aiming to add 5 000 MW of renewable electricity before 2030 through a competitive process of auctions to identify the lowest-cost projects. Furthermore, a carbon levy participates in these objectives. Introduced in 2017 at the rate of $20/tonne of CO_2e and raised to $30/tonne in 2018, the levy applies to diesel, gasoline, natural gas and propane, but not to electricity. The tax is intended to rise to $40/tonne in 2021 and $50/tonne in 2022, to comply with federal requirements. Several exemptions apply, such as marked farm fuel, biofuels, fuel sold for export and some industrial processes. Rebates also apply to low- and middle-income Albertans who spend a significant portion of their income on energy expenses (Alberta 2018a).

In addition to the carbon levy, large industrial emitters – over 100 000 tonnes/year – transitioned from the Specified Gas Emitters Regulation (SGER) to the Carbon Competitiveness Incentives program on January 1, 2018. In the former, these emitters were required to limit a facility's emissions intensity compared to its historical performance. If they did not, they were required to buy credits from better-performing facilities, purchase Alberta-based carbon offset credits or contribute to Alberta's Climate Change and Emissions Management Fund. In contrast, the Carbon Competitiveness Incentives Regulation requires facilities' emissions to be less than the amount freely permitted in their sector of activity. If they do not meet this benchmark, these emitters face options similar to those set out in the SGER.

While Alberta's carbon pricing policies represent concrete action, the implementation of an annual cap on GHG emissions is far from restrictive as the 100 Mt figure is almost 50% above current levels. As a result, the cap implies a significant increase in both the province's overall emissions (and Canada's), and will offset efforts to reduce emissions through the other measures mentioned above. Moreover, regulations on how to enforce the methane emission target have yet to be released.

3.4.3 Saskatchewan

The fourth largest GHG emitter among the provinces and second in GHG per capita, Saskatchewan has long opposed any serious capping or reduction of its emissions, 62 % of which come from electric and energy production sectors. Under pressure from the federal government, in 2017, the government of Saskatchewan released the Prairie Resilience Action Plan, which describes the province's approach and strategy for climate change. The document is mostly descriptive and reiterates the province's strong opposition to a carbon tax, as required under the PCF. It also states that the plan will be followed by more detailed actions, which however were not available at the time of writing. In addition, SaskPower, Saskatchewan's provincial electric utility, set a target in 2015 of doubling its share of renewable electricity generating capacity to 50% by 2030.

Saskatchewan is one of the four provinces that still use coal as a source of electricity generation. The province's opposition to phasing out coal by 2030 to comply with the federal plan has led the two governments to work on setting up an equivalency agreement, which would allow Saskatchewan to meet the new federal emission requirements on an electricity system-wide basis. In Saskatchewan, this implies taking into account the reductions in emissions made at the Boundary Dam Carbon Capture Project, a commercial-scale station that uses a CCS technology.

3.4.4 Ontario

Ontario's early actions to reduce emissions and foster renewable energy include the phasing out of coal-fired electricity and its Green Energy and Green Economy Act (2009), which introduced feed-in tariff support for installations using renewable sources to produce electricity. Preferential rates declined significantly over the years, and the province has since introduced a number of measures to pursue its progress toward meeting its 2020 and 2030 GHG emission reduction targets (-15% and -37% from 1990 levels, respectively).

Notably, the Ontario government passed the Climate Change Mitigation and Low-Carbon Economy Act, 2016, which requires the province to develop climate action plans and specify how cap and trade proceeds will be spent in order to support projects with GHG emission reduction potential. The province also announced the Climate Change Action Plan in 2016, a five-year plan that introduced key actions aiming to help homes and businesses reduce energy costs and participate in meeting the province's emission reduction targets. It also set up the Green Ontario Fund, which finances programs and rebates and is funded by revenues from the cap-and-trade system.

In October 2017, the government of Ontario published its Long-Term Energy Plan, which aims to ensure affordability and reliability to energy consumers over the next 20 years. The Independent Electricity System Operator (IESO) and the Ontario Energy Board was tasked with developing implementation plans, to be submitted to the Minister in early 2018 (Ontario 2017).

Finally, Ontario set up a cap-and-trade system for GHG emission permits, which was linked to that of California and Quebec in January 2018. Allowances for trade-exposed industries are temporarily provided.

Initially, revenues from the carbon market were to be invested in GHG-reducing initiatives, including energy retrofits and incentives for the purchase of electric vehicles. The latter came through the Electric and Hydrogen Vehicle Incentive Program (EHVIP), which offers rebates of up to $14,000 for the purchase of hydrogen or battery-electric vehicles (as well as lower amounts for plug-in hybrid electric vehicles) (Ontario 2018a). Ontario also offered up to $1,000 for the installation of charging stations for home or business use (Ontario 2018b). It also supported the Electric Vehicle Chargers Ontario grant program that was to develop a network of charging stations across the province (Ontario 2018c).

Immediately after its election, In June, the Progressive conservative government announced its intention to withdraw from the carbon market and abolished all related programs. At the moment, the government has not announced any measure to bring the province to meet its 2030 GHG emission reduction target of 37% from 1990 levels. To the contrary, the Ontario government has sided with Saskatchewan in its fight against any federally imposed carbon tax, claiming that technological development was sufficient to meet GHG reduction targets.

3.4.5 Quebec

Quebec's 2020 objective of reducing GHG emissions by 20% over 1990 levels was presented in its *Plan d'action 2013-2020 sur les changements climatiques*. This target, as well as the later commitment to decrease GHG emissions by 37.5% by 2030, are to be achieved in large part through investments by the *Fonds vert*, a fund dedicated to projects with GHG reduction potential.

The fund has been financed by proceeds from Quebec's participation in the Western Climate Initiative's cap-and-trade system with California since 2013, which Ontario joined in 2018. The system covers companies in the industrial and electricity sectors that emit more than 25 000 tonnes of CO_2e annually (for instance, aluminum, refineries, cement plants, and electricity producers), as well as fossil fuel distributors.

In 2016, the Quebec government published its *Politique énergétique 2030*, which outlines targets for the province's transition to a low-carbon economy, as well as the diversification of the province's energy supply and a new approach to fossil fuel energy. The policy sets targets for energy efficiency (+15% by 2030), as well as for a decrease in the consumption of oil products. Legislation formalizing the policy was passed at the end of 2016. The policy also created an institutional body, *Transition énergétique Québec*, tasked with developing cohesive action plans every five years to ensure progress toward the objectives. The first such plan is to be published in 2018.

Over the past few years, Quebec has acted on the electrification of transport, in particular, and offers up to $8 000 as a rebate for the purchase of electric vehicles, in addition to providing $600 for the installation of charging stations in residences. In January 2018, Quebec also started enforcing a zero-emission vehicles standard, which asks automakers to accumulate credits by selling zero-emission or low-emission vehicles. Credits accumulated by automakers must represent 3.5% of total sales in 2018, increasing gradually to 22% in 2025 (MDDELCC 2018). A specified portion of these credits must come from zero-emission vehicles. Automakers that do not meet targets can buy credits from others.

Furthermore, Quebec charges several taxes on fuel, on top of the federal excise tax described in Section 3.2 above (and in addition to federal and provincial sales taxes). This includes a fixed tax on gasoline of 19.2¢/litre (20.2¢/litre for diesel), as well as a public transit tax of 3¢/litre in the Greater Montreal region. The provincial tax is reduced for some remote regions or areas close to the United States border (NRCAN 2018b).

So far, however, efforts toward these objectives have met with limited success. The Fonds vert, in particular, has invested more than $1.4 billion as of early 2017, while contributing to avoid slightly over 600 kt of emissions for the province – well under 1% of the province's total emissions (MDDELCC 2017). Accordingly, it seems likely that, internally, Quebec will miss its 2020 target, and will have to purchase of a large quantity of carbon allowances through the carbon market.

3.5 Policy overview in other provinces

3.5.1 Manitoba

Manitoba's strategy for energy and climate change is described in its Climate and Green Plan 2017, and includes energy efficiency objectives for domestic natural gas and electricity demand over a 15-year period. This followed the province's Climate Change and Green Economy Action Plan of 2015, which set out GHG reduction targets. The 2017 plan is also noteworthy for its presentation of a carbon tax at a flat rate of $25/tonne of CO_2e, which the province argues will produce more reductions over the 2018-2022 period compared to the federal requirements (a rate increasing annually from $10/tonne in 2018 to $50/tonne in 2022). In early 2018, Manitoba decided to sign on to the PCF, but reiterated its commitment to its flat rate.

3.5.2 New Brunswick

In late 2016, New Brunswick released its Transitioning to a Low-Carbon Economy action plan, which was followed by the introduction of the Climate Change Act and an update to the action plan in late 2017. The publications include GHG emission reduction targets, as well as several other actions respecting climate change. Details have yet to be released, including those on the province's strategy in relation to the phase-out of coal-fired electricity generation.

With regard to the PCF, the Climate Change Act also includes a partial shifting of the gasoline tax toward a fund designed to implement GHG emission-reducing projects. So far, the federal government has refused the equivalency in terms of meeting the carbon pricing requirements.

3.5.3 Nova Scotia

In late 2016, Nova Scotia and the federal government announced that they had reached an equivalency agreement in principle regarding the federal objective of phasing out coal-fired electricity production by 2030. The agreement would allow the province to extend its use of coal beyond 2030. Nova Scotia also announced a cap-and-trade system that would cover its largest carbon emitters, although the details are not available at this stage.

3.5.4 Prince Edward Island

In 2017, the government of Prince Edward Island released its 10-year energy strategy. The province has agreed to the PCF, but few details are available about its strategy at this time.

3.5.5 Newfoundland and Labrador

Many of the objectives tied to GHG emissions from industrial facilities are planned to be regulated under the 2016 Management of Greenhouse Gas Act, which aims to use revenues from carbon pricing on industrial emitters to support the development of emission-reducing technology.

3.6 Key trends

This chapter covered the main policies put forward by the federal government and its counterparts in the provinces and territories. Three main trends emerge from this overview.

Most provinces have been working with action plans and strategies, as well as setting up targets for greenhouse gas emission reductions. Several provinces have also initiated a transformation of their energy mix that accompanies these targets. A majority of provinces now have a medium-term objective that includes a target for one or both of GHG emission reduction and renewable energy, as well as a long-term view (2050) for GHG reductions. Many provinces presented a new or updated action plan during that period as well, which outlines general ideas on how to achieve these objectives. For instance, efforts at phasing out coal in electricity generation – whether through a complete elimination or an equivalency agreement – have been announced to reduce emissions from the electricity sector.

There has been a clear acceleration of such strategies since 2016, following Canada's signature of the Paris Agreement and the announcement of the PCF. The federal government is joining in somewhat late in the process, in an effort both to catch up to provincial initiatives and to provide better coordination of these efforts at the national level.

Nevertheless, and although most provinces have welcomed these efforts from their federal counterpart, strong disagreements remain: Saskatchewan has refused to embark on the PCF and its associated carbon-pricing system. Manitoba has only recently accepted the PCF to meet the federal government's deadline in order not to be excluded from the Low Carbon Economy Fund, but has so far reiterated its commitment to the $25/tonne flat rate for its carbon tax, remaining at odds with federal requirements. Furthermore, the assessment by the federal government of the equivalency of provincial carbon pricing systems, notably Quebec's cap-and-trade arrangement, is only planned for 2020. Should the auction prices be below the targeted price levels, it remains unclear how this issue would be resolved.

Despite the proliferation of action plans and targets, a more in-depth analysis of the policies quickly revealed several important caveats. It should be noted that, in general, details on how targets will be reached, including costs, technologies and pathways, are scant or entirely lacking. This makes it difficult to see how these strategies will transform into reality. GHG emission reduction targets, for instance, are rarely accompanied by substantial policies and means to steer the different sectors or individual behaviours in a direction that will make meeting the target a serious possibility. This difficulty is compounded by the fact that many action plans and similar documents are not formally legislated and can be reversed by a change in government. The result is a policy and regulatory environment that is either vague, unstable, or both, which complicates the tasks of the different actors involved. The mid-term review of Quebec PACC 2013-2020, for example, with little to show for its $1.4 billion expended, illustrates how difficult it is to obtain results without a clear strategic plan that integrates the various actions (MDDELCC, 2017).

This is also an important caveat with regard to scenario analysis, since abrupt or frequent modifications to these policies may change the long-term perspectives highlighted by the scenarios. Attention to this issue should be a priority of any government attempting to commit to medium- and long-term targets.

Even when action plans and legislation have been followed by concrete measures, the effectiveness of these policies in producing the results needed for the targets to be met is largely insufficient. British Columbia's carbon tax, for instance, has not resulted in any substantial reductions in emissions, even at its $30/tonne rate since 2012. Quebec's cap-and-trade market has so far resulted in a carbon price well below the $20/tonne mark, which suggests it will not have any substantial impact on GHG emissions in the short term. Investments from the proceeds through the *Fonds vert* have not resulted in emission reductions sufficient to allow the province to meet its 2020 target without buying the majority of its credits from its partners.

This suggests that Ontario's expected participation in the carbon market with Quebec and California, Alberta's carbon tax, and any pricing mechanism aligned with the requirements of the PCF before 2022, would at best result in modest reductions unless they are accompanied by much stronger programs to encourage reductions.

Nowhere is this clearer than in Canada's recent 7th National Communication and 3rd Biennial Report submitted to the United Nations Framework Convention on Climate Change (ECCC 2017b), in which Canada outlines its forecast for meeting its 2030 emission target. Of the 221 Mt GHG reductions needed to achieve 30% with respect to 2005, and despite policies presented or currently considered, the government estimates that 59 Mt would come from Ontario and Quebec's purchase of international allowances to California, with an additional 66 Mt of reductions to be identified (see Figure 5.6 and Table 5.28, p. 153).

Policy focus: accelerating the deployment of GHG reduction strategies

This means that the current set of policies, even if they are fully implemented and work as intended, will still fall short of the GHG reduction target by 30%. Even more importantly, however, for this to work would require a 15% additional reduction in California, on top of its already ambitious 40% 2030 objective, or a significant production of compensatory credits from across the United States. In addition to being unrealistic, it highlights the necessity for Canadian governments to rapidly take concrete and much stronger measures to make progress toward the 2030 and 2050 objectives.

After this overview of Canada's energy system and of policies currently in place, the remainder of this report examines results from scenarios based on possible avenues for meeting these objectives. These results, and the discussion that follows, provide ideas for where to focus efforts and inform future initiatives in this sense.

4

Meeting energy demand while reducing GHG emissions: prospective scenarios

We now turn to the future and examine a number of energy-related scenarios that mainly vary in terms of GHG reductions. We examine various GHG reduction scenarios given that climate change will remain at the core of energy-related decisions made by governments, the private sector and citizens over the next decades.

Highlights

Reduction scenarios based on provincial, federal and international targets and objectives are modelled on the 2030 and 2050 horizons, with results disaggregated at the provincial level.

The projected growth in energy demand is, overall, lower than that projected a few years ago.

GHG reduction targets translate into reduced energy demand due to direct and indirect energy efficiency gains (mostly through electrification).

The transformation of the transport sector will be central to GHG emission reduction efforts.

Replacement of fossil fuel powered systems by electricity for space heating is a key contribution to GHG reductions.

Even without changing its processes, the industrial sector can reduce its emissions through the use of low-carbon energy sources for heat production.

4.1 Scenarios

Throughout this Outlook, we consider four GHG emission reduction scenarios, as well as a reference case (as described in Table 4.1), analyzed through NATEM.[1]

Among the four GHG reduction scenarios, one key distinction must be further noted. While FIM, FED and 80P present scenarios based on federal targets and declined in the different forms explained in Table 4.1, PRO foregoes federal targets and instead analyzes possible developments based on current provincial targets. As a result, in the three federal-based scenarios, the model allocates reductions optimally across provinces in order to reach federal targets, based on costs and available technologies. As discussed in the rest of this document, in some cases this results in certain provinces reducing their emissions further than others. Section 7.4, in particular, addresses the variation in provincial efforts when joined together in a national strategy.

Finally, it is worth noting some of the key underlying assumptions used by the model:

- Prices of imported and exported energy commodities;
- Evolution of technical and economic attributes of technologies over time;
- Demand projections for energy services;

Table 4.1 – Description of the reference and GHG reductions scenarios

Name	Description
BAU	The **B**usiness-**A**s-**U**sual, or reference scenario.[2] This scenario presents results using no GHG reduction targets. It is aligned with the reference scenario used in the National Energy Board's Canada's Energy Future 2017 Outlook, imposing no additional constraints in terms of GHG emissions reductions.
PRO	The **PRO**vincial scenario. This reduction scenario imposes individual provincial targets for emissions – when they exist – as detailed in Chapter 3. It gives an idea of the evolution of the country's emissions if provincial leadership were to be the dominant factor, with little to no involvement from the federal government.
FIM	The **F**ederal scenario with **I**nternational carbon **M**arket purchases. This reduction scenario imposes the federal government's stated 2030 and 2050 targets, which aim for 30% and 80% reductions from 2005 levels respectively. In this scenario, 25% of these reductions come from international carbon market purchases, in line with Canada's recent 7th National Communication and 3rd Biennial Report submitted to the United Nations Framework Convention on Climate Change (Canada 2017d). As a result, this scenario's central aim is to use the current federal government's plan and projections for 2030 and extend them to 2050.
FED	The **FED**eral scenario. This reduction scenario uses the same federal government's 2030 and 2050 targets as FIM (30% and 80% with respect to 2005), but all reductions must be achieved domestically – i.e., without the option of purchasing credits elsewhere. As in FIM, this puts the federal framework for GHG reductions at the centre of the scenario, but shows what achieving these targets without the help of foreign jurisdictions would require..
80P	The **80 P**ercent scenario. This last reduction scenario is the most aggressive in terms of emission reductions, aiming at 80% reduction, but this time from 1990 levels, by 2050, corresponding to an 83% reduction with respect to 2005. This provides a perspective in relation to the Kyoto Protocol, where most parties' targets were set using 1990 levels as a reference (see UNFCCC Kyoto Protocol).

[1] NATEM stands for North American TIMES Energy Model, an energy systems optimization model implemented by ESMIA Consultants Inc. It makes use of The Integrated MARKAL-EFOM System (TIMES) model generator, developed and distributed by the Energy Technology Systems Analysis Program (ETSAP) of the International Energy Agency (IEA) and used by institutions in nearly 70 countries.

[2] Throughout this document, we use the terms "BAU" and "reference" interchangeably.

- Climate change policies in other countries (affecting demand for oil and gas);
- Technological developments;
- Developments on international markets/North American markets.

A discussion of the impact of each of these assumptions and the associated uncertainty is presented where relevant.

4.2 Energy demand by source

As shown in Figure 4.1, total energy demand in Canada, as computed by the NATEM model, is largely independent of the various reduction scenarios and increases only slightly over time, a significant departure from historical trends. This corresponds to an economy that, in order to meet the imposed GHG emission reduction targets, moves from less efficient (fossil fuels) to more efficient (electricity, in particular) energy forms, able

Figure 4.1 – Final energy consumption by source

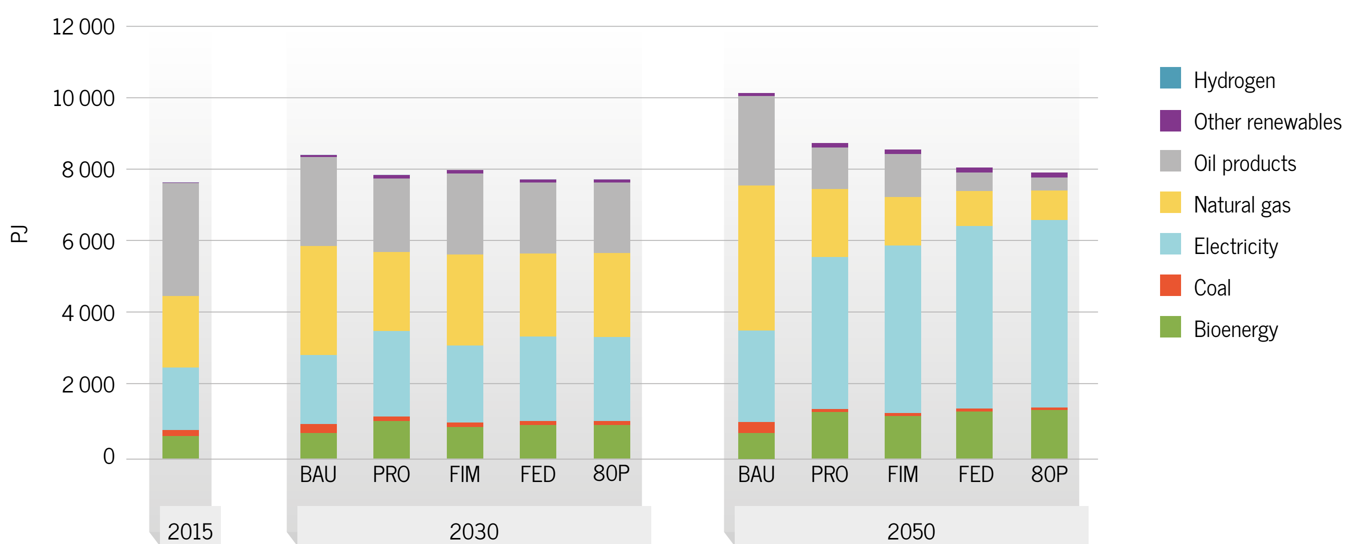
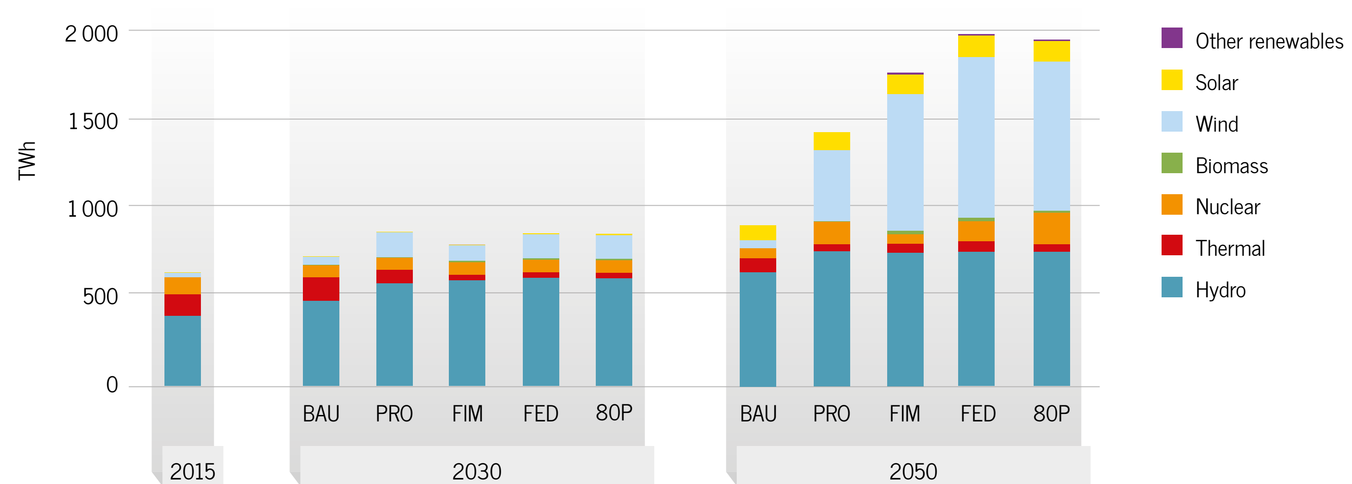


Figure 4.2 – Electricity generated by source



Note: 1 TWh is equivalent to 3.6 PJ

to provide more services for the same number of joules while continuing to improve overall energy efficiency.

In 2050, excluding the BAU scenario, total energy consumption will be only slightly higher than in 2030. However, the various scenarios show a significant difference in the mix of energy used, which reflects the diverse technological choices, fuel switching, and energy efficiency measures taken to achieve the various GHG reduction targets. As prices for clean energy are expected to fall significantly, pressure to reduce demand will be weakened, even for the FED and 80P scenarios.

More specifically, the share of natural gas and oil products diminishes across scenarios (from PRO to 80P), a trend that is explained by a greater use of electricity (from 48 to 66%), which decreases energy losses and thus increases the service rendered by energy for the same number of joules. In fact, an electric car uses about three times less energy per km than a gasoline-powered car, as most of the electricity is turned into motion, while only about one-fifth of the energy contained in gasoline serves to move the car.

These scenarios lead to three major observations:

1. The demand for oil products is set to decrease – even in BAU – as early as 2030, a trend unlikely to be limited to Canada, even without a significant increase in market prices.

2. The demand for natural gas increases to practically the same level across all reduction scenarios for 2030, but declines in them all for 2050. Although it returns to 2015 levels in PRO, it falls by at least 30% in other scenarios – almost 60% in 80P.

3. To achieve even the least stringent GHG targets, electricity will need to take a larger share of the mix – as much as 66% of all energy used by 2050 – and be mainly generated from non-GHG emitting sources as shown in Figure 4.2. Because of the important transformation in this sector, a complete chapter (Chapter 6) is dedicated to it.

4.3 Energy demand by sector

Figure 4.3 presents energy demand by sector for 2030 and 2050. For 2030, residential, commercial and agricultural sectors vary by only a few percentage points across scenarios, even with the most stringent targets. Industry and transport, however, are much more variable, differing by more than 10% in response to technological changes, which bring significant energy efficiency gains, and the need to reach the carbon targets.

Energy consumption remains fairly stable between 2030 and 2050 in the residential, commercial and agricultural sectors, as the efficiency of heating does not change significantly between fossil fuel furnaces and electric boards. Industry sees both its share and its absolute consumption increase, more or less due to its link with the overall economic growth of the Canadian economy and in line with previous trends. If transport sees its share decrease in all scenarios, the absolute reduction varies across scenarios.

To enhance understanding of these results, the evolution of energy profiles for each sector is examined below.

4.3.1 The residential, commercial and agricultural sectors

In the residential, commercial and agricultural sectors (Figure 4.4), results for 2030 show a larger share for centralized electricity for all scenarios, but especially for 80P. The slight differences in the mix in 2030 indicate that objectives for that period are similar and that the policies that control this transformation are already in place.

The 2050 results reveal an entirely different picture. Although total energy consumption increases only slightly in these sectors, electricity plays a much larger role in all scenarios compared to BAU, with FIM, FED and 80P showing similar levels. Solar PV, in particular, is expected to contribute a significant share of the energy for these sectors in all scenarios, including BAU. The key difference from BAU to 80P is the diminishing share of natural gas: while natural gas delivers 45% of the energy consumption for BAU, it all but disappears in 80P, where electricity and bioenergy compensate.

Results are similar across provinces (not displayed), with the role of solar PV varying somewhat as a function of projected availability.

4.3.2 The industrial sector

Results for the industrial sector (Figure 4.5) show a similar increase in the use of electricity at the expense of natural gas and coal and coke in 2050. All scenarios clearly present a lower overall demand than BAU in 2050, illustrating the importance of direct and indirect energy efficiency (through electrification) in contributing to long-term GHG emission reduction efforts. Variation across scenarios in this respect largely rests on the extent of this electrification, which compensates for the decrease in fossil sources (60% between BAU and 80P).

The picture is more mixed for 2030, where all scenarios suggest a net increase in the use of both

Figure 4.3 – Final energy consumption by sector

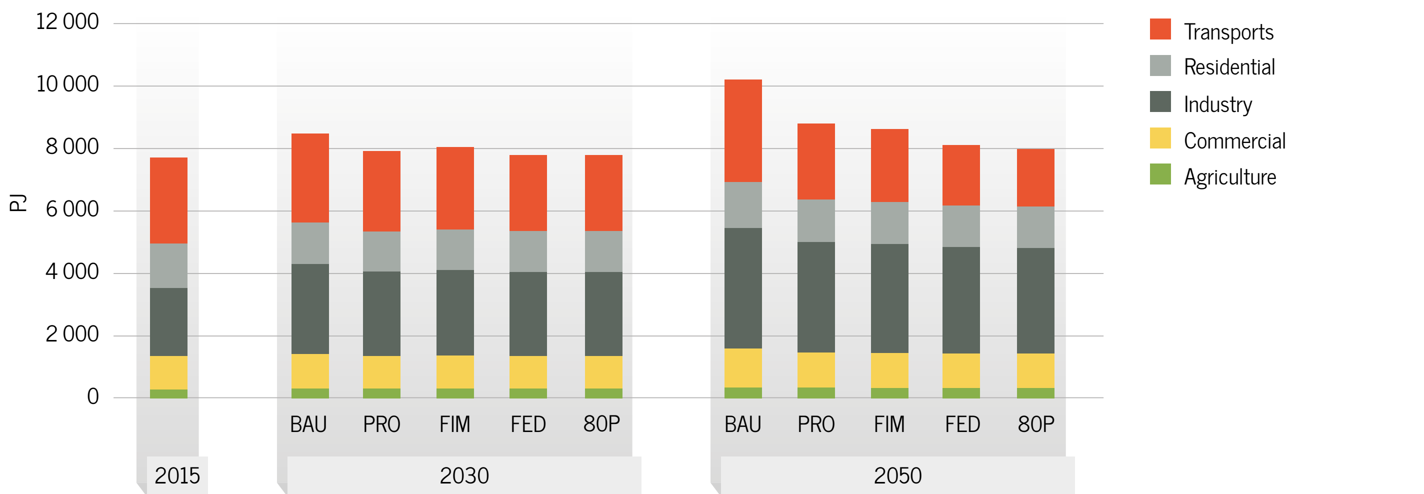


Figure 4.4 – Final energy consumption in residential, commercial and agricultural sectors

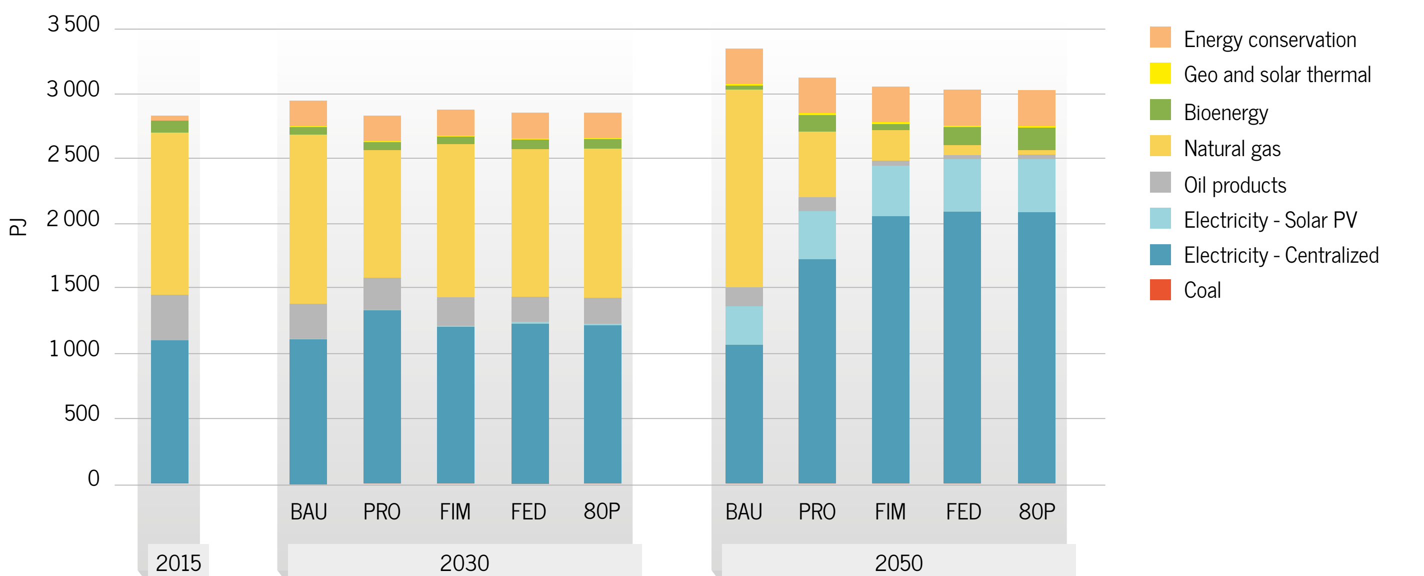


Figure 4.5 – Final energy consumption in the industrial sector

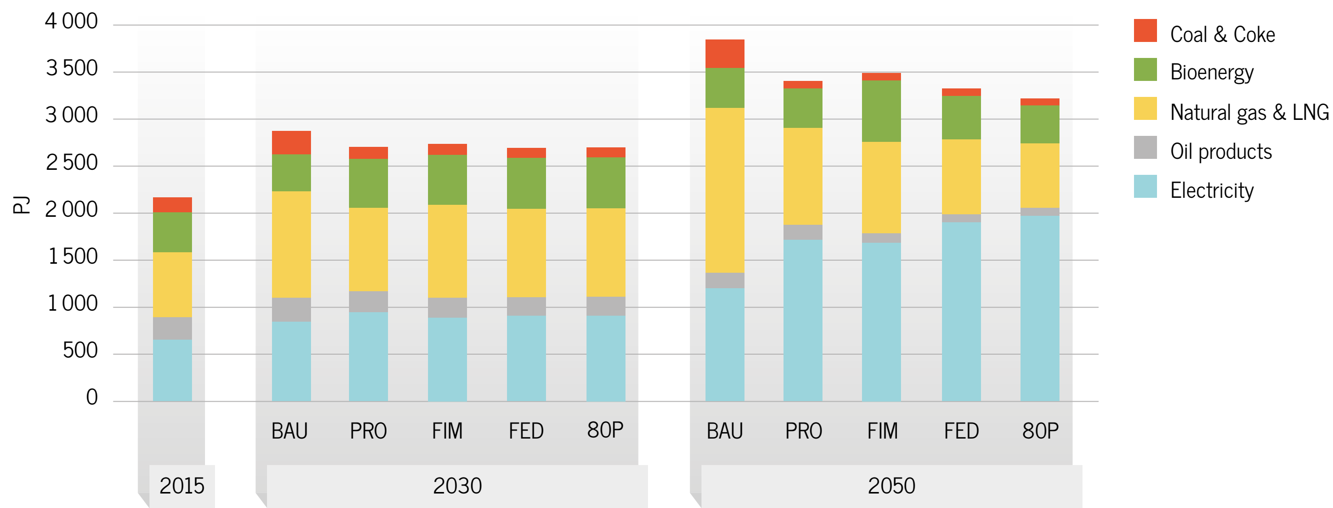
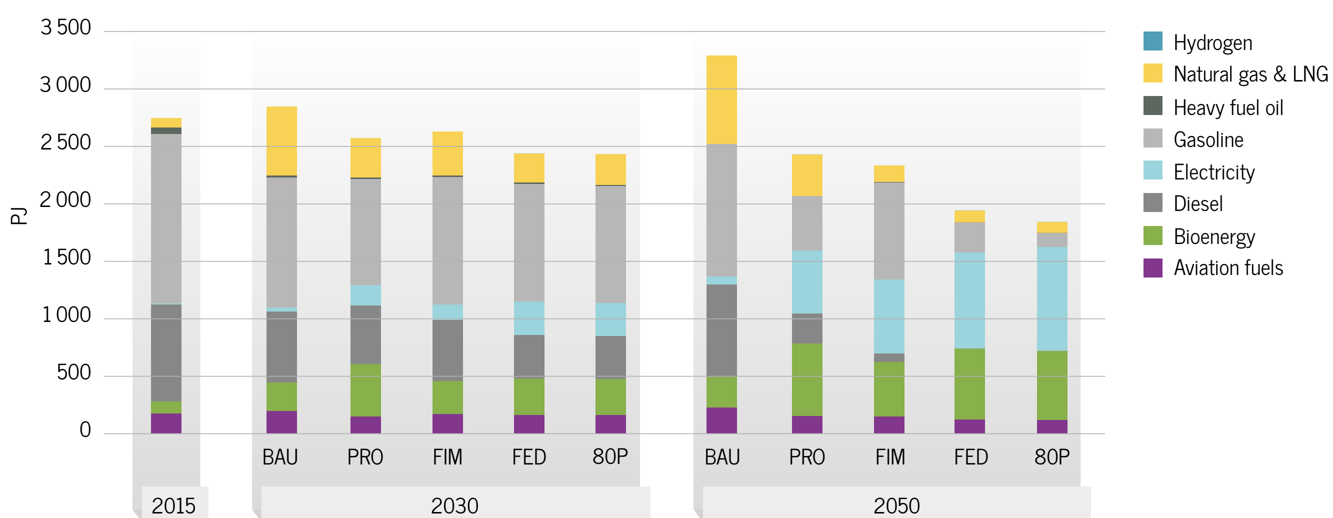


Figure 4.6 - Final energy consumption for total transportation



natural gas and electricity, with a slight reduction for oil products. All scenarios maintain the use of coal and coke, mainly due to the lack of details for switching alternatives in the NATEM model.

Historical data suggests that there is relatively little elasticity in the energy-intensive industries, where energy costs are considerable and energy efficiency measures have generally already been applied. This explains why energy consumption in the industrial sector is fairly independent of GHG reduction targets. Important gains in this sector will require breakthroughs in new technologies and processes for which costs cannot be easily evaluated.

4.3.3 Transportation

The transportation sector shows the most significant variation in energy demand across scenarios (Figure 4.3) and how this energy demand will be met varies greatly depending across scenarios (Figure 4.6).

Figure 4.7 – Space heating systems in the commercial sector

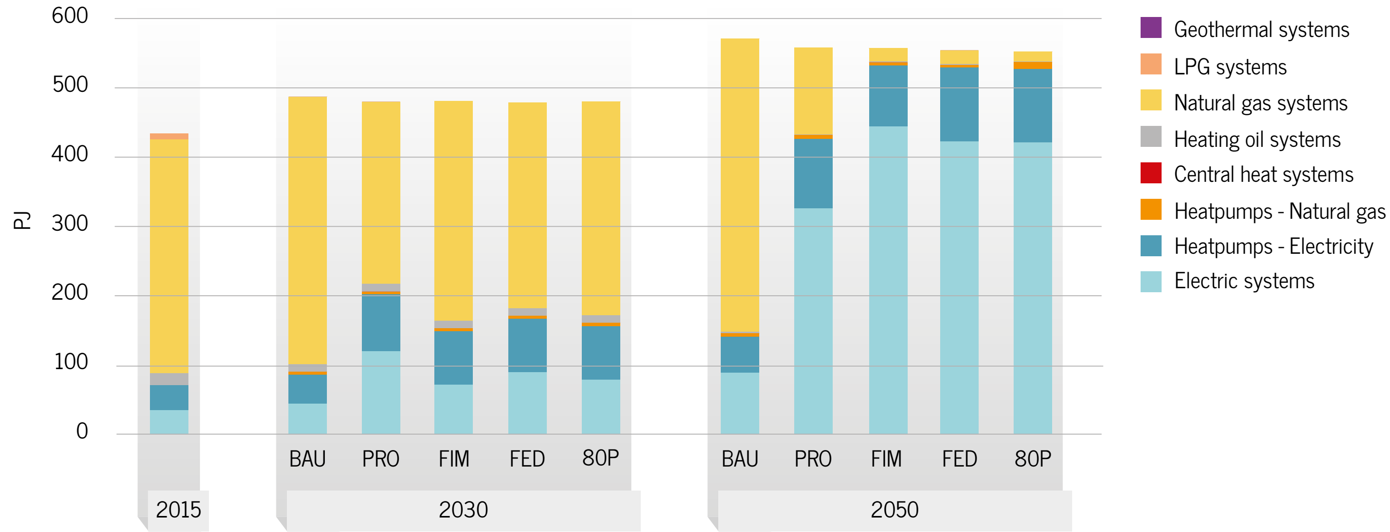
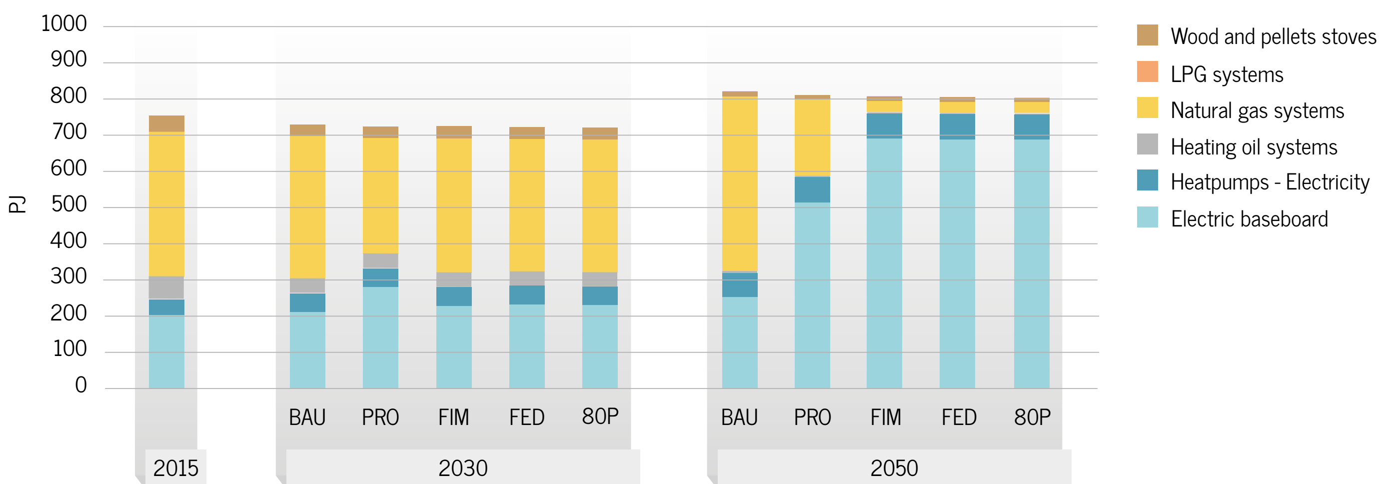


Figure 4.8 – Space heating systems in the residential sector



BAU is very conservative as to the transformation of the transport sector. The use of electricity remains marginal at 2% of the total energy use by mid-century. Nevertheless, gasoline and diesel usage decreases, but to the benefit of natural gas, which is multiplied by a factor of more than nine to reach 23% of the total in 2050.

Taking into account the life expectancy of vehicles and the limited supply of electric vehicles, all scenarios show only a relatively low penetration of electricity in the transportation sector by 2030 (13% in 80P, the most aggressive scenario). Interestingly, PRO is relatively close to this number, reflecting the importance of provincial objectives for the sale of electric vehicles.

When GHG reductions are less stringent, natural gas shows the greatest gain in absolute demand over the next decade: between now and 2030, the role of this energy source goes up by a factor of six in BAU. Even for 80P, the contribution of natural gas is multiplied by 3.5, compared with today. However, in absolute numbers, bioenergy sees the largest increase for PRO, FED and 80P, primarily for heavy transportation, where alternatives to diesel and gasoline are more difficult to find with current and prospective technologies.

In 2050, demand decreases sharply in all GHG-reduction scenarios compared to BAU. This reduction is not caused by a smaller demand, but rather by energy efficiency gains resulting from an increased use of electric motors instead of internal combustion engines, as discussed above. This trend is clearly observed in Figure 4.7, which shows an increasingly dominant share of electricity, accompanied by a drastic reduction in the use of gasoline and natural gas. Largely replaced by bioenergy, diesel all but disappears in FIM, FED and 80P. These results illustrate the crucial importance of the transport sector in GHG emissions reductions, as well as the difficulty of achieving the targets with efficiency improvements only in fossil fuel powered engines, as fuel switching is a key measure to reducing emissions from transportation.

4.4 Heating

Given that space heating represents more than half the final energy demand in both the commercial and the residential sectors, it deserves special attention here, particularly since it is currently largely ensured by natural gas systems (Figure 4.7 and Figure 4.8).

In all scenarios, total demand is expected to grow slowly over the next decades, following a long-observed trend, indicating that more energy efficient technologies — using geothermal energy, thermal walls, etc. — are still too expensive for the services required in comparison to standard technologies, including heat pumps. The NATEM model used here is based on a conservative hypothesis where progress is considered exogenously. It is clear, however, that increases in demand could result in price reductions that would affect the penetration of these technologies.

Results show the increased importance of electric systems and heat pumps in 2030, although natural gas remains the first source of heat for all scenarios except 80P. This trend continues aggressively for 2050 where, except in BAU, we observe a steep increase in electric heating systems with a near complete elimination of any alternative, including natural gas. Overall, electric systems and heat pumps represent the bulk of space heating for 2050 in scenarios FIM, FED and 80P for the commercial sector. The switch to electricity allows some energy efficiency gain in the more aggressive scenarios that is reflected in the evolution of the total demand.

Many similarities are noted in the results for space heating in the residential sector. Figure 4.8 shows the same increase for electric systems and heat pumps, although it seems to take longer to occur and standard electric boards remain dominant over heat pumps. Here as well, this trend takes place at the expense of natural gas systems and, by 2050, all non-electricity-based sources become marginal except in PRO.

Overall, the replacement of fossil fuel powered systems (natural gas in most provinces, and oil products in others) by electricity in space heating is a key contribution to GHG reductions for the commercial and residential sectors, especially for 2050. Of all GHG-reduction scenarios, only PRO maintains a significant fraction of natural gas, which is nevertheless limited to only a few provinces. Natural gas, for example, remains dominant in PRO for Alberta until 2050.

4.5 Key trends

While a number of countries, such as Switzerland and Germany[3], have introduced considerable reductions in energy use as part of their scenarios to achieve their GHG emission goals by 2050, such extensive transformations cannot take place without a significant change in the energy services produced, be they in goods, transportation or heating. **Trends across OECD countries for the past 40 years suggest that it is very difficult**

[3] Switzerland plans a 43% reduction in per capita energy use by 2035 with respect to 2000, while Germany plans a 50% reduction in per capita primary energy use by 2050 with respect to 1990. See: Office fédéral de l'énergie, *La stratégie énergétique 2050 après l'entrée en vigueur de la nouvelle loi sur l'énergie, Switzerland (18 Jan. 2018),* International Energy Agency, *Policies and measures: Energy Concepts (Germany, 2010)* https://www.iea.org/policiesandmeasures/pams/germany/name-34991-en.php

to significantly change total per capita energy consumption and that efficiency gains are typically used to add services rather than to decrease the demand.

Moreover, while only half a decade ago, low-carbon energy production was still very costly compared to fossil fuels, **recent years have seen a profound transformation with prices of PV and wind electricity falling below that produced by even the most efficient gas plants**. This is why all our scenarios maintain trends in energy service demand and focus rather on the transformation of the type of energy used.[4]

Since the cheapest way to produce heat from electricity is often to send current through a resistor (a process that is 100% efficient), **electrifying heat production, for industrial processes or space heating, does not significantly reduce total energy consumption**. This is generally the case unless governments impose standards or subsidize more efficient, but more expensive, technologies such as heat pumps, solar and geothermal technologies. Heat pumps, moreover, could gain traction more rapidly than predicted here if a larger number of Canadians chose to install air conditioning as summer heat waves intensify due to climate change.

All reduction scenarios predict a significant decrease in the use of fossil fuels, particularly oil products, over the next decades. It is likely that this trend will also be observed worldwide, affecting overall demand, which will lead to decreasing investments and oil production, with the impact on prices remaining difficult to predict.

In the coming decades, Canadians should brace themselves for a major transformation of the energy sector, although there is no cause for alarm as **this transformation will not affect access to energy for consumers in any sector; only the type of energy available will change**. The most important hardships will be noted in the oil and gas sector, which is expected to undergo a significant reduction in demand, requiring some provinces to reconfigure their economy and retrain their workforce. By contrast, however, meeting the increased demand for electricity will trigger massive investments required to generate, distribute, and use this form of energy.

[4] NATEM, however, includes its own price elasticity of demand, allowing for endogenous changes in demand for the various GHG reduction scenarios compared to the baseline.

5

How energy production must evolve to meet the GHG targets

Canada is a major energy producer and exporter, yet its energy production will be affected by both changes in the demand and constraints on GHG emissions. Model outputs show that not all sectors will be impacted in the same way. This will differ on a per province basis, in correlation with resource distribution, availability and the evolution of the import/export market, which is particularly important as more than half of Canada's primary energy production is destined for export.

Highlights

Total energy production is expected to grow in all scenarios.

Unconventional oil production must remain around current production levels in order to meet the 80% reduction target.

Biomass production is expected to be multiplied by three in all GHG-reduction scenarios by 2050.

- To be cost effective, it must be integrated with other objectives such as waste management, agricultural diversity and sustainability, and regional development.

Energy exports are not expected to be significantly affected by internal GHG targets.

Energy imports could be cut by more than half as Canada turns to regionally produced renewable energy.

Depending on the GHG reduction scenario, an accelerated transformation of the economy away from the fossil fuel industry can be expected, mainly after 2030.

.

5.1 Primary energy production

Primary and secondary energy production[1] are usually separated, especially when a significant amount of electricity is generated in thermal plants where considerable energy is lost. Although electricity is largely decarbonised in Canada, this is not the case in all provinces. It therefore remains pertinent to discuss primary energy production and its evolution over the next few decades in the traditional manner. The next chapter will focus solely on electricity production.

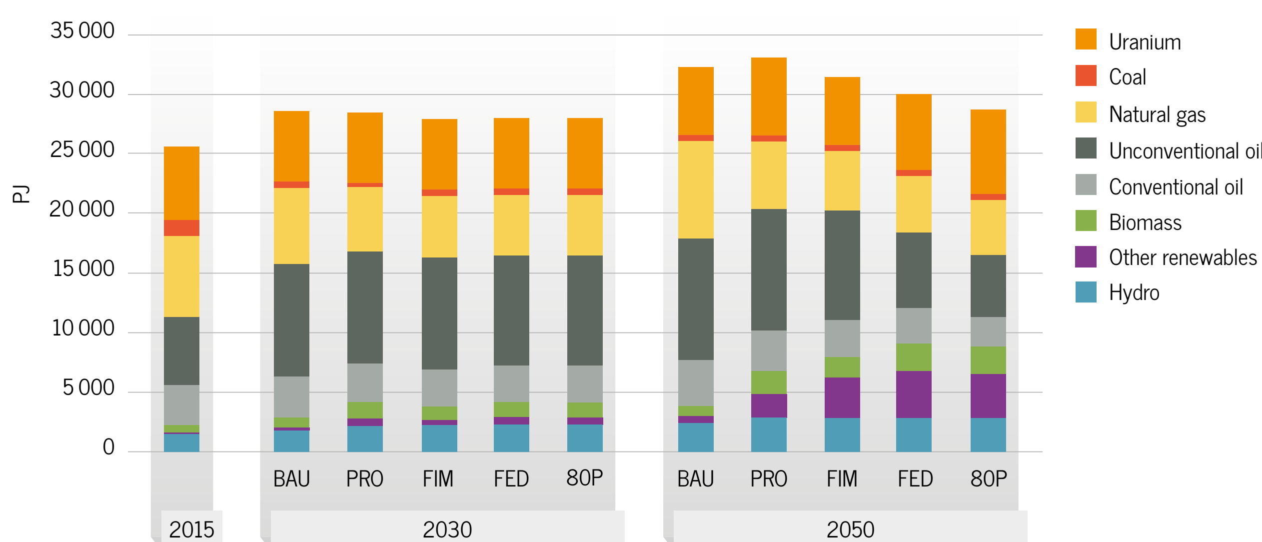
Figure 5.1 shows the predicted evolution of Canadian primary energy production as a function of various scenarios. As mentioned earlier, these scenarios assume that the rest of the world will move at its own pace, irrespective of Canada's GHG targets. Oil and gas prices on the global market are therefore the same for all scenarios. This hypothesis is of course a simplification, as it is likely that Canada will act on its targets only if the rest of the world shows clear leadership, directly affecting energy prices on the global market.

Overall total energy production is expected to rise slightly over the next few decades in all scenarios, mostly due to increased unconventional oil and, in GHG reduction scenarios, biomass production. For 2030, for all scenarios, unconventional oil grows by 60 % with respect to 2015, a growth that reaches 80 % for BAU and PRO in 2050. This progression would then be reversed in the most demanding scenarios, with a 2050 production back to 10 % above 2015 level for FED, and even 10% below 2015 level for 80P, as these last two scenarios impose direct and indirect constraints on fossil fuel production.

A first trend highlighted by Figure 5.1 is that Canada should remain an important producer of fossil fuels in 2030: in all scenarios production is expected to climb, with FED showing the smallest increase at 800 PJ, compared with BAU's 2,600 PJ. The growth comes from oil sands, as coal and natural gas production falls. While these numbers seem significant, they actually represent a growth of between 5% and 15% over 15 years, much less than predicted before oil prices fell a few years ago (IEA 2011, pp. 125-126).

While the scenario results are all quite similar for 2030, the picture is more diverse in 2050. BAU and PRO push unconventional oil to a new high (10,200 PJ), almost doubling current production, while FIM barely reduces this production to 9,200 PJ. With stricter GHG emission limits, FED and 80P impose a decrease in fossil production, mainly capping oil around current production levels, while effecting a one-third reduction in

Figure 5.1 – Primary energy production



[1] Definitions of energy-related concepts are given in Appendix B

natural gas extraction. Nevertheless, this leaves considerable fossil production, even in the most stringent reduction scenario: between 12,000 PJ (80P) and 19,000 PJ (PRO), respectively 22.5% below current production levels and 21.5% above. If, in BAU, fossil fuels represent 70% of primary energy, their share would still be 45% in the most ambitious reduction scenario (80P).

In all scenarios, coal production is expected to fall by 60% of its 2015 level by 2050, becoming even more marginal, at around 500 PJ, with further decreases only possible through the modification of certain industrial processes.

Unsurprisingly, renewable energy production undergoes a major transformation in most scenarios. From 2,200 PJ in 2015, including hydro, wind, solar, biomass and other sources, total renewable production is expected to increase by between 25% and 85% by 2030. This growth is comparable, in absolute numbers, to that of fossil fuel production, albeit in different scenarios. By 2050, renewable production could vary from 3,900 PJ (BAU) to 9,000 PJ (FIM, FED, 80P), an increase in that case of almost 7,000 PJ from current levels.

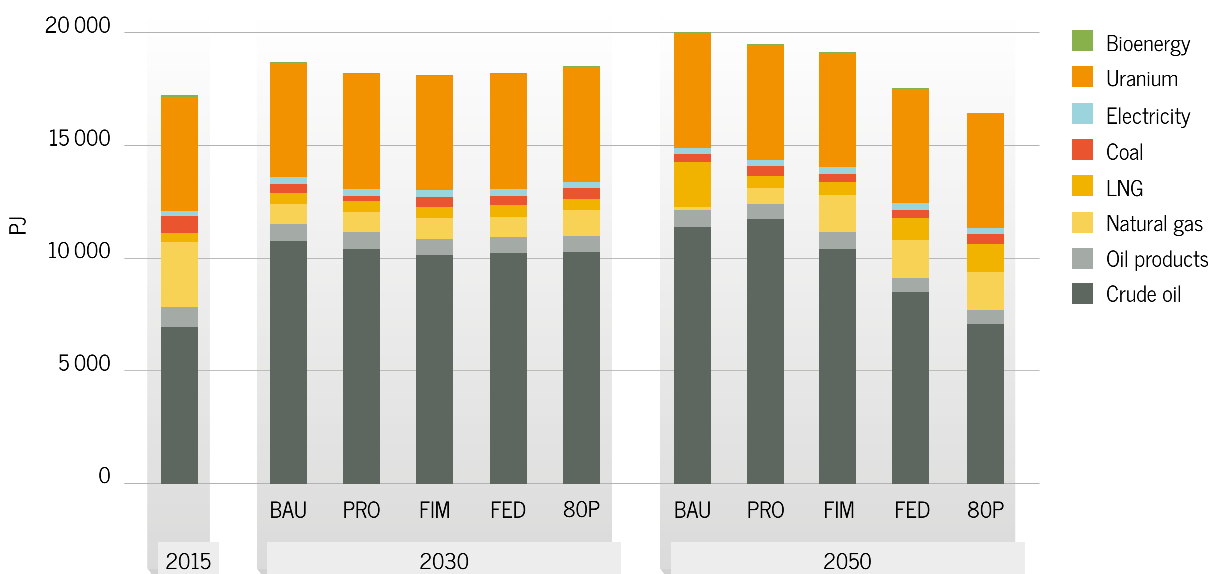
As for uranium, which primarily targets export markets, all scenarios anticipate an almost constant production level over the next few decades, with very little impact on access to energy and GHG emissions.

5.2 Local consumption and export markets

Canada is considered a major energy exporter (Figure 5.2) given that a significant portion (close to 60%) of the energy it produces is directed to foreign markets, chiefly the USA. Transformation of world energy systems could therefore have a significant impact on this trade as most of the renewable energy that will be added over the next few decades is expected to take place at the expense of fossil fuels. Shifts in domestic consumption, however, which will reduce oil and gas imports, especially in the East, could even have a notable positive impact on Canada's trade balance, especially as important infrastructure investments will be required.

In fact, although internal fossil fuel consumption varies significantly between scenarios, coal, gas and oil exports are only slightly affected, as the NATEM model leaves (by assumption) the rest of the world on the same trajectory irrespective of Canada's choices. In this context, with decreasing domestic demand, fossil fuel exports are expected to climb from 7,700 PJ in 2015 to around 10,000

Figure 5.2 – International exports



How energy production will respond to the evolution of demand

Figure 5.3 – International imports

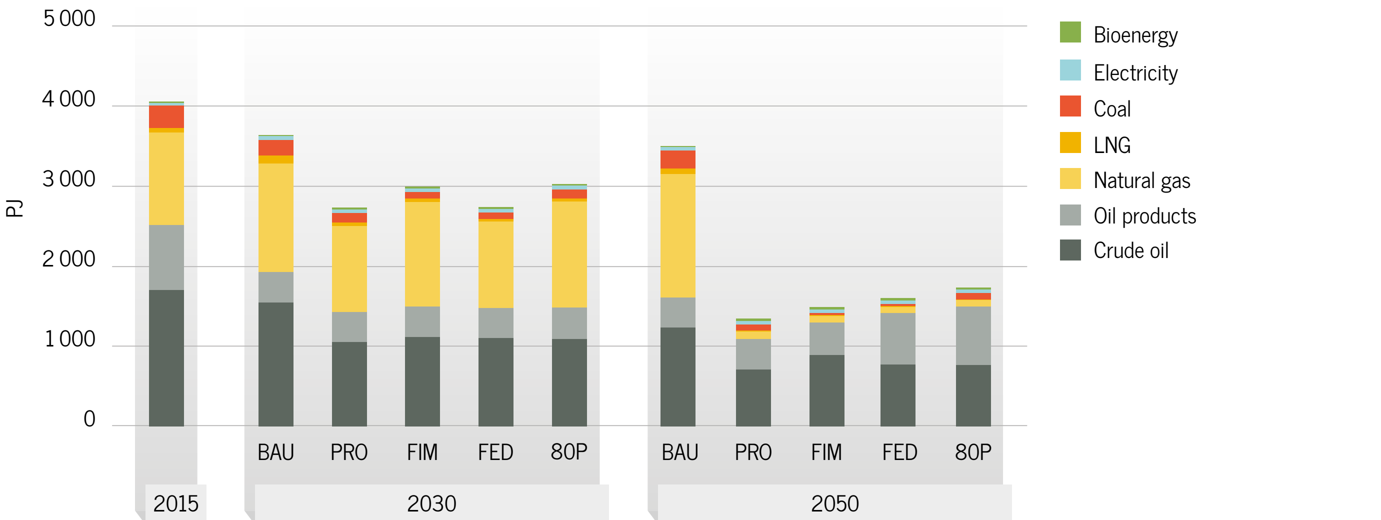
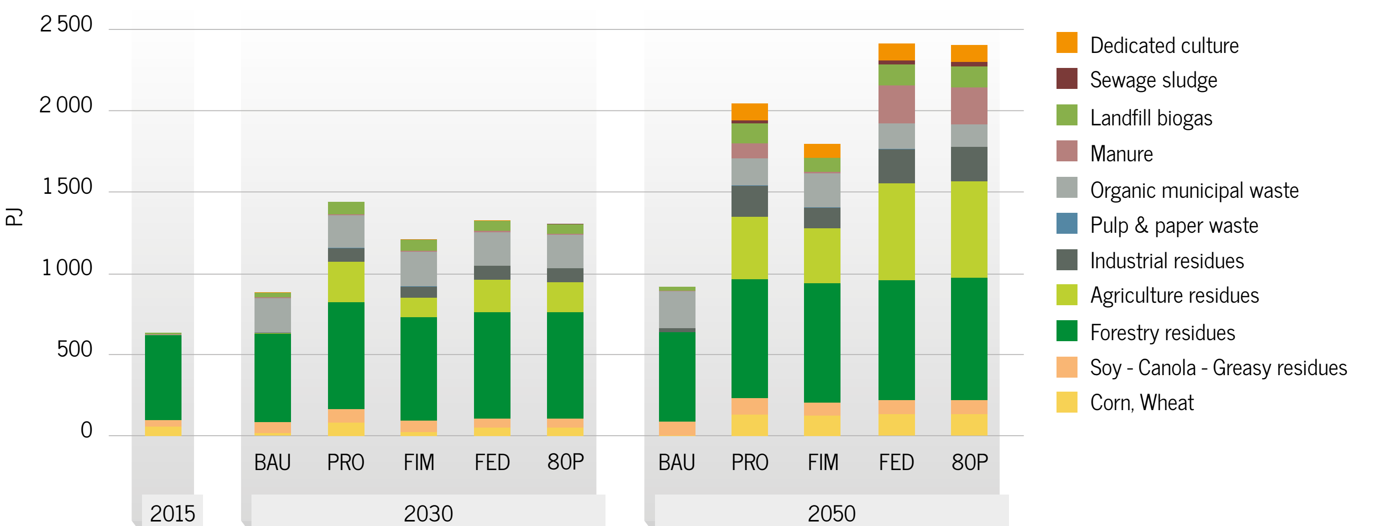


Figure 5.4 – Bioenergy sources by type



PJ in 2030, and 10,500 or 12,000 PJ in 2050, to which we should add about 5,000 PJ of uranium.

Of course, if the rest of the world follows a trajectory similar to Canada's, with aggressive GHG reductions around the planet, international demand for oil and gas products will fall, directly affecting Canada's energy exports. In this context, with international pressure to address climate change, Canada would not be wise to expand subsidies to this sector; an accelerated transformation of the economy away from this industry, particularly in oil- and gas-producing provinces, will significantly reduce the social costs of a worldwide transition away from fossil fuels. In other words, prevention is better – and cheaper – than cure.

Imports are considerably lower than exports (Figure 5.3) and diminish noticeably in the reduction scenarios in 2050 due to the almost total elimination of natural gas imports. Crude oil imports are relatively constant across scenarios in both 2030 and 2050, likely due to geographical constraints in trade infrastructure and demand.

While crude oil imports are lower in 2050, imports of oil products increase across scenarios. This suggests that part of the efforts to reduce Canadian GHG emissions in aggressive scenarios will consist in shifting oil refinery emissions elsewhere (overwhelmingly to the United States).

5.3 Biomass

Results for biomass usage are presented in Figure 5.4 to Figure 5.6. For both 2030 and 2050, the quantity of forestry residues remains significant, but the steep increase in overall biomass consumption results in a smaller share for this feedstock, especially in 2050. In particular, industrial residues, manure and dedicated culture become significant sources in 2050 for all reduction scenarios, whereas agriculture residues are already a dominant source in 2030.

Figure 5.5 focuses specifically on wood biomass. Biofuel production, and to a lesser extent, electricity generation provide most of the increase in demand in 2050 in comparison to 2030. While there has been considerable talk across Canada about the use of wood biomass, data suggests that the available quantities remain limited, even when allowing for high-cost production. This indicates that even though wood biomass could represent an interesting economic opportunity in some regions of Canada, this energy source will not become a significant contributor to energy transition.

As Figure 5.6 shows, while biomass as a primary energy source is currently used for industrial purposes, space heating and biofuel production, all reduction scenarios show that the increase in demand would be driven by different uses. Although space heating from these sources all but disappears by 2050, the considerable expansion of primary biomass in 2030 and 2050 results from an increase in electricity generation, renewable gas production and biofuel production, with gas taking a larger share with more ambitious GHG reduction targets.

Overall, biomass results indicate very considerable differences between BAU and all other scenarios, suggesting that policies aiming to encourage some of these activities may be important in helping to ensure the attainment of 2030 and

Figure 5.5 – Wood biomass uses by type (and potential for Canada)

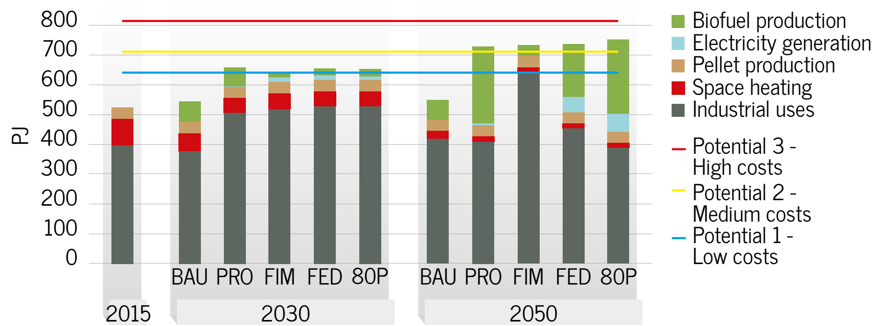
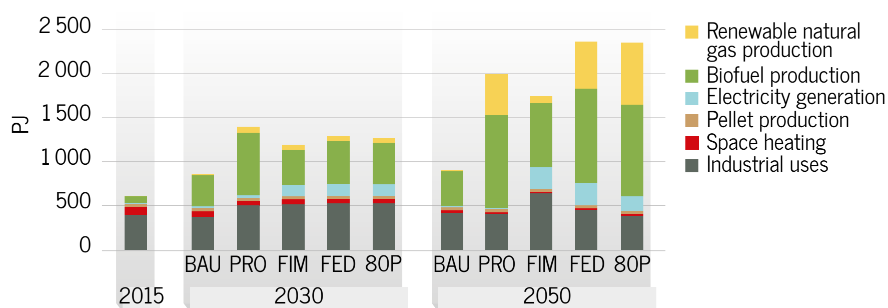


Figure 5.6 – Primary biomass uses by type



2050 GHG emission reduction targets. However, their role is likely limited to specific sectors and, to be further deployed, biofuel production will have to be integrated into other objectives such as waste management, agricultural diversity and sustainability and regional development.

5.4 Provincial overview

Given the important geographical variations in primary energy production, Figure 5.7 details the evolution of provincial profiles in this respect. Most provinces are predicted to evolve from their current production mix and resource endowment while maintaining until 2050, in spite of significant changes, a production that reflects their own historical orientation.

How energy production will respond to the evolution of demand

As discussed in Section 5.2, Canadian primary energy production expands slightly, and the provincial differentiation serves to illustrate the main sources of the increase for the country as a whole. Increases in renewable electricity (hydro, solar and wind) are mainly found in New Brunswick, Nova Scotia, Ontario, Quebec and Prince Edward Island, where it serves both to replace current thermal electricity generation and to meet the larger electricity demand. In addition, the larger share of the increase in biomass production comes from Ontario and Manitoba.

The second general observation noted in Section 5.2 is that fossil fuel production remains important in all scenarios in 2050. This is confirmed by a glance at Alberta and Saskatchewan's production, where the quantities produced remain considerable in 2050, although with the expected variation across scenario. Unconventional oil in Alberta, in particular, shows much smaller quantities produced in the more aggressive scenarios.

The situation is different for Newfoundland and Labrador's oil production and – to a somewhat lesser extent – British Columbia's natural gas production, which are expected to decline significantly by 2050. The difference between the reference and GHG reduction scenarios for these two provinces is striking, demonstrating the effect of long-term GHG emission reduction objectives on the most emission-intensive sectors of energy production.

Figure 5.7 – Primary energy production per province

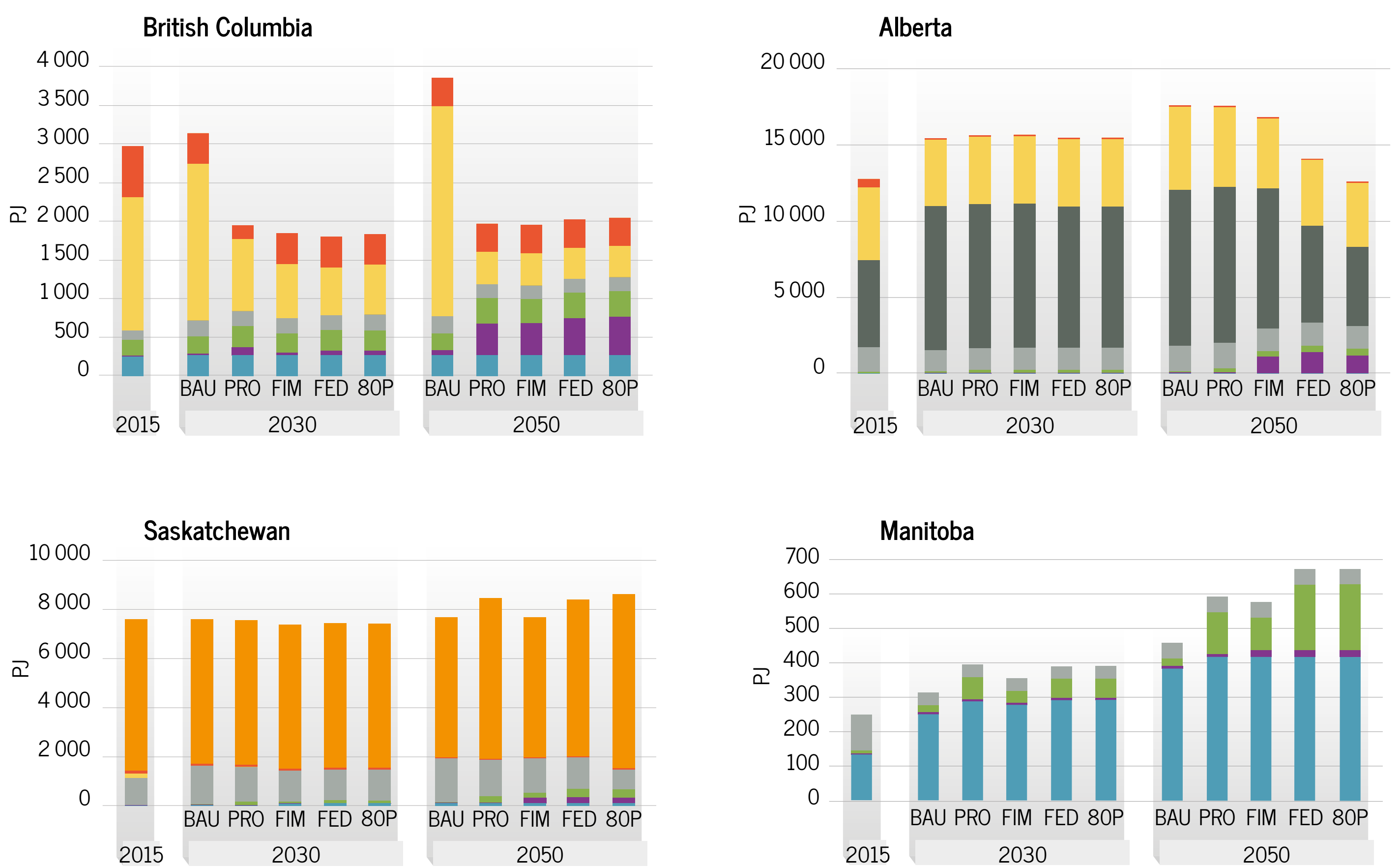
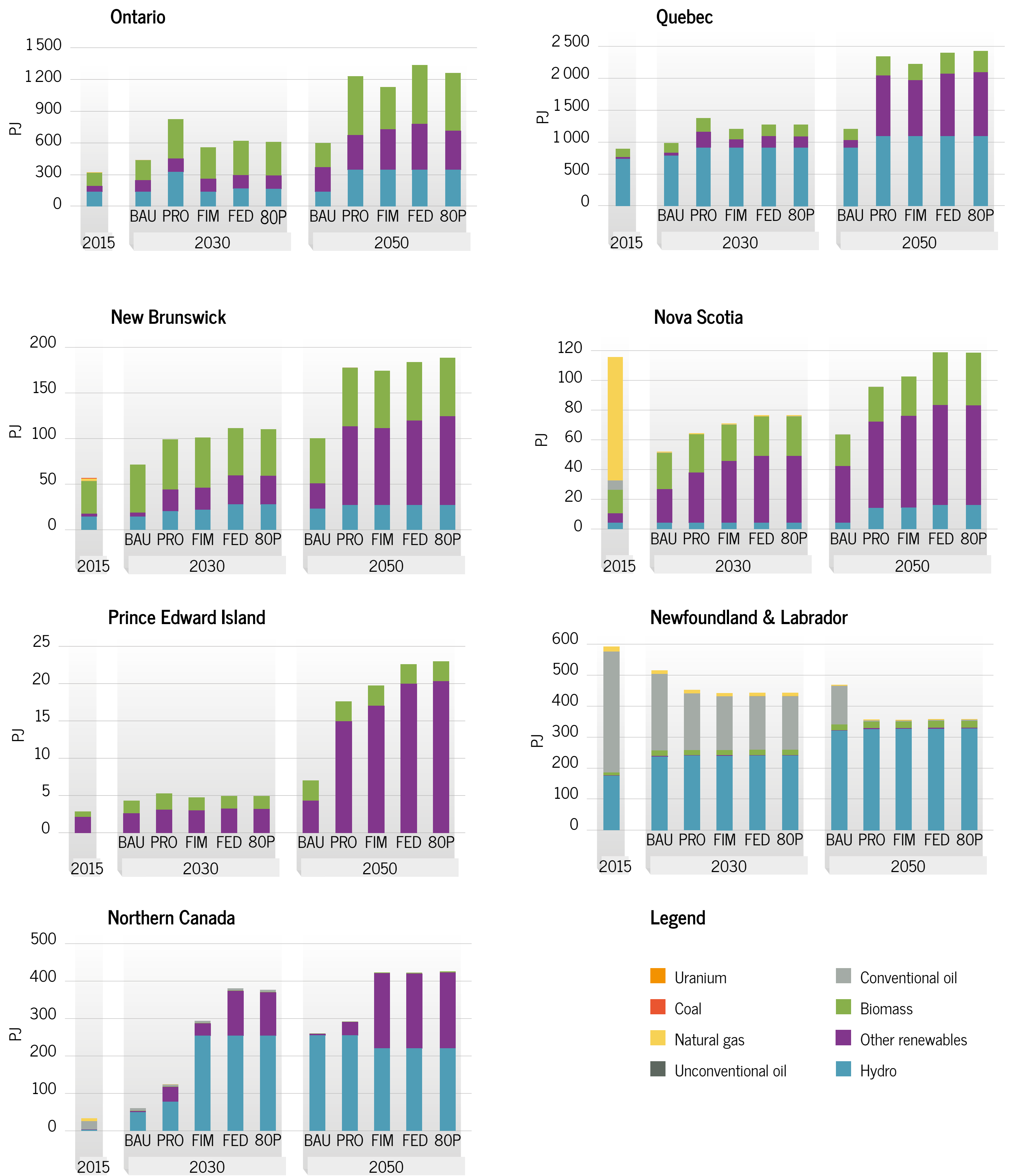


Figure 5.7 – Primary energy production per province



Note: Northern Canada refers to Yukon, Northwest and Nunavut territories

5.5 Key trends

A number of elements respecting the evolution of primary energy production over the next decades merit closer attention.

First, uranium and fossil fuel production is largely dependent on export markets, worldwide demand and pricing. Irrespective of these markets, however, **Canada can still meet its most aggressive GHG emission reduction targets without significantly reducing its fossil energy exports**. However, even with a very generous allocation of GHG emission rights to the oil and gas sector, Canada can only do so much to support its export business: should the world reduce its oil and gas demand, with prices falling rapidly, Canada would be left with much smaller export markets. While the government should not impede private investments in the sector, it should avoid introducing additional subsidies that artificially lower production costs and should instead support the conversion of the economy away from fossil fuels over a few decades.

Second, a number of observations noted about other low-carbon energies are also worthy of attention. With the prices of intermittent renewable electricity falling rapidly, **bioenergy is expected to play a smaller role in energy transition than predicted even a few years ago**. Nonetheless, especially in transportation, this role could be crucial to achieving the most aggressive GHG emission reduction targets, while keeping costs in check. As bioenergy does not develop significantly in the BAU and PRO scenarios, substantial investments are still required to optimize pricing and technologies. **Nuclear energy is also expected to remain an essential part of Canada's energy portfolio, but no growth in total energy production share is expected**, according to model outputs.

With energy production much more widely distributed across the country, many of the current energy-poor provinces will gain significantly from the energy transition. However, provinces relying heavily on fossil fuel production, such as Alberta, Newfoundland and Labrador and Saskatchewan, will have to diversify their economy, especially if worldwide demand for their products falters.

6

The ever-growing importance of electricity

As electricity is central to the energy transition process necessary for Canada to reach its GHG emission targets, this chapter presents a more detailed picture of how the electricity sector will have to evolve to meet the targets set in the various scenarios defined for this Outlook. Even though Canada's electricity is largely decarbonised, there is a wide variation in the sector's emissions across the provinces. This sector still needs to evolve significantly over the next decades. In other words, the grid of the provinces that continue to rely predominantly on thermal production will have to decarbonise and growing electricity needs will have to be met without increasing its GHG emissions.

Highlights

All scenarios point to an accelerated electrification of the Canadian energy system.

This electrification will evolve very differently across Canada given that the resources available differ considerably.

With a strong flexible base load generation and considerable hydroelectric reservoirs, Canada will not need as much intermittent renewable capacity as other parts of the world.

Building new hydroelectric capacity can be avoided with the large-scale deployment of wind and solar production.

Most of the growth in electricity production will come from wind, exceeding hydroelectricity in all national reduction scenarios.

Photovoltaic will remain below 10% of total electricity generation, still surpassing nuclear.

As self and local electricity production will become more important, provinces will need to develop policies regarding grid management and electricity integration.

The growing electrification of energy consumption in various activities will require active public support of new technologies across sectors.

6.1 Evolving toward a lower carbon mix

As discussed in Chapter 4, electricity is central to the energy transition necessary to reach Canada's GHG emission targets, even for the least ambitious scenarios. Canada's current electricity generation is dominated by hydro and nuclear generation, making it one of the OECD countries with the lowest GHG emissions per kWh generated. Over the coming decades, the transformation of Canada's energy system will see an increase in its overall generation of electricity, along with the reduction, if not the elimination, of the remaining thermal electricity generation based on fossil fuels.

Figure 6.1 shows the primary energy sources used in electricity generation, while Figure 6.2 indicates which technologies drive this generation. Demand for electricity increases in all scenarios, even in BAU (+42 % by 2050). This increase is, as expected, more significant with more stringent emission restrictions as pursuing a major process of electrification is the only way to maintain the required energy services for a developed society while decreasing GHG emissions. Most of the generation increase occurs after 2030, ranging from 124% (PRO) to 209% (FED) by 2050.

In all scenarios, we see the share of thermal generation decreasing in 2030. While this reduction is negligible for the less constraining scenarios (BAU and PRO), it intensifies as GHG reduction objectives move more in line with international goals (FED and 80P), dropping to 15–20% of current generation levels. We also see, again in all scenarios, a small but absolute increase in thermal generation by 2050, mainly through natural gas, in order to balance the strong increase in intermittent generation from wind.

Wind generation shows the fastest increase over the next three decades in all scenarios but BAU, rising from 27 TWh (today) to 405 TWh for PRO and as much as 918 TWh for FED – surpassing hydroelectric generation by 165 TWh (20%).

With current projects such as Site C (BC), the Romaine (QC) and Muskrat Falls (NL), hydropower is predicted to cover most of the increased demand for 2030. Some additional generation is also seen in all scenarios for 2050. While this increase in hydro generation is possible from an economic point of view, there is considerable opposition to this technology, both from communities directly affected by the dams and flooding and from the general public. It is therefore likely that our scenarios overestimate the role of hydropower in Canada's future electric systems. Limiting new hydroelectric

Figure 6.1 – Energy consumed for electricity generation

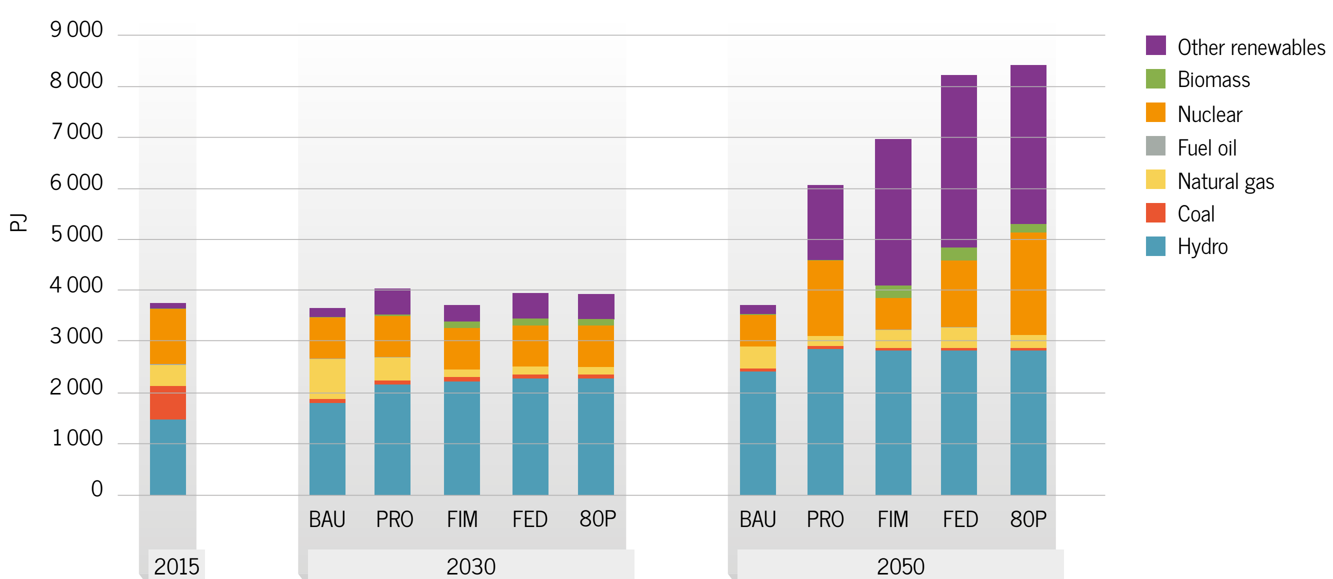
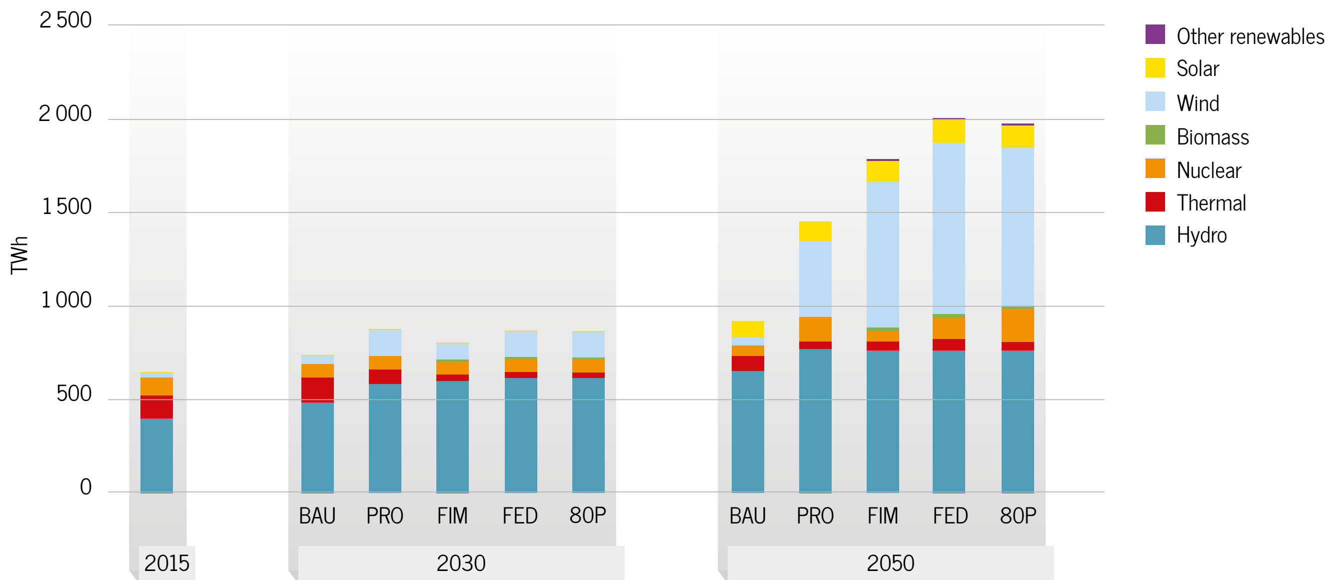


Figure 6.2 – Electricity generation by energy source



developments while maintaining GHG emission targets, however, will require either accelerating the development of other low-carbon energy sources or reducing demand, by improving building quality and decreasing the energy intensity associated with the transportation of goods and persons.

Although all scenarios show a decrease in nuclear energy for 2030 (from 96 TWh to 71 TWh), generation will likely increase for 2050 (179 TWh in 80P). Only scenario FIM shows a further reduction in generation (to 55 TWh), similarly to BAU. From an economic perspective, even the most aggressive GHG reduction scenarios leave some (limited) space for the growth of this energy source. However, as a proportion of total electricity generated, nuclear energy is not expected to be as high as it is today (15%), with 2050 percentages ranging from 3% to 9% across scenarios.

Photovoltaic is expected to contribute only a relatively small fraction of the total electricity generation in 2030, but should pick up in the following decades, surpassing nuclear in all scenarios but PRO, while remaining well below 10% of total generation.

6.2 Provincial evolution

While national electricity generation trends help summarize the transformation of the Canadian energy sector, this transformation is, first and foremost, a provincial matter, with extensive differences based on historical choices and access to local natural resources. To some extent, these differences will continue in the future, but all scenarios show that new generation in all provinces will primarily stem from renewables, as Figure 6.3 shows.

As electricity demand is expected to triple by 2050 in almost all scenarios, provinces where thermal sources dominate (Alberta, Nova Scotia and Saskatchewan) will see their generation substantially modified, chiefly through massive wind generation by 2050 – as early as 2030 for Nova Scotia – in all scenarios but BAU. There is one exception though for Saskatchewan: in PRO, thermal generation almost doubles by 2050 (from 17 TWh to 32 TWh) as electricity demand becomes dominant with the electrification of transportation. All other scenarios show a reduction of thermal generation to 7 TWh.

In the BAU scenario, New Brunswick would see its thermal generation quadruple by 2050 to satisfy the increased demand, making it the dominant source, with 38% of total generation. Other scenarios show that new demand is to be met mainly through wind for 2050, but through a mix of wind and nuclear for 2030, nuclear being phased out of the mix by 2050.

Low-carbon electricity producers – British Columbia, Manitoba, Ontario, Prince Edward Island, Quebec and Newfoundland and Labrador – will continue in this direction even while increasing their production. In Manitoba and Newfoundland and Labrador, the expected new generation for 2050 is still almost exclusively derived from hydropower, in contrast to British Columbia and Quebec, where it is predominantly from wind.

Based on prices and GHG reduction constraints, the model also integrates considerable hydro development, with a 50% increase in generation (from 199 to 295 TWh) in Quebec, 90% in Newfoundland and Labrador (47 to 88 TWh), 150% in Ontario (37 to 93 TWh), and 210% in Manitoba (36 to 113 TWh). For its part, British Columbia is not expected to expand hydro generation significantly.

While its current generation is negligible, Northern Canada is expected to become an important electricity producer, increasing from 1 TWh to at least 70 TWh (BAU) by 2050. Most of this will come from two sources, hydro and wind, and will serve to meet demand in neighbouring provinces. Although generation is dominated by hydropower in the BAU scenario, in the more aggressive reduction scenarios (FIM, FED and 80P) the generation of 115 TWh is distributed evenly between wind and hydro.

Figure 6.3 – Electricity generation by energy source per province

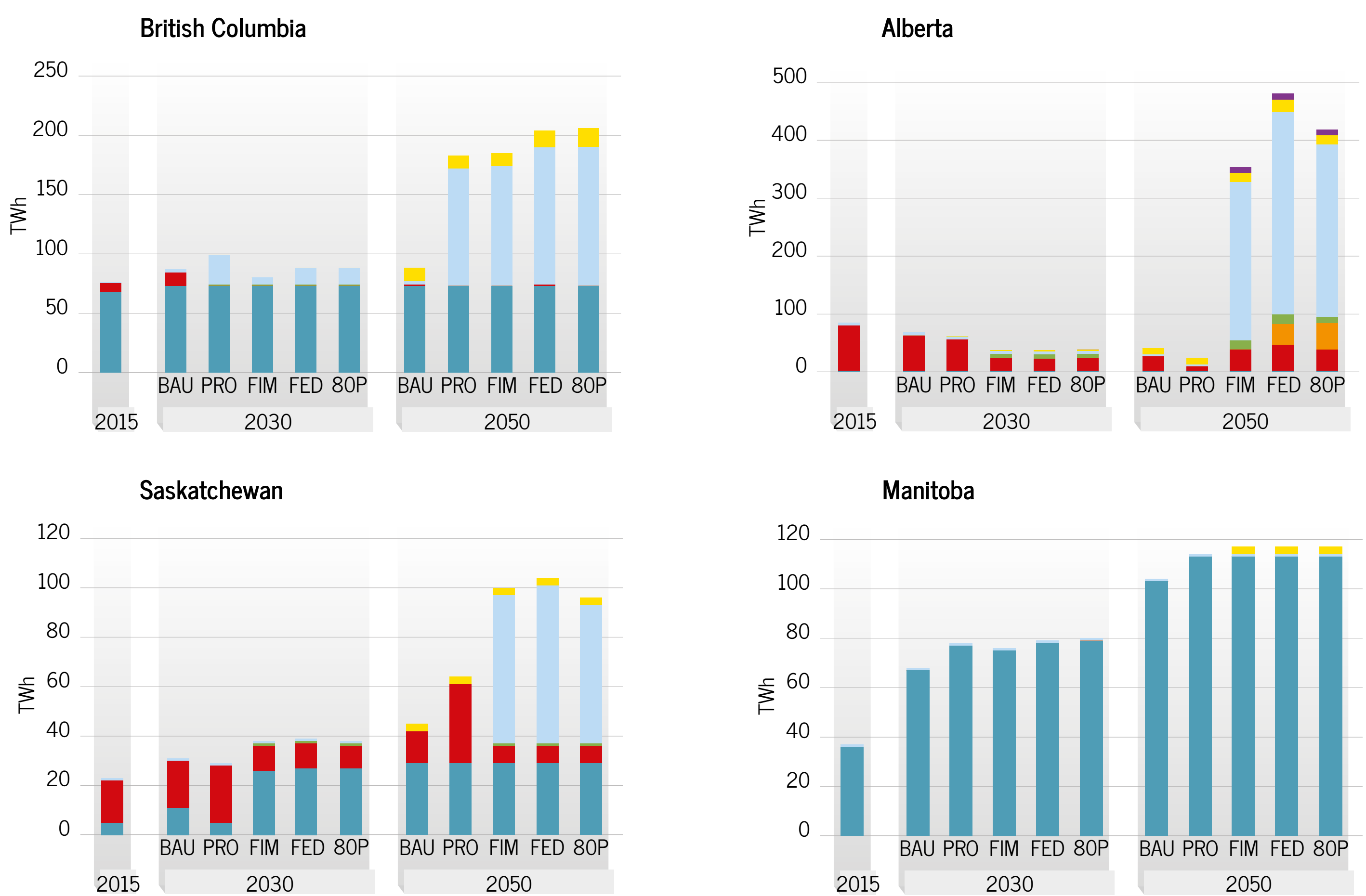


Figure 6.3 – Electricity generation by energy source per province

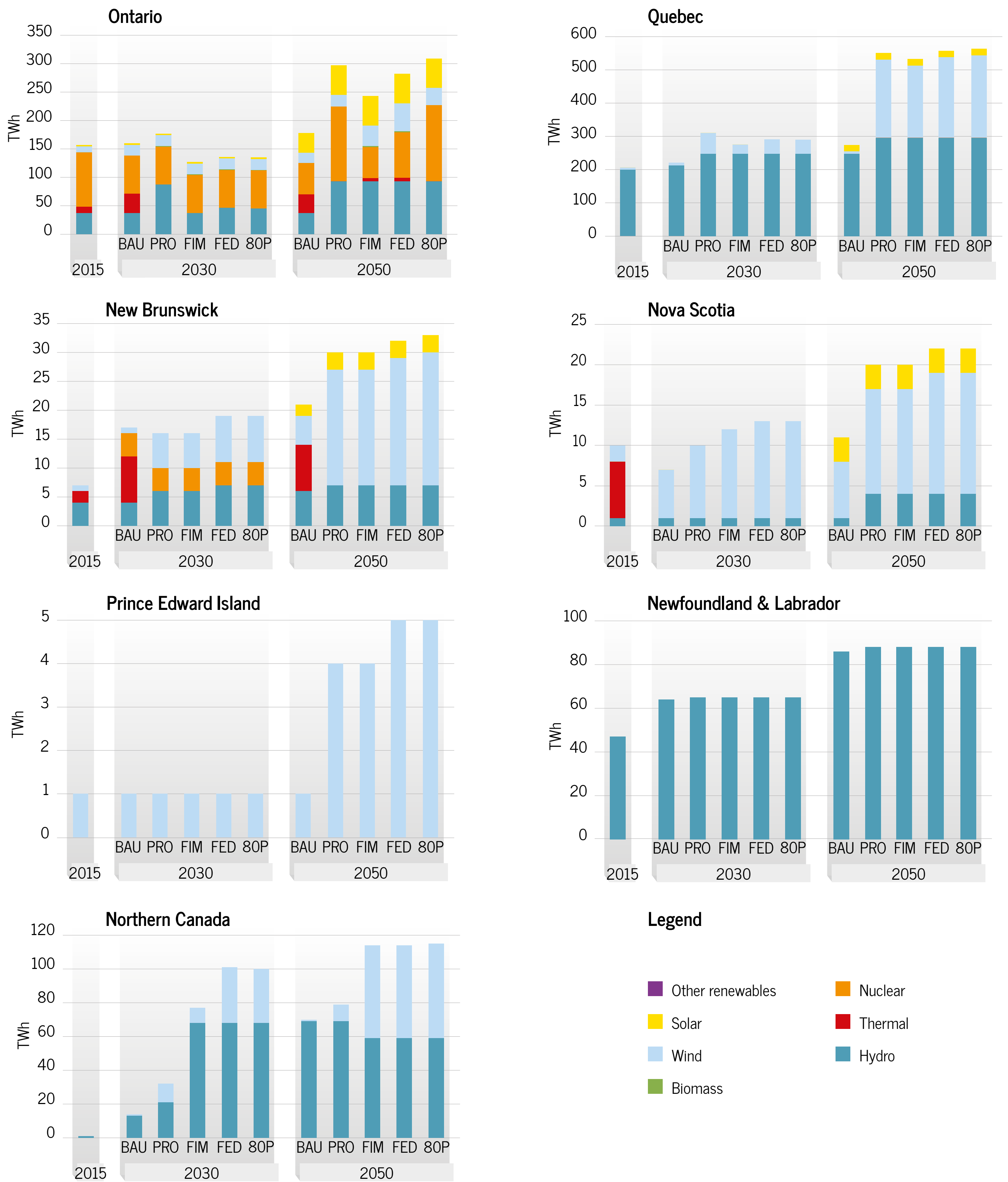
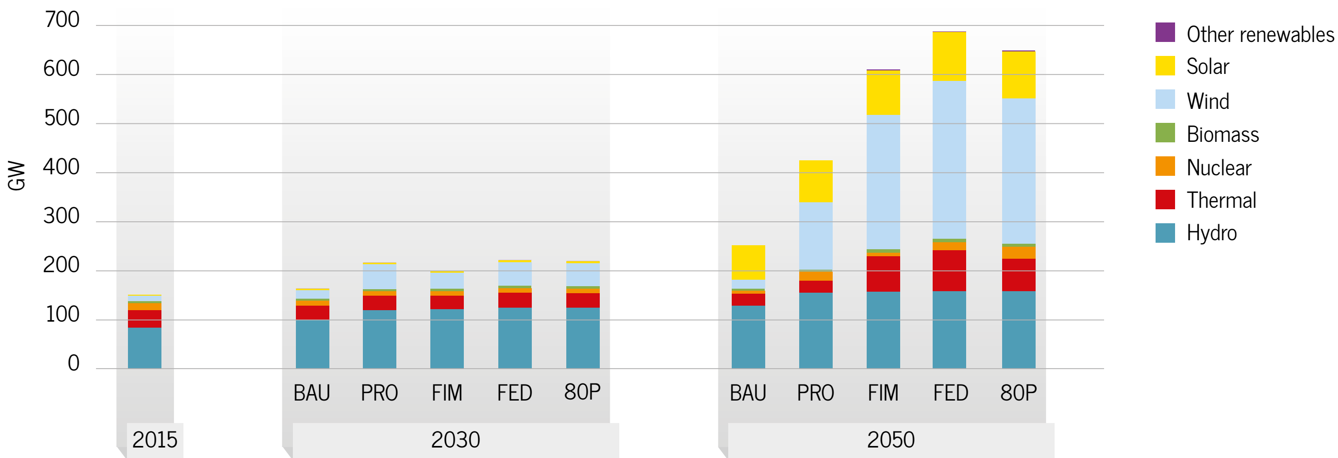


Figure 6.4 – Electricity installed capacity by energy source



6.3 The growth of electricity generation: a future dominated by wind

With a strong flexible base-load generation and considerable hydroelectric reservoirs, Canada will not be required to build up as much renewable capacity as other countries. To generate 43% of the total electricity in the 80P scenario, Canada will only have to build wind capacity that represents 46% of the total (Figure 6.4). Thanks to the availability – and flexibility – of hydropower, curtailment is limited, making this investment very cost competitive. With generation less aligned with demand, investment costs in solar will be higher: to generate 6.5% of the total electricity in 80P by 2050, solar capacity will need to represent 15% of the total installed capacity. This explains why, in spite of its relatively low cost, solar production does not play a greater role in the various scenarios presented here.

Again, this situation could change rapidly depending on how electricity storage technologies evolve, a factor that was not included in the current scenarios.

6.4 A limited role for other technologies

In spite of its current role in Saskatchewan, carbon capture and storage technologies (CSS) do not appear in our scenarios due to their considerable costs and uncertainty about their development. While viewed as a viable option a few years ago, most CCS demonstration plants have been abandoned worldwide, as wind and solar technologies are gaining ground, reducing the rate of technological advances that is required to lower prices. It is likely that Canada will not be able to pursue this approach alone, an analysis that is reflected in the pricing scheme assumed by our various scenarios.

Generation from other technologies such as tidal, geothermal and biomass thermal are also generally left out of our scenarios due, again, to the remarkable decline in price of wind and solar. Because of the relatively low efficiency of geothermal and biomass electricity generation – typically below 30% – it is likely that these technologies will be mainly used in the future for direct heat production or as part of co-generation setups in combination with solar and wind technologies. Their role will therefore be limited to specific regions that have access to significant local resources.

6.5 The electrification of the Canadian economy

Even if, in all scenarios but BAU, the total energy demand remains almost constant between now and 2050 (see Chapter 5), the demand for electricity will at least double over that same period, and could almost triple in the most aggressive scenario (80P). This shift to electricity will require new tools, machinery and infrastructure that open up considerable opportunities for development and innovation. Figure 6.5 clearly illustrates the substantial energy transformation that the Canadian economy must undergo to reach its GHG reduction targets.

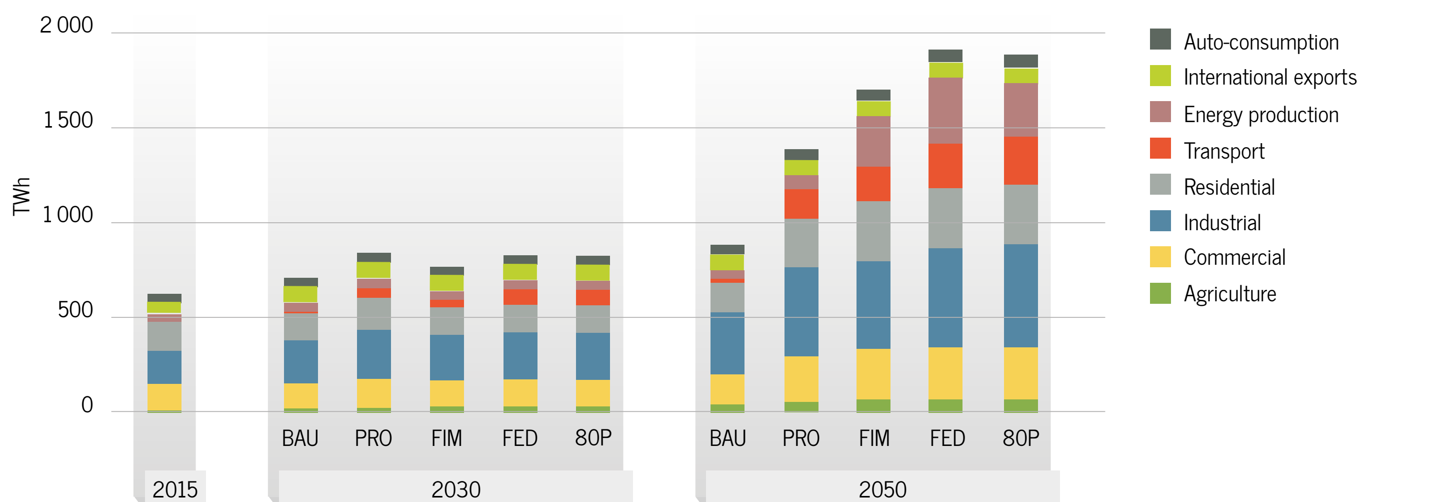
With an increase of this size, all sectors will be affected. Some transformations will be straightforward: the electrification of residential — and, up to a point, commercial — space heating, for example, can be carried out relatively cheaply with well-established technologies. Other sectors will require more substantial investments: heavy industry, particularly mining and oil and gas, which currently rely almost exclusively on fossil fuels, will have to adapt and develop production technologies capable of producing sustained high-power energy in the remote regions where they operate. Similarly, the electrification of the transportation sector relies on technologies that are now only partially available at competitive prices. Receiving worldwide attention and investments, however, it is very likely that solutions will become available in time to comply with most scenarios.

Given the depth of the electrification of Canada's energy systems, it will not be possible to wait until 2040 before taking action. As new infrastructure and equipment are needed, investors will have to consider, starting today, whether their choice is compatible with the long-term GHG reduction goals, and whether it is better to put the money down today or whether it pays more to wait a few more years before making the transformation. However, unless Canada's pathway becomes clearer, it will remain difficult for investors to accurately evaluate the costs of the various options and to make the most cost-effective decisions from both short- and long-term perspectives.

6.6 Differences across the scenarios

In spite of common trends, the various scenarios propose energy pathways for Canada that differ somewhat as to the extent of its electrification. The reference (BAU) scenario suggests a relatively steady growth: 14% between 2015 and 2030 and 42% between 2015 and 2050, which brings total generation from 649 to 920 TWh over this period. While the increase is in line with historical trends, there is significant shuffling even in BAU. Driven by energy prices and announced coal plant closures, two sectors will plummet over the next 30 years: nuclear, with production falling from 96 to 55 TWh, and fossil fuels with a similar decrease, from 123 to 80 TWh. In BAU, this reduction and the overall rise in electricity demand are primarily met by hydro (from 399 to 653 TWh) and solar production (from

Figure 6.5 – Electricity consumption by sector



3 to 85 TWh), which becomes the second electricity source by 2050. Wind in BAU is set to plateau at about 45 TWh by 2030.

For 2030, electricity generation is relatively uniform across the various GHG reduction scenarios, ranging from 806 TWh (FIM) to 879 TWh (PRO). The generation increase mainly comes from a significant growth in hydro production that is at least 100 TWh higher than for BAU, at the expense of thermal, which could almost disappear, falling as low as 31 TWh in the most aggressive scenarios. While solar and biomass do not contribute much to electricity generation by 2030, wind expands considerably in all GHG reduction scenarios: between 87 TWh (FIM) and 140 TWh (PRO, FED and 80P). At 71 TWh, nuclear is identical in all five scenarios.

In all reduction scenarios, hydro production should further increase by an additional 160 TWh, reaching 760-770 TWh annually by 2050. In spite of this trend, hydro's share in electricity generation, which should hover around 70% in 2030 for all scenarios, up from about 61% today, is reduced by 2050 to 53% for PRO and even 38 to 42% for FED, 80P and FIM. These reductions are due to a massive increase in wind production that could reach 405 TWh (PRO), 781 TWh (FIM), 850 TWh (80P) or even 918 TWh (FED). Furthermore, solar production reaches between 104 TWh (PRO) and 121 TWh (FED) for a total of between 1452 TWh (PRO) and about 2000 TWh (FED), three times the current demand level.

In spite of the significant growth in electricity demand, generation from thermal sources (excluding nuclear) should be between only 40 and 60 TWh, and biomass remains negligible (between 1 and 20 TWh). While nuclear production is modeled to decrease slightly by 2030, its long-term future varies significantly by scenario, falling to 55 TWh for BAU and FIM, but increasing to 116 TWh (FED), 131 TWh (PRO) or even 179 TWh (80P).

In spite of these differences, the various GHG reduction scenarios are clear: reaching GHG targets will require not only decarbonising electricity generation, but also significantly increasing its share of energy demand. However, with so much hydro and nuclear, it is clear that Canada can electrify its energy sector at a lower cost and more easily than almost any other country.

Thus, these results suggest that there is little risk for investors and governments to go ahead and support green and low-carbon electricity generation, irrespective of the detailed reduction targets.

6.7 Key trends

The electrification of the Canadian energy system is almost unavoidable. Its final shape, however, remains much more undefined due to a number of current hurdles and competing trends. First, the capacity of the Canadian provinces to work together to develop a solid East-West electric backbone, able to support increased interprovincial electricity trade, remains uncertain. Without such a structure, the average cost of electrification will be higher and some provinces might have trouble achieving the targeted levels (Billette de Villemeur et al. 2016). Even though electricity generation falls under provincial jurisdiction, there is a clear role here for interprovincial talks and federal leadership (SCNR 2017).

The role of self-generation in the electrification process is very much an open question at present. Scenarios presented here lack the information to account for this aspect. However, as observed in other countries, the tipping point required for citizens and businesses to install rooftop PV is near. Because of the Canadian climate and its industrial structure, this self-generation will need to be assisted by a solid and resilient grid, as well as by a sufficient amount of centralized generation. Yet there is a clear need to develop self-generation policies ahead of the mass movement to avoid a profound perturbation that could lead to rapidly increasing prices for industry and heavy users, thus affecting Canada's competitiveness in a number of economic sectors.

7

Impacts of the reduction scenarios on GHG emissions

Energy production and consumption represent over 80% of Canada's GHG emissions. For this reason, several of the policies described in Chapter 3, as well as the GHG emission targets underpinning the four scenarios presented here, focus on reducing emissions from energy-related activities. In fact, over the last few years, in addition to the federal targets, many provinces have established their own GHG emission targets and objectives, generally without determining a clear pathway on how to reach them. The scenarios presented here compare these various objectives and their projected impacts on the diverse energy sectors.

Highlights

At this time, implemented policies are barely sufficient to keep emissions constant until 2030 and could lead to a 10% increase in emissions by 2050.

Additional reduction measures are likely to be difficult to impose politically from a purely federal perspective.

No province has measures in place that would ensure meeting the federal target for 2050.

Marginal costs for emission reductions are decreasing.

A provincial strategy will lead to unevenly distributed and higher marginal costs than even the most aggressive national scenario.

In the more aggressive scenario, half of the reductions can be achieved at less than $300/t and about three-quarters can be achieved at less than $500/t

Impacts of the reduction scenarios on GHG emissions

7.1 Energy-related emissions

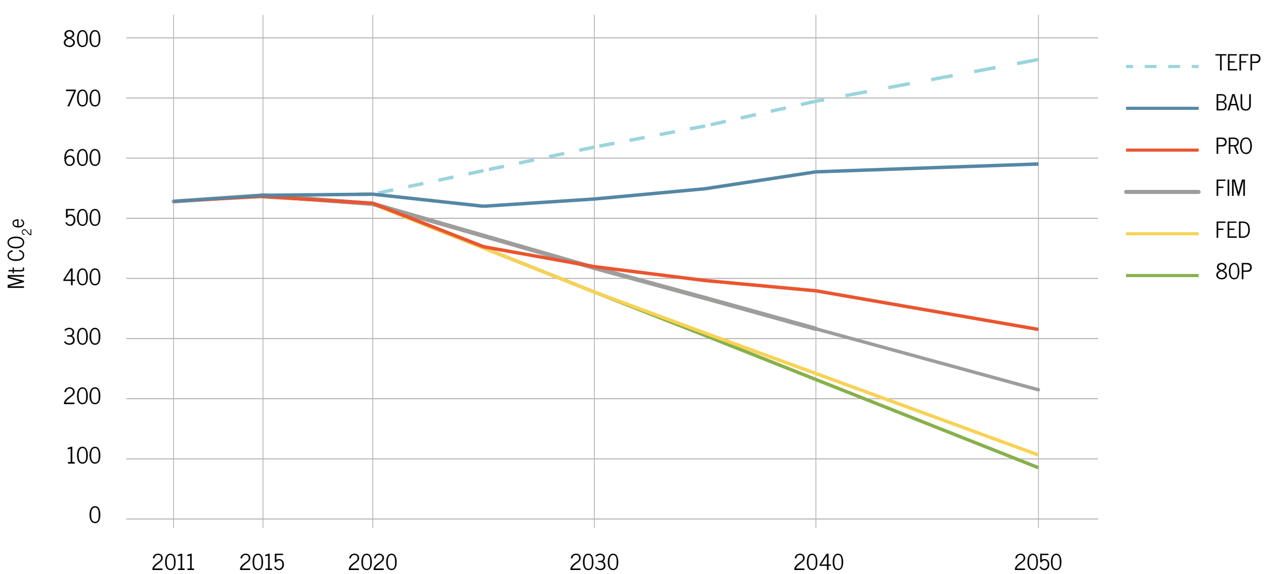
Figure 7 1 presents results for energy-related GHG emissions for Canada in the reference (BAU) and GHG scenarios. Emissions from agriculture waste and industrial processes are thus not addressed in this Outlook and not included in the results presented below. It should also be noted that because of the uncertainty tied to the evaluation of their true size, fugitive emissions are also excluded from the following discussion. We shall return to these issues in Chapter 10.

The policies already in place are barely sufficient to keep emissions roughly constant until 2030, and without additional measures, emissions would even increase by almost 10% from 2030 to 2050. Yet they constitute a significant departure from a similar reference scenario produced in 2016 as part of the Trottier Energy Future Project (TEFP 2016), which suggests that the trend regarding emissions is changing (albeit still too slowly). Assuming the successful achievement of their respective targets, all four GHG emission reduction scenarios result in a significant departure from the BAU scenario.

Further observations can be noted. First, the absence of 2050 targets for some provinces (notably Alberta and Saskatchewan) means that PRO results in smaller reductions for this time horizon, followed respectively by FIM and, with similar reductions, FED and 80P. These last three reduction scenarios present a relatively constant diminishing rate in GHG emissions, which suggests that the 2030 targets for these scenarios do not constitute a discontinuity on the path to the 2050 projections. However, the significant discrepancy in 2050 GHG emissions between PRO and the other three scenarios suggests that it will likely be difficult, from a purely federal perspective, to politically impose additional reductions to those already planned on the provincial level.

The difference in slope between FIM and FED (again see Figure 7.1) is due, in the first case, to the purchase of emission rights on an external market (currently California) for an amount corresponding to 25% of the GHG reduction target. The present federal plan includes the purchase of 59 Mt of emission rights from California to reach the 2030 target, requiring California to exceed its own reduction target of 40%, to reach a 55% reduction target instead. To be economically reasonable, these reductions will have to cost less than reducing GHG emissions in Canada.

Figure 7.1 – Energy-related GHG emissions



Note: The additional line (TEFP) reproduces the GHG emissions for the reference scenario adopted for the Trottier Energy Future Project (TEFP) published in 2016.

Such an orientation might be plausible for 2030, as the marginal reduction costs in the FIM scenario are as low as $61/t[1], a quarter of the $231/t calculated for the FED scenario. Of course this would make sense as long as the cost of obtaining emission rights from California remains below this marginal reduction cost and these rights are available. However, we are not currently aware of any analysis performed by Ottawa, Toronto or Quebec that details levels at which it will be more cost efficient for Canada to turn to California for its extra GHG reductions. Irrespective of this cost, such a scenario would nevertheless mean that at least $3.5 billion would be transferred to transform California's economy in 2030, an amount that would increase every year unless Canada chooses to close the gap between its targets and its real emissions. Should the WCI be unable to deliver on these permits, the US$81.9/t ceiling price embedded in the market will kick in, lifting the limit on GHG emissions.

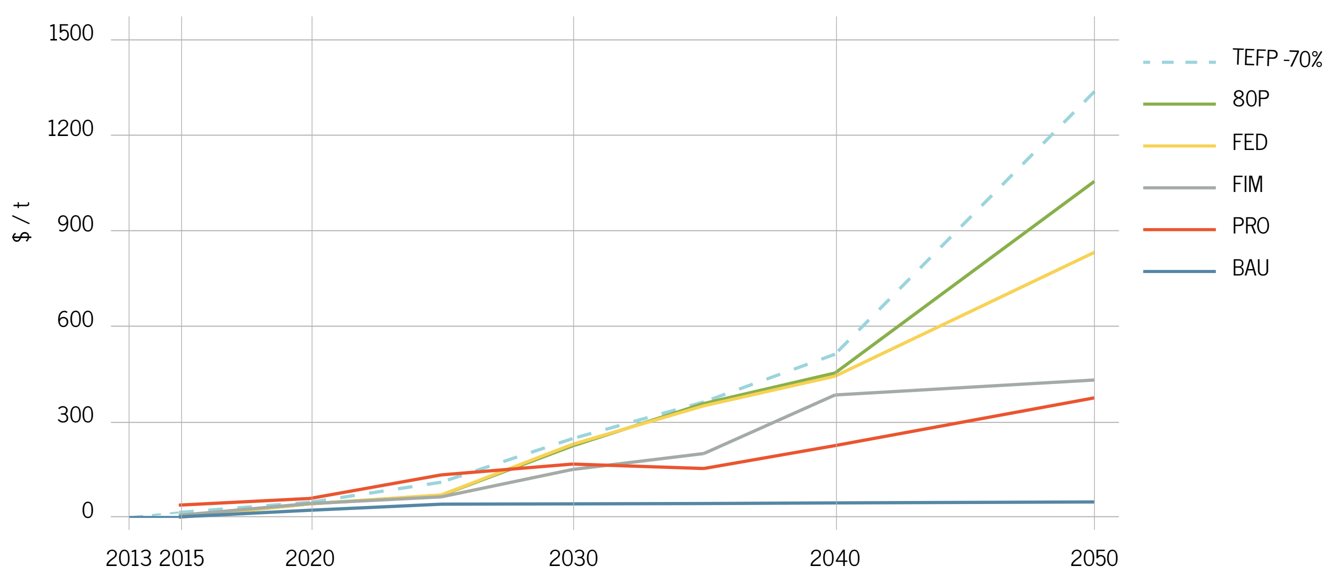
Taken at face value, by 2050, in this FIM scenario, Canada would need to buy emission rights representing about 130 Mt tons, which would constitute a capital flight of $56 billion per year at the marginal cost, again assuming that the market can support this demand.

7.2 The cost of reducing energy-related emissions

Figure 7.2 presents the marginal reduction costs under the different scenarios. For PRO, the figure displays the average marginal cost for each province to reach its respective target. For FIM, FED, and 80P,[2] the figure shows the Canadian marginal cost (taking into account the GHG reduction targets imposed at the Canadian level). Results for 2050 show that more aggressive targets correspond to higher marginal reduction costs. However, the difference among the various scenarios is less than a factor three: from about $400/t for PRO to slightly above $1000/t for 80P.

While these marginal costs may seem high, putting them in perspective suggests the opposite. First, PRO, which imposes much lower GHG reduction targets, leads to marginal costs that are half those

Figure 7.2 – Marginal reduction costs

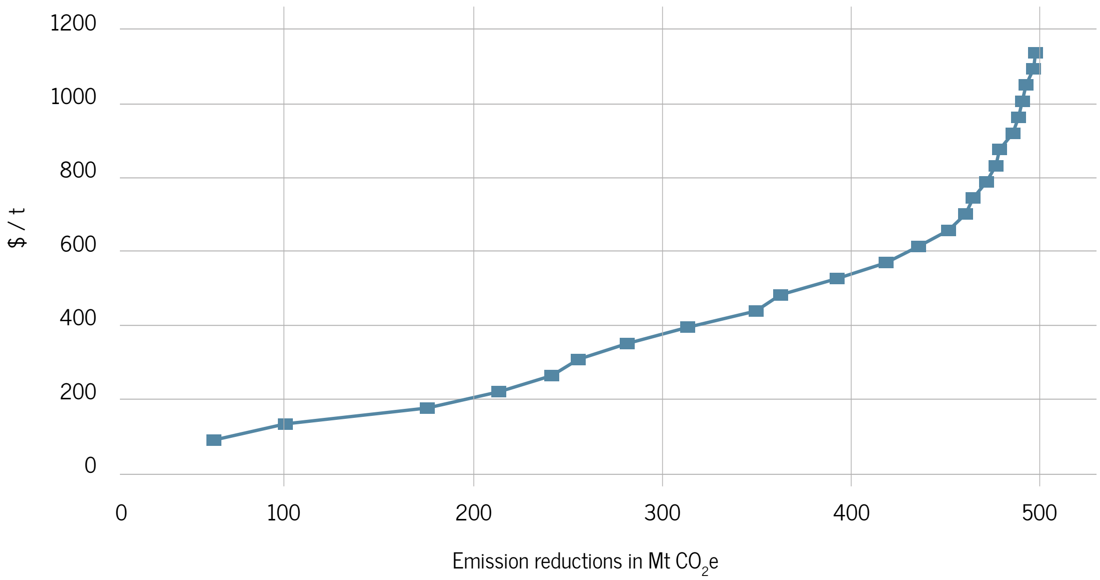


Note: The additional line (TEFP) reproduces the marginal reduction costs for scenario 8a of the Trottier Energy Future Project (TEFP), which leads to a 70% GHG reduction from 1990 by 2050.

[1] Marginal reduction costs are in dollars per tonne of CO_2 equivalent, but written in dollars per tonne to ease readability.

[2] Under FIM, FED and 80P, each province will have the same marginal reduction cost (which would be the equivalent here of a federal carbon tax imposed in each province), but will reach differentiated reduction levels (in percentage, based in particular on the reduction options available in each province) as will be presented in Chapter 8.

Figure 7.3 – Marginal abatement cost curve for 2050



of FED, the federal's most aggressive targets. This indicates that there is a considerable set of significant actions that can take place between $150/t and $225/t by 2030 and between $375/t and $830/t by 2050. This is confirmed in looking at the marginal abatement cost curve for 2050 (Figure 7.3). This curve, built from emission reductions achieved in the model's solutions under various carbon tax prices, shows that about half of the reductions can be achieved at less than $300/t and that about three-quarters of the reductions for 80P can be achieved at less than $500/t.

A more empirical argument is found in a recent report by Quebec's ministry of the environment (MDDELCC 2017) on the cost of the 2013-2020 climate change plan. This report shows that most actions taken to achieve 2020 targets were already costing more, and often considerably more, than $300/t. Even though our modelling approach suggests that there are much less expensive ways to reduce GHG emissions over the next few years, the high price already paid in Quebec shows that the 2050 marginal costs will not impose too heavy a burden on the economy – especially since, by definition, the marginal costs will be applied to proportionally smaller amounts of GHG as the transition takes place, decreasing the direct economic impact of the reduction efforts.

Finally, results from our latest analyses suggest that marginal costs associated with deep decarbonization are rapidly decreasing: 2050 marginal costs in the stringent 80P scenario are significantly lower than those evaluated only a few years ago as part of the TEFP for a less ambitious scenario (-70 % from 1990 for 2050, scenario 8a), indicating both how rapid technological changes can modify the cost of transition and how Canada could move rapidly to guarantee that it benefits from and contributes to these technological changes.

7.3 Evolution since the publication of the Trottier Energy Futures Project (TEFP)

It is worth explaining the main differences in terms of projected emissions and marginal abatement costs compared with TEFP, the most recent large-scale study exploring deep decarbonization pathways for Canada using the same optimization model as this Outlook.

7.3.1 Reference GHG emissions trajectories

As mentioned above, with a 12% increase between 2011 and 2050, the reference scenario (BAU) shows a considerably reduced growth in emissions as compared to the TEFP's reference scenario, where the increase was 44% for the same period (Figure 7.1).

Two main factors are responsible for this difference. First, TEFP's reference case was calibrated to the 2013 version of the National Energy Board projections (NEB 2013), which were based on more optimistic future oil and gas prices than those used for this Outlook (NEB 2017), while keeping similar socio-economic growth rates (NEB 2017), as shown in Table 7.1. Although these projections are not direct inputs to the model, they are used to project the 70 end-use demands for energy services and to build a consistent storyline with macroeconomic drivers.

The second main factor is the addition of several recent federal and provincial policies that have a significant impact on GHG emissions. These include the Federal Clean Fuel Standard announced in 2016, which will require the lifecycle carbon footprint of fuels to decrease over time in a performance-based approach (up to -12.5% in 2030 compared with 2010). Another recent policy with a significant impact on GHG emissions is the Pan-Canadian Approach to Pricing Carbon Pollution. Accordingly, the current reference scenario includes a carbon tax starting at $10/t in 2018 and increasing by $10/t per year to reach $50/t in 2022 (the tax is kept constant until 2050). Other examples include the revision of the coal phase-out regulation, emission standards for heavy-duty vehicles and multiple provincial policies (described in more detail in Chapter 3).

Table 7.1 – Comparison of macroeconomic drivers

Variable	Unit	NEB 2013 2035	NEB 2017 2035	NEB 2017 2040
Oil price - West Texas Intermediate	US$ 2016 / bbl	116	78	78
Gas price - Henry Hub	US$ 2016 / MMBTU	6.49	4.18	4.33
Gross Domestic Product	Index ; 2011=1	1.62	1.53	1.66
Population	Index ; 2011=1	1.26	1.23	1.27

7.3.2 Marginal abatement costs

The decrease in the reference emissions trajectory, combined with additional reduction options in the model, lead to significant decreases in marginal abatement costs compared with TEFP. The most significant additional reduction options considered in this study are:

- The entire renewable natural gas supply chain and consumption in all sectors, namely upgraded biomethane from organic municipal waste, biogas from manure, landfill biogas, waste water, etc. and syngas from biomass gasification.
- The possibility of adding incremental hydro capacity at exiting sites to account for dependable capacity and support intermittent renewables.
- Some carbon capture and storage options for natural gas power plants.
- Electrification of heavy freight transport.
- Solar PV on residential and commercial building rooftops with battery storage options.

TEFP allowed for deriving optimal solutions to achieve progressive reductions in GHG emissions of up to 70% from 1990 by 2050. The marginal abatement costs for this ultimate scenario reached close to $1400/t in 2050 (Figure 7.2) and achieving a more ambitious target was not possible due to the lack of reduction options in some sectors. This Outlook includes a more ambitious scenario (80P) reaching an 80% reduction from 1990 by 2050 at $1055/t. Moreover, the FED scenario, involving an 80% reduction from 2005 by 2050 (equivalent to a 75% reduction compared with 1990 levels) can be achieved at $832/t.

7.4 Emissions at the provincial level

Depending on the scenario, the provinces will be diversely affected by GHG reductions. In this section, we first consider the national scenarios – BAU, FIM, FED and 80P. We then turn our attention to the PRO scenario, where provincial targets and objectives are used to construct a national evolution.

7.4.1 National targets scenarios

The national BAU scenario leads to very different pathways for each province. By 2030, without additional constraints, GHG emissions are expected to stay flat or decrease in all provinces except British Columbia (+10%), Ontario (+12%) and New Brunswick (+5%) (Figure 7.4). As a share of current emissions, the biggest changes are expected to be in Nova Scotia, with a decline of almost 65%, and Prince Edward Island (-25%) Overall, only three provinces (New Brunswick, Nova Scotia and Newfoundland and Labrador) and Northern Canada are set to meet 2030 federal targets in the BAU scenario and none by 2050.

This trend is largely maintained for 2050, with Alberta, Saskatchewan, Manitoba, Quebec and New Brunswick keeping their emissions almost constant, while Nova Scotia, Prince Edward Island, Newfoundland and Labrador and Northern Canada see their emissions decrease over time mainly due to the electrification of a portion of their energy consumption. Only British Columbia and Ontario see their consumption increase over the next 30 years, each by 32%, in spite of their respective aggressive targets.

Therefore, differences in per capita emissions in BAU remain, similar to today's situation for 2030 and 2050, with the Alberta and Saskatchewan fossil fuel industry raising per capita emissions for these

Figure 7.4 – Energy-related GHG emissions per province

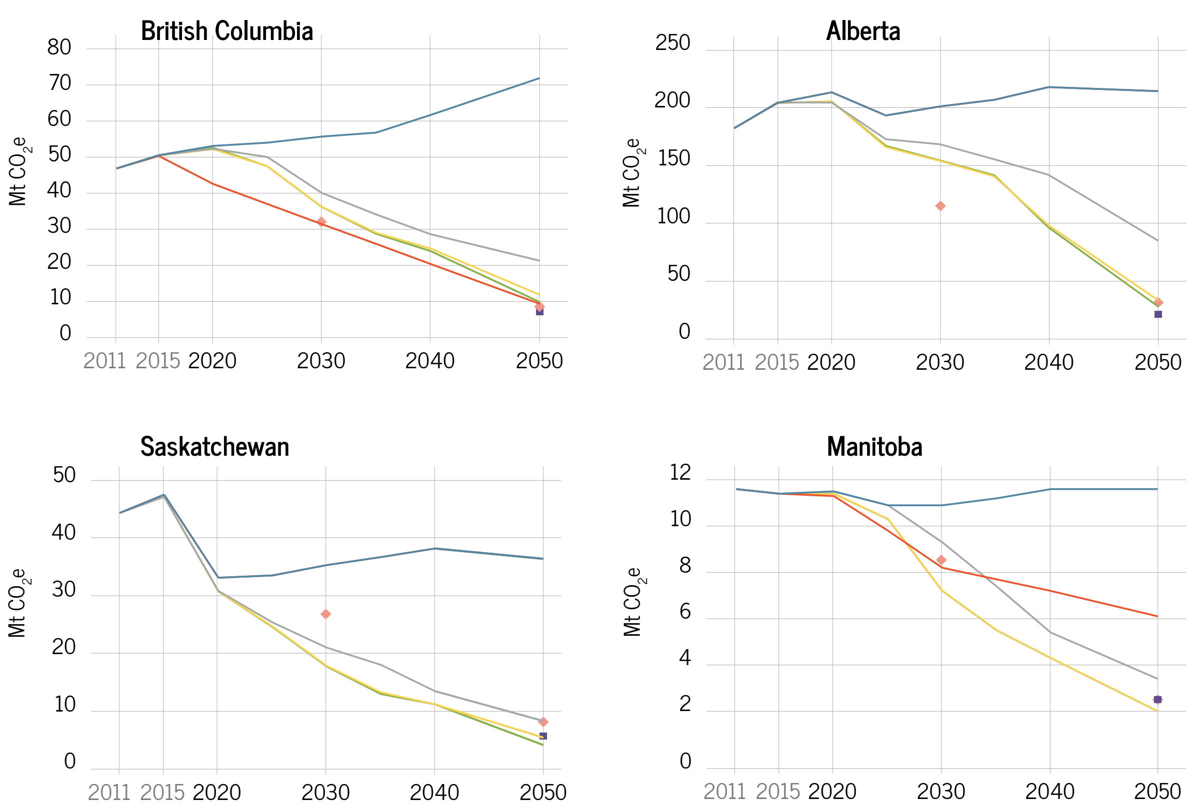
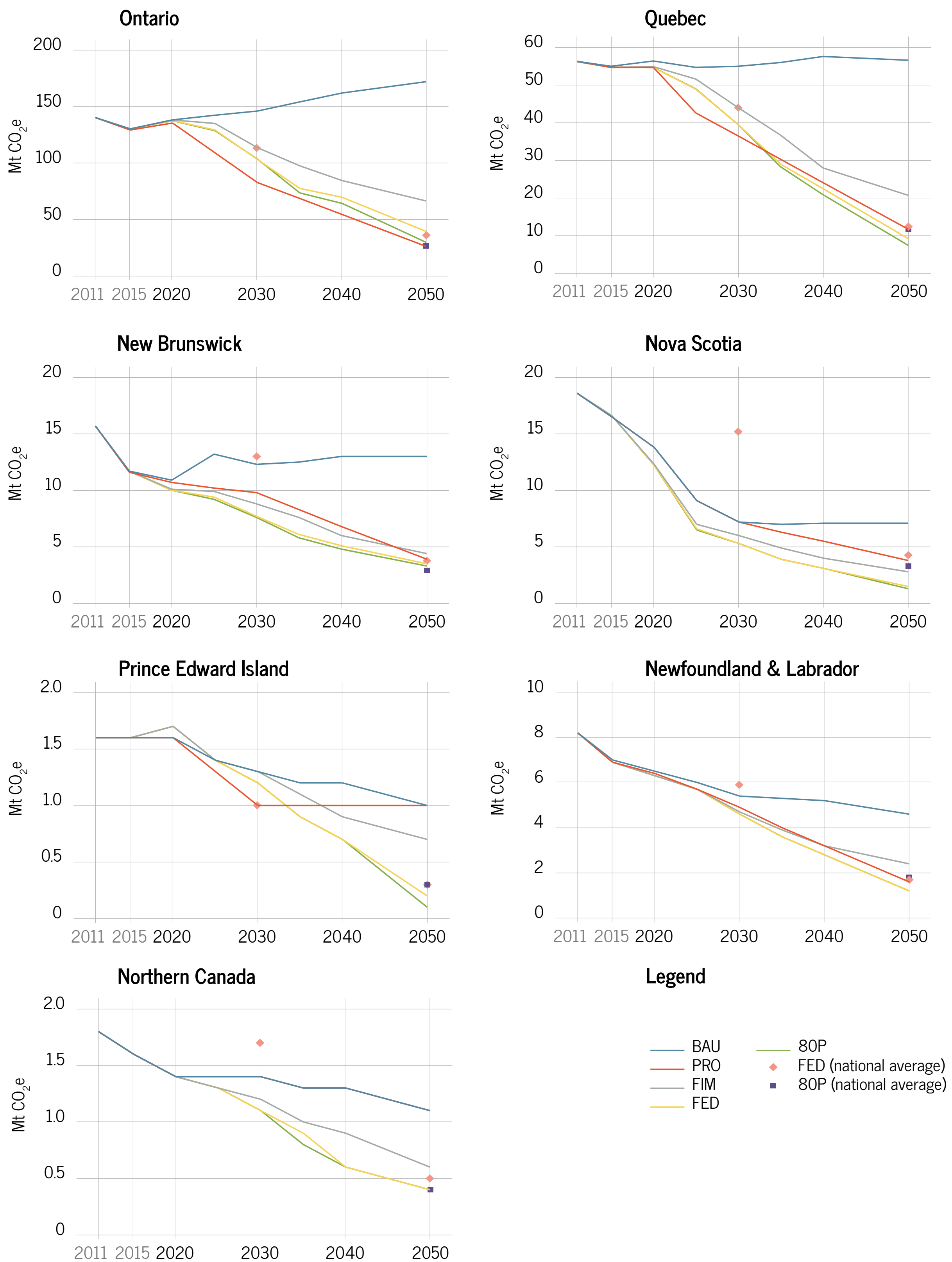
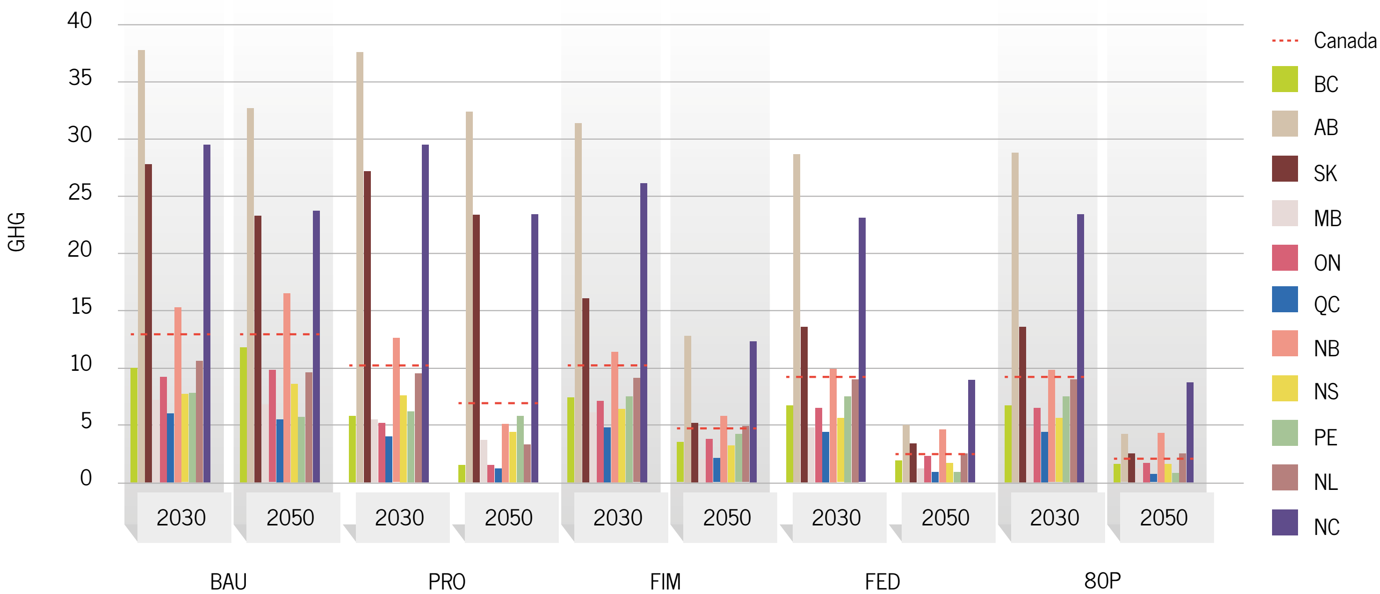


Figure 7.4 – Energy-related GHG emissions per province



Note: Due to the absence of provincial/territorial targets, the BAU curve for Alberta, Saskatchewan and Northern Canada is identical to PRO. Symbols refer to the national average for 80P and FED scenarios.

Figure 7.5 – Energy-related GHG per capita by province



Note: the horizontal lines indicate the Canadian per capita emissions.

provinces above 30 tCO_2e, with most other regions, apart from Northern Canada and New Brunswick, showing emissions around or below 10 tCO_2e.

As expected, the more stringent targets for FED and 80P affect all provinces significantly. Due to the sum game, the largest emitting provinces are severely constrained by these targets, as can be seen by comparing the national levels (red symbols) with the provincial emissions in Figure 7.4. A difference remains, however, due to varying marginal costs across the provincial economies.

For 2030, for example, British Columbia, Alberta and Prince Edward Island maintain emissions above the FED and 80P targets, by up to 33%, or 40 $MtCO_2e$, in the case of Alberta. Conversely, a number of provinces seem to have very accessible GHG emission reductions available: Saskatchewan, New Brunswick and Nova Scotia, in particular, would reduce their emissions well below the national targets in 2030. By 2050, however, the importance of the targets is such that profound changes must be made to the economy across the country and almost all provincial reductions be aligned with the national targets. Reducing the national targets by allowing up to 25% of the emissions to be bought on an international market mainly allows the largest industrial provinces (British Columbia, Alberta, Ontario and Quebec) to retain higher emissions, whereas this has much less impact on Saskatchewan, Manitoba, the Maritimes and Northern Canada.

Per capita emissions follow these trends (Figure 7.5). For FED and 80P, emissions will remain high in Alberta, Saskatchewan and Northern Canada by 2030, but will rapidly decline after that – even reaching the national target in the case of Saskatchewan. Even though, as a ratio, the difference between provinces will remain important, per capita differences will be relatively small in absolute value.

Finally, we can compare the reduction in each province with respect to the national targets (Figure 7.6) as an indirect measurement of the relative reduction cost for each economy. For 2030, in the FED scenario (30% of 2005 emissions), reductions would take place disproportionally in Saskatchewan (63% reduction), Nova Scotia (68%) and, to a lesser extent, Manitoba (37%), New Brunswick and Newfoundland and Labrador (both 34%). Contrary to expectations based on the provincial targets, for 2050 (80% of 2005 emissions), BC (77%), Ontario (70%), New Brunswick (70%) and Northern Canada (75%) will reduce their emissions by less, due to higher reduction costs.

Figure 7.6 Provincial percentages of emissions with respect to 2015 for the FED scenario

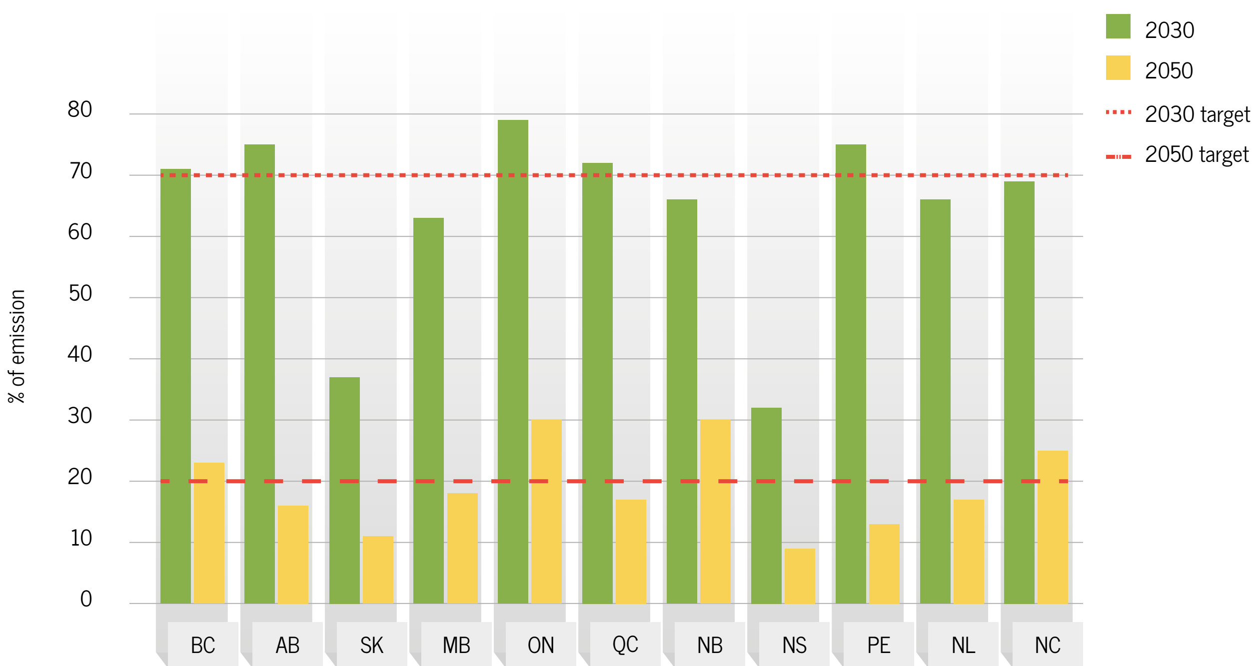
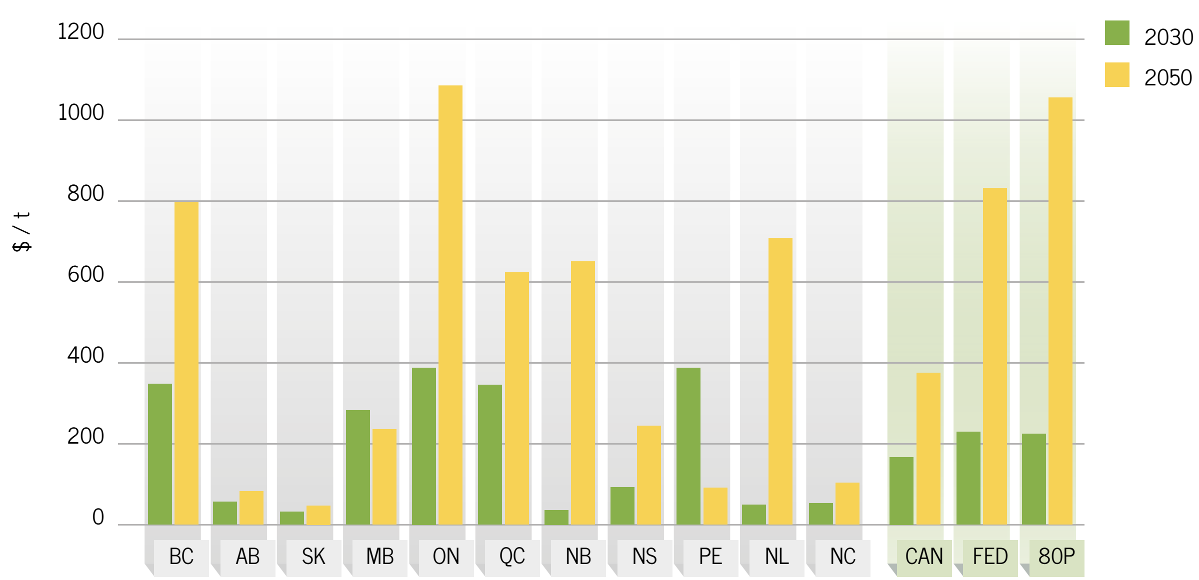


Figure 7.7 Marginal cost per province for the PRO scenario



Note: The average Canadian cost is also indicated (CAN) as well as that for FED and 80P scenarios.

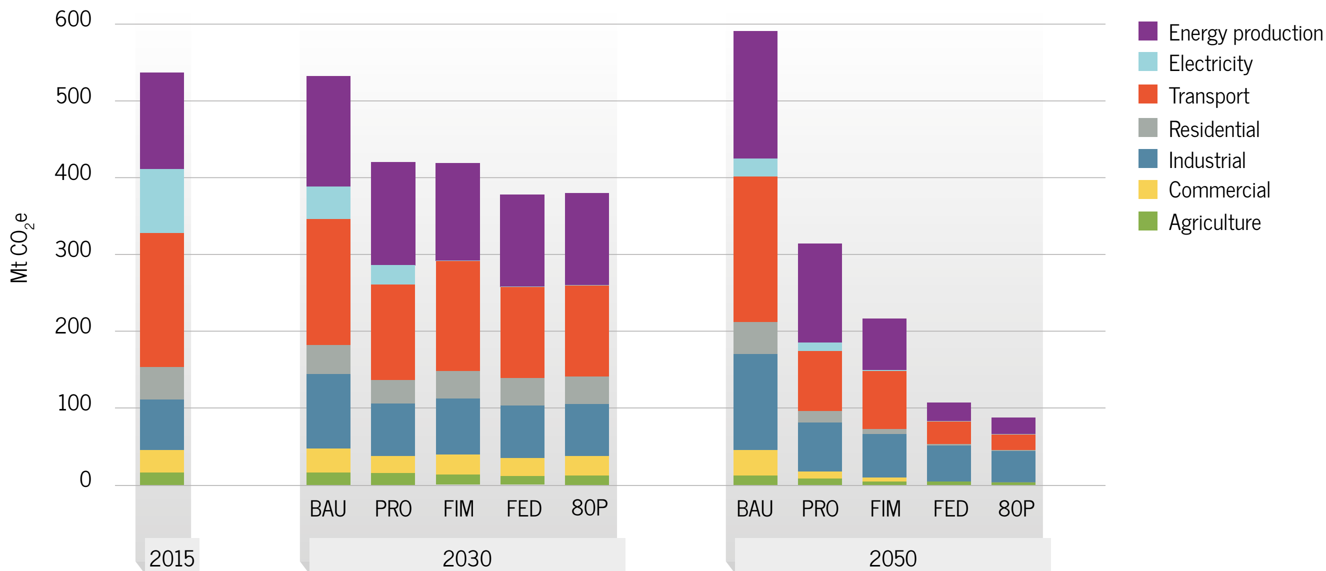
7.4.2 Provincial targets scenario

The PRO scenario allows us to see how the various provinces' GHG emission targets or objectives compare, both in terms of emissions and the marginal costs to attain them.

Figure 7.4 showed that the provinces' goals differ significantly. Targets for Alberta and Saskatchewan, for example, are weak enough to be on top of the BAU curve. Thus, PRO GHG targets constitute absolutely no constraint for these two provinces, leading to emissions that are well above the FED

Impacts of the reduction scenarios on GHG emissions

Figure 7.8 – Energy-related GHG emissions by sector



and 80P national targets. All other provinces have 2030 targets that are stricter or similar to the FED and 80P national targets, a gap that closes by 2050 for all these provinces except Prince Edward Island.

This difference in principal targets means that for the two most intensive GHG producing provinces, emissions would remain well above 30 tCO_2e per capita by 2050, creating considerable strain with respect to other provinces that will have reached their most aggressive targets in the PRO scenario (Figure 7.5).

This is evident when looking at the marginal costs for each province in the PRO scenario (Figure 7.7), and comparing them with the national cost for the PRO, FED and 80P scenarios. For Alberta, Saskatchewan, Newfoundland and Labrador and Northern Canada, marginal costs for GHG emission reductions are around or below $50/t in 2030. Since this includes the $50/t imposed by the federal government, these results indicate the absence of any real constraint for these provinces, compared with more significant efforts in British Columbia, Manitoba, Ontario, Quebec and Prince Edward Island, where marginal costs are between $350/t and $400/t. The tension is likely to increase for 2050, as the spread in marginal costs increases, even among the most ambitious provinces. For example, while marginal costs reach between $600/t and 800/t for British Columbia, Quebec, New Brunswick and Newfoundland and Labrador, they climb to $1085/t for Ontario, whereas they are between $47/t and $88/t for Alberta and Saskatchewan.

Comparing these prices with the national value for 80P and FED, we see that at $230/t in 2030, the value is below that of the most aggressive provincial targets. This suggests that it would be possible to make the transformation more easily at a lower economic cost by involving Alberta and Saskatchewan. In turn, by 2050, the marginal costs closest to this figure involve transforming Ontario, the largest province.

7.5 Emissions by sector

Turning to emission reductions by sector, Figure 7.8 highlights the evolution of GHG emissions while Figure 7.9 presents the sectorial GHG reduction efforts. First, in the absence of constraints on GHG emissions (BAU), the only sectors expected to reduce energy-related emissions are agriculture and electricity generation, due, in the latter case, to the planned closure of coal power plants and the falling prices of renewable electricity. Therefore, when not constrained by a specific sectorial target, BAU still favours a substantial transformation of the electricity sector by non-emitting sources.

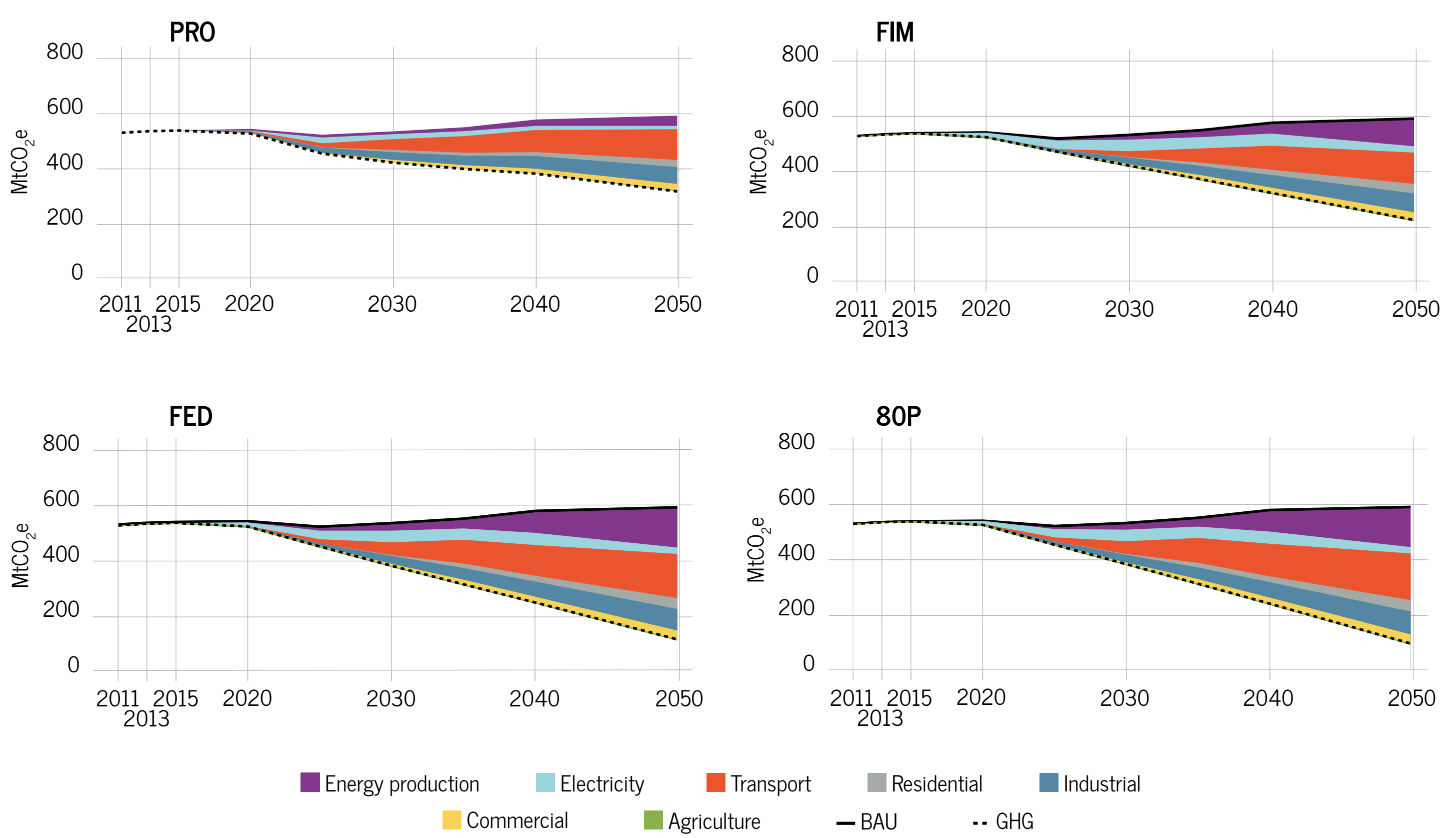
Impacts of the reduction scenarios on GHG emissions

For their part, emissions from the commercial and residential sectors seem to remain essentially constant, suggesting the possibility of small but easy energy efficiency gains, or of transfers from fossil fuel heating to electric sources. Although transportation is expected to decrease its emissions slightly by 2030, due to current fuel efficiency standards, this reduction lasts only for a decade or so: in the absence of stricter regulations, emissions will rise again (by 12%) between 2030 and 2050.

The industry and energy production sectors will be responsible for most of the growth in GHG emission – with emissions from the industrial sector doubling between 2015 and 2050, and those from energy production going up by 30%, to represent 50% of all energy-related emissions. Again, this result supposes that the rest of the world does not act to substantially reduce emissions, and that worldwide, the economy and technology will not impose a more profound transformation of the Canadian energy system. For example, as more and more countries adopt plans to prevent the sale of new internal combustion engines by 2040, it is likely that the availability of current fuel-based technology will be strongly reduced, pushing Canadians towards low-emission vehicles, even against their wishes, and decreasing demand for oil.

Reaching provincial targets (PRO) leads to GHG emission reductions of 110 $MtCO_2e$ in 2030 with respect to the BAU scenario and 275 $MtCO_2e$ by 2050 – significant numbers certainly, but insufficient to bring Canada more than about halfway towards the international objectives of 80% reduction for developed economies by 2050. Since these targets leave the structure of the energy production sector largely unaffected with respect to BAU, including oil sands and electricity generation, the transformation takes place in energy consumption, with transport-related emissions falling from 2015 levels by 29% (2030)

Figure 7.9 – Emission reductions by sector per scenario



and 55% (2050), and space heating emissions by 26% (2030) and 66% (2050). This pressure on energy consumption explains why marginal costs for PRO represent 75% of those of 80P in 2030, a percentage that drops to 36% by 2050, as the two scenarios more significantly diverge.

The change for both FED and 80P is more dramatic across the sectors, showing a qualitatively similar transformation. By 2030, both scenarios imply an almost fully decarbonised electricity system, leaving more time for the rest of the economy to decarbonise. Because of its sheer size, transport must be addressed over the long run. Nevertheless, both scenarios indicate that this sector must start transforming immediately, with a reduction of 32% needed to meet 2030 goals, similar to those of PRO. With less pressure on space heating, this sector sees its emissions decreasing by only 15% with respect to 2015. For 2030, these transformations lead to total emissions of 380 $MtCO_2e$ for FED and 80P, 153 $MtCO_2e$ below BAU and 42 $MtCO_2e$ below PRO, while preserving current emissions in the energy production sector.

For 2050, the difference between FED/80P and the other scenarios is much more striking: emissions are practically zero in electricity generation of course, and also in the commercial and residential heating sector as well as agriculture: four of the major sectors will be therefore almost fully decarbonised. As for industry, it seems to be more difficult to transform as it retains 60% of its current GHG emissions, even in the most stringent scenario (80P). In absolute numbers, however, transportation and energy production undergo the most major changes: from 175 to 29 or 20 MtCO2e for transportation and from 126 to 24 or 21 MtCO2e for energy production, implying a steep restructuring of these sectors, both in terms of the actors producing equipment and infrastructure, and those delivering services, as discussed in the previous chapter.

Buying 25% of the emission reductions from the WCI in 2030 primarily reduces pressure on the transportation system, which is required to reduce its emission by only 18%, less than what is required by PRO. For 2050, transportation emissions in FIM are at the PRO level, while space heating and electricity generation are almost totally decarbonised. In spite of lower pressure to reduce GHG emissions, emission cuts in the energy production sector are needed as well in FIM, with 67 $MtCO_2e$ compared with 129 $MtCO_2e$ for PRO and 166 $MtCO_2e$ for BAU.

7.6 Key trends

The various scenarios run in this Outlook indicate how rapidly energy-related technologies and our expectations regarding further developments have evolved over the last few years. Low-carbon electricity generation is sufficiently competitive, albeit with the help of federal targets, to overcome fossil fuels even in the BAU scenario. This suggests that, **as the world invests in low-carbon solutions for other sectors, particularly transportation, we could see a significant decrease in the cost of reducing GHG emissions**.

However, even as the cost of energy production and energy consumption technologies fall, some sectors require considerable time – and more research – to transform. As we see here, this is the case for the transportation, space heating and industrial sectors. It is important for these sectors to provide long-term objectives and programs, as well as to support research and industries that will be able to plan their long-term investments in both personnel and technologies.

As for the energy production sector, particularly as concerns fossil fuel extraction, GHG reductions can be achieved from a change in extraction processes or in the international demand for its product, which will drive prices and production. As other governments around the world put in place policies to reduce their demand for fossil fuels, especially in the transport sector, **more pressure will be put on the Canadian oil and gas industry to divest from the costliest productions, accelerating the economy's transformation away from these high-emission activities**.

The various scenarios also underline the deep divide between provincial and federal targets and objectives. In fact, a province-by-province comparison of the PRO scenario with the federal targets shows that, at the moment, all provincial targets match the federal target for 2030, with the exception of Saskatchewan and Alberta, although only three provinces (New Brunswick, Nova Scotia, Newfoundland and Labrador) and Northern Canada are on track to meet these targets. None have put measures in place that would ensure meeting the federal target for 2050. For Alberta and Nova Scotia, the provincial targets are weak enough not to constitute any constraint on the BAU scenario. This means that the marginal costs in the provincial scenarios will be very unevenly distributed across Canada, with the more aggressive provinces paying much more than even in the most aggressive national scenario. There is therefore a strong incentive for all provinces to move together on reducing GHG emissions. This is likely to create tension and increase the costs of transforming the Canadian economy. **As the rest of the world moves forward, there is a strong need for the various levels of governments to work towards common or at least compatible targets that will facilitate investments and cost-reducing measures.**

8

A diversity of situations at the provincial level

Canadian provinces present a diversity of energy production and consumption profiles. This diversity is reflected in their economy as well as in the cost and impact of achieving GHG reduction targets in each province. This chapter first provides an overview of the situation in each province before moving on to discuss differences, similarities and some opportunities for national initiatives.

Highlights

Great diversity in energy production and consumption across provinces makes designing nation-wide programs a challenge.

- A national plan to support cross-provincial interconnections would facilitate the decarbonization of electricity generation on which the rest of the energy transition can rely.
- Transportation should also be looked at from a national viewpoint, even though many solutions are local or remain in the hands of the provinces.

Electricity generation in most provinces will at least double by 2050, mainly from low-carbon sources.

It will be cheaper for oil- and gas-producing provinces to decrease their emissions than it would be for Ontario.

In almost all provinces, space heating appears to be an easy and early target.

Two thirds of Canada's energy-related emissions in 2050 could come from Alberta, pushing up the effective GHG reduction costs and thus seriously affecting the rest of Canada's industrial sector.

Despite the political challenges resulting from this cross-provincial variation, leadership from the federal government could facilitate avenues for cooperation.

8.1 Observations by province

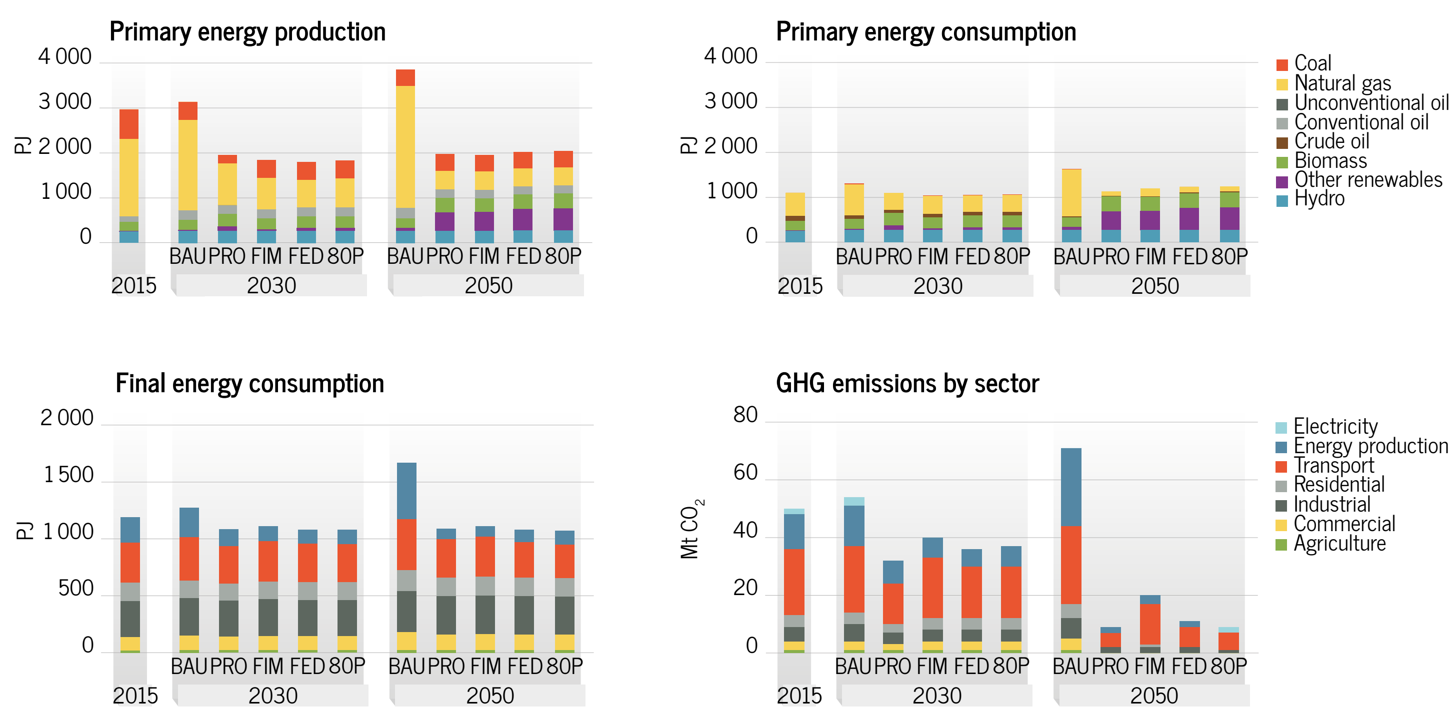
8.1.1 British Columbia

Contrary to most provinces, British Columbia sees its GHG emissions go up significantly in BAU, mainly due to the growth of its gas sector. If nothing is done above and beyond current measures, GHG emissions will rise by more than 10% by 2030 and even 43% by 2050, accounting for more than a third of its total emissions in 2050. As a result, the province would miss its own target requiring that GHG emissions be cut by 80% with respect to 2007 by 2050.

The difference between PRO and BAU demonstrates the distance between wishes, represented by the provincial targets, and the current trend presented by BAU, which takes into account measures already in place. In fact, the situation is compounded for the province: on the one hand, its government sets ambitious targets for GHG reductions and on the other, it pushes for gas development, contributing to significant increases in GHG emissions for the province, both as fugitive methane emissions and as demand for fossil fuel to extract and transport natural gas explodes. This is particularly clear in the PRO scenario, which applies provincial targets: by 2030, emissions for the oil and gas sector would have to decrease by one third from current levels to meet the province's own goal, while they are expected to grow by 17% in BAU. Clearly, unless British Columbia significantly changes its course and implements a credible action plan, it will miss its own targets by a substantial margin, a situation that is mirrored across the country.

If the province wants to protect its oil and gas sector, at least for the next decade or so, with an electricity generation that is already largely decarbonised, it will have to rapidly and aggressively target emissions from space heating and transportation. However, by 2035-2040, it will be impossible for the province to meet national or provincial objectives unless it finds ways to significantly reduce GHG emissions from its gas sector. As mentioned in the previous chapter, marginal costs for PRO are above the national average, suggesting that British Columbia would clearly benefit from a national integration of targets.

Figure 8.1 – British Columbia's energy profile



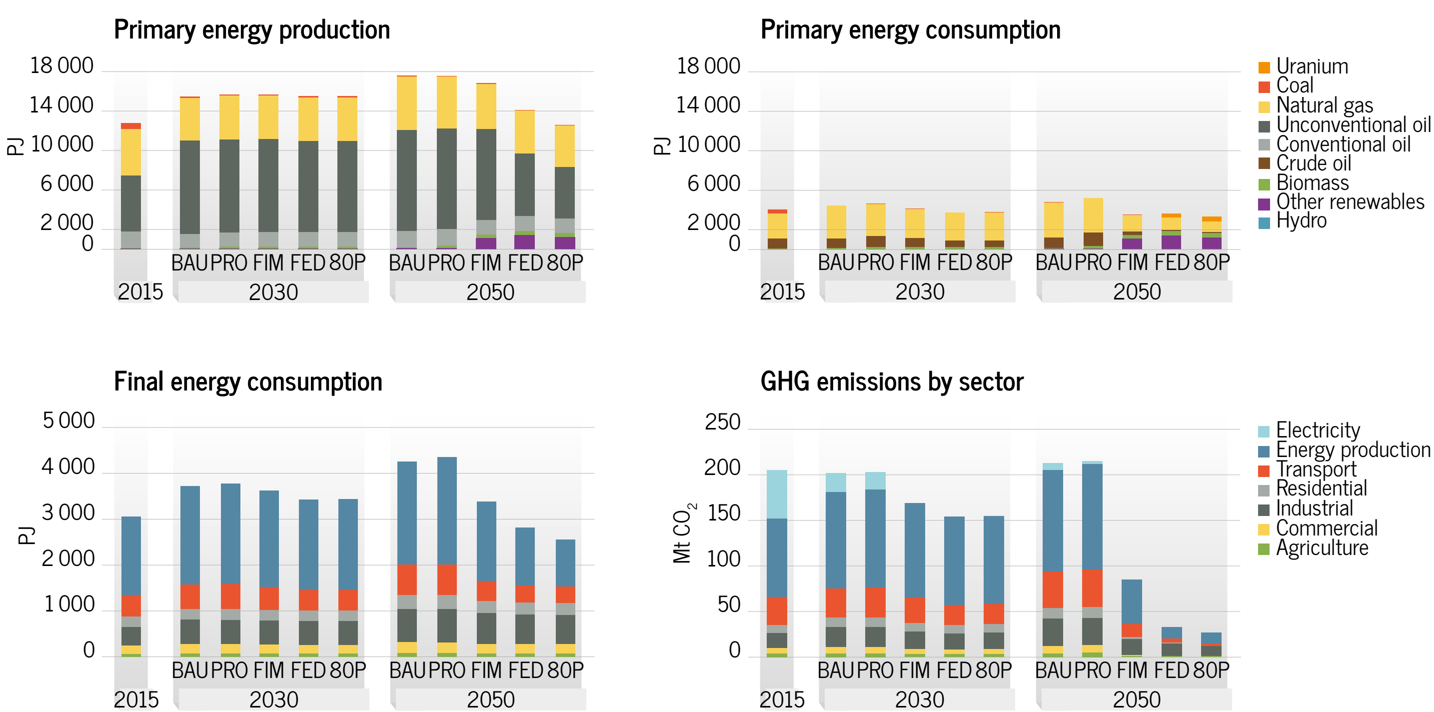
In terms of energy production, in addition to gas, BAU shows a slight growth in intermittent renewables. GHG reduction scenarios also project a significant growth in bioenergy, which could climb by as much as 63%, representing more than 25% of energy consumption by 2050, constituting, along with Manitoba, the highest share in Canada.

8.1.2 Alberta

In terms of GHG emissions, the importance of Alberta's oil and gas sector's energy consumption is difficult to overstate, as it accounts for more than half of final energy consumption. In BAU, which does not include future oil sands projects or fugitive emissions associated with the extraction, transformation and transport of fossil fuels, Alberta's energy-related GHG emissions are planned to remain roughly constant until 2050, at around 200 $MtCO_2e$. This represents almost two thirds of Canada's emissions, as most other provinces also maintain their emission levels, a share that could increase significantly if other provinces move on their own targets, as described in PRO. In this case, while most of Canada would see its emissions decrease significantly, Alberta would be almost alone in moving its emissions up, with the 100 $MtCO_2e$ cap set by its current government. Accordingly, by 2030, Alberta's emissions could represent up to 48% of Canada's energy-related GHG, reaching 68% in 2050. Such levels would be politically difficult to maintain, as it would force the rest of Canada to move even more aggressively on GHG reductions to compensate for Alberta's choices, pushing up the effective GHG reduction costs and seriously affecting the rest of Canada's industrial sector – unless Alberta agrees to economically support the imbalance created by this situation.

The three other scenarios (FIM, FED and 80P), set with respect to national objectives, propose a very different pathway, with GHG emissions falling by 10% to 30% in 2030 and as much as by 85% in 2050. While this maintains a high per capita emission level, it is in line with the current proposition for Canada's emissions. In 80P, for example, Alberta's emissions could still contribute around 40% of the country's emissions up to 2030, and then slowly fall to about 32% by 2050. Not surprisingly, FED and 80P scenarios imply that, by 2050, the oil and gas sector production would emit at most 16 to 20% of current levels. This can be achieved only through carbon capture, technological transformations and/

Figure 8.2 – Alberta's energy profile



or a major decrease in production, significantly affecting the sector's production levels and costs.

As we consider the emissions by sector, we note that according to even the most aggressive scenario, Alberta can spare most of the oil and gas sector until after 2030, as long as it greens electricity generation and a good part of transport. However, except for BAU and PRO this will not be sufficient to reach the 2050 targets: by then, all space heating and electricity generation and most transportation will have to be carbon free, leaving only emissions for the industrial and oil and gas sector.

As explained previously, our scenarios do not include the actions taken worldwide. The importance of GHG reductions around the planet will greatly impact oil and gas prices and demand. If scenarios FIM to 80P reflect what is happening across the planet, it is likely that the overall price for fossil fuels will fall, reducing the importance of this sector for Alberta and pushing the province to accelerate its industrial and economic transformation. Should the rest of the world increase its demand, it will be very difficult for Alberta and Canada to meet their emission targets, as pressure to produce will be substantial.

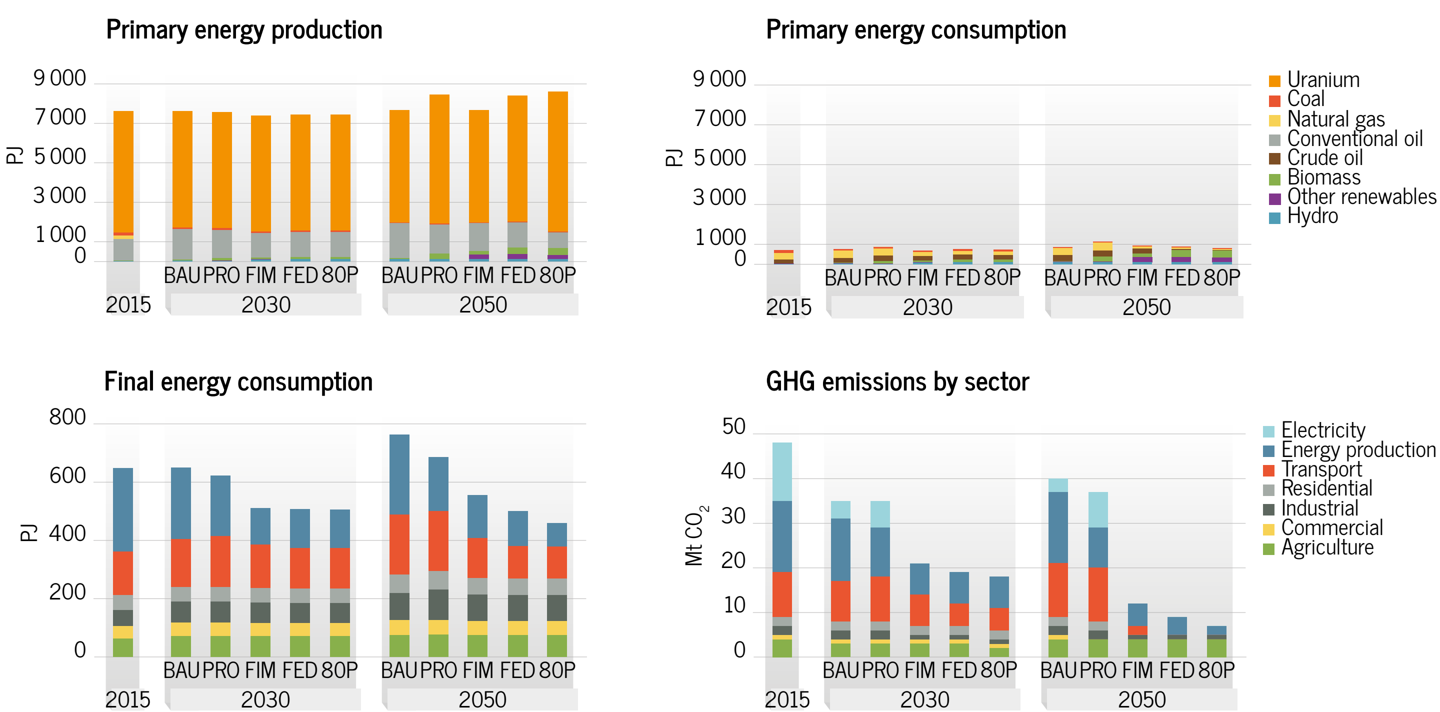
8.1.3 Saskatchewan

Saskatchewan presents a distinct production profile given the dominant contribution of its uranium resources. It is also an important producer of conventional oil. Similarly to Alberta, the provincial objectives for both 2030 and 2050 lead to GHG emission levels equivalent to those in BAU. This is mostly due to expectations in the electricity generation sector: while PRO allows an increase in GHG emissions linked to this sector, BAU shows the general national trend of an overall greening of the national electricity grid by 2050.

Both BAU and PRO forecast a 12 $MtCO_2e$ reduction for 2030 with respect to 2015, largely due to the closure of coal plants following federal requirements (about 8-9 $MtCO_2e$). The rest is essentially from the energy production sector, with a 2-5 $Mt.CO_2$ reduction. Other sectors remain largely untouched, a situation that is unchanged for 2050 where both scenarios even predict a slight growth in emissions.

More aggressive scenarios (FIM to 80P) impose significantly lower emissions across the board as early as 2030. All three scenarios will require that electricity be zero emission by 2030, with a 60%

Figure 8.3 – Saskatchewan's energy profile



reduction in the oil and gas sector with respect to 2015. These scenarios also show significant reductions in the transportation and agriculture sectors, down to half of 2015 levels for FED and 80P. Like all the other provinces, space heating should also start moving to low-carbon solutions relatively rapidly.

By 2050, FIM to 80P scenarios require all sectors to be almost zero emission except for the oil and gas production and agricultural sectors, while the oil and gas and industry is expected to have reduced emissions by 60% to 75% with respect to 2015. The agricultural sector could remain untouched.

Like Alberta, Saskatchewan is a province where the difference between its own target and the national target is greatest. Unless the worldwide oil and gas market plunges, we can therefore expect considerable tension between these provinces and the rest of Canada. As other provinces transform their economy to decrease their impact on climate change, pressure will mount on Saskatchewan to act, either by paying for reductions outside of its territory or by cleaning up its own energy system.

If the rest of the country does not move, however, Saskatchewan will certainly be comforted in its position that there is no point in making grand gestures, unless Canada as a whole delivers.

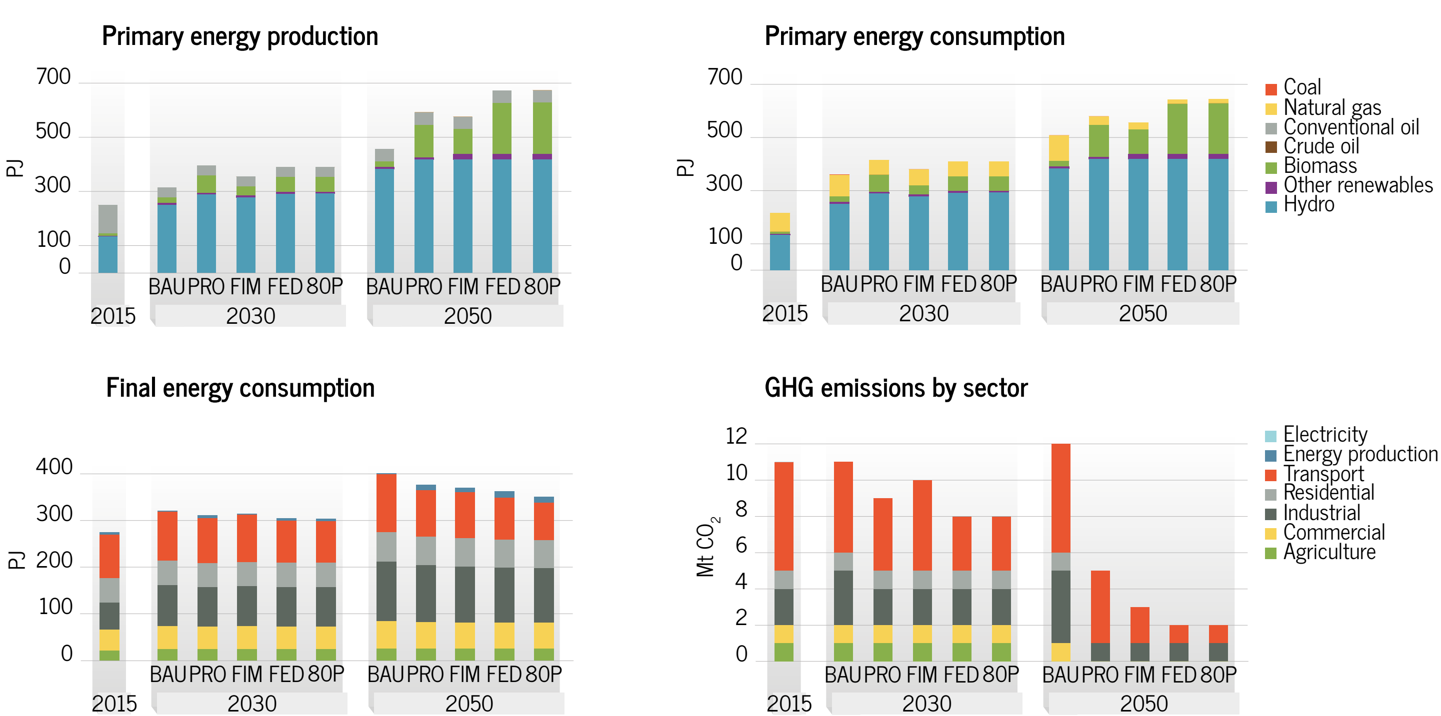
8.1.4 Manitoba

With an electricity generation based on hydroelectricity and little oil and gas production, Manitoba's energy system transformation is both straightforward and difficult, although the provincial target expresses a willingness to reduce GHG emissions.

While BAU indicates a significant growth in primary energy production, this movement is associated with a fairly constant GHG emission level for the next 30 years due to the large proportion of renewable energy. While the PRO target would reduce emissions by 50% by 2050 with respect to 2005, a reduction well short of the national objective of 80%, it would nevertheless force a considerable decarbonization of Manitoba's economy.

Interestingly, with its relatively high cost of transformation, the FIM scenario leaves Manitoba

Figure 8.4 – Manitoba's energy profile



relatively untouched until 2030, forcing changes only over the following 20 years. For their part, GHG reduction scenarios FED and 80P chiefly indicate a fairly uniform reduction, with all remaining GHG emitting sectors — space heating, agriculture, industrial and transport — contributing.

By 2050, scenarios FIM to 80P impose deeper transformations, primarily in space heating and agriculture, in order to leave some fossil fuels for use in the industrial and transport sectors.

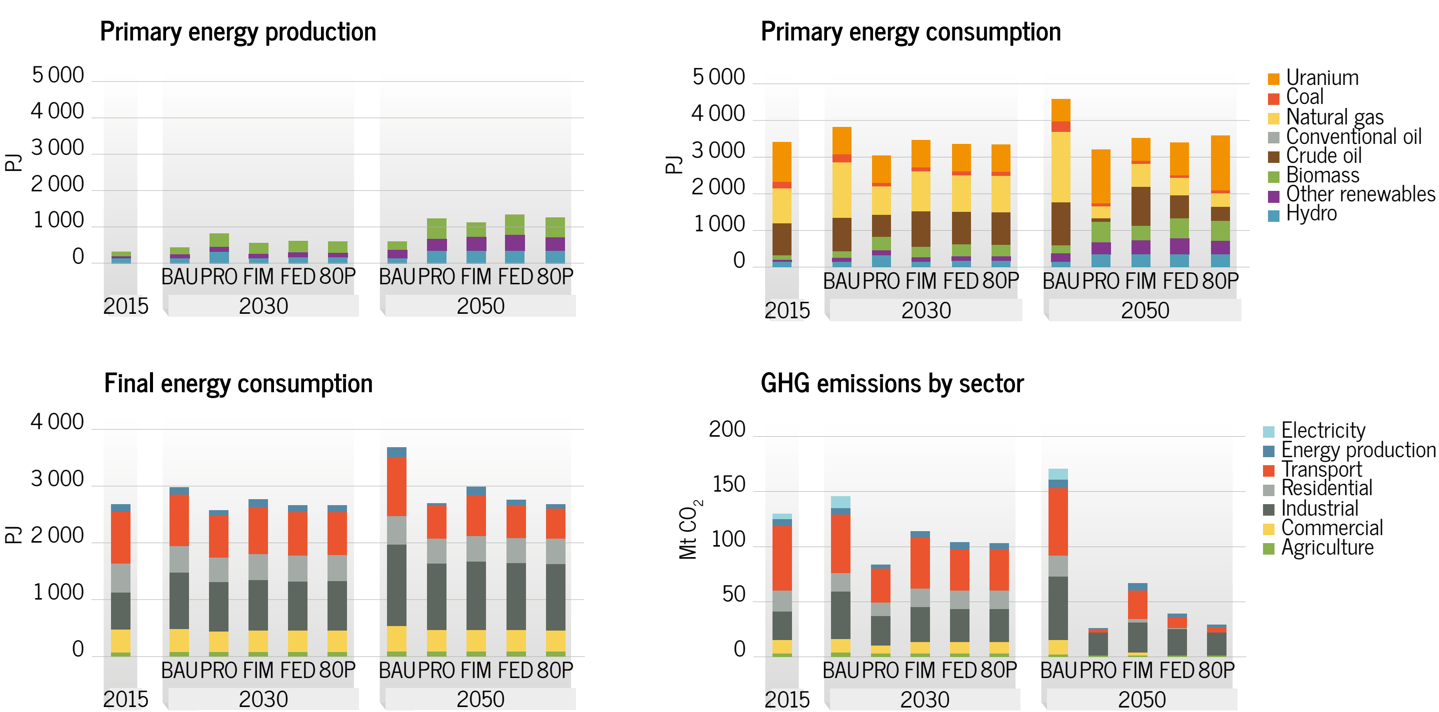
8.1.5 Ontario

Ontario's profile shows a stark discrepancy between primary energy production and consumption, as the overwhelming share of energy consumed in all scenarios comes from outside the province. This is true even in the most aggressive scenarios for 2050, where production from renewables more than doubles.

Like British Columbia and Quebec, Ontario has adopted a very aggressive set of GHG reduction targets, as can be seen by comparing BAU with PRO. In fact, the provincial targets are more demanding than the current 2030 federal goals (FED) and the 80P levels, limiting the potential for conflict between Canada's most populous province and the central government – as least on the target side – over this period. Even by 2050, PRO imposes GHG emission levels of 3 $MtCO_2e$ below 80P and 13 $MtCO_2e$ below FED.

However, as with Quebec, these targets can be reached through the carbon market established with California, making the realistic scenario closer to FIM. Based on the federal prediction on carbon credit purchase (FIM), it appears that Ontario could well buy all 2030 reductions through credits obtained from California, postponing its own energy systems transformation until after 2030. While this is not an option with the new Conservative government elected in 2018, according to the model, the most aggressive targets will only be achieved at a relatively high cost if they are to be met within the province only. For example, the marginal reduction cost for PRO is at $1085/t by 2050, well above the Canadian FED marginal cost of $800/t and on par with the $1055/t of 80P, which corresponds to the same target (80% reduction with respect to 1990).

Figure 8.5 – Ontario's energy profile



Interestingly, within NATEM optimisation modelling, Ontario is the only province that sees its electricity generation decrease for the national reduction scenarios (FIM, FED and 80P) by 2030, as it turns to nearby provinces to import from cheaper sources. However, electricity generation is expected to grow after 2030 as demand rises to compensate for strong reductions in fossil fuels, roughly doubling by 2050.

By 2050, to reach reductions internally, PRO and 80P require all sectors to be almost completely decarbonised with the exception of industry and a small part of transport and energy supply (refineries).

8.1.6 Quebec

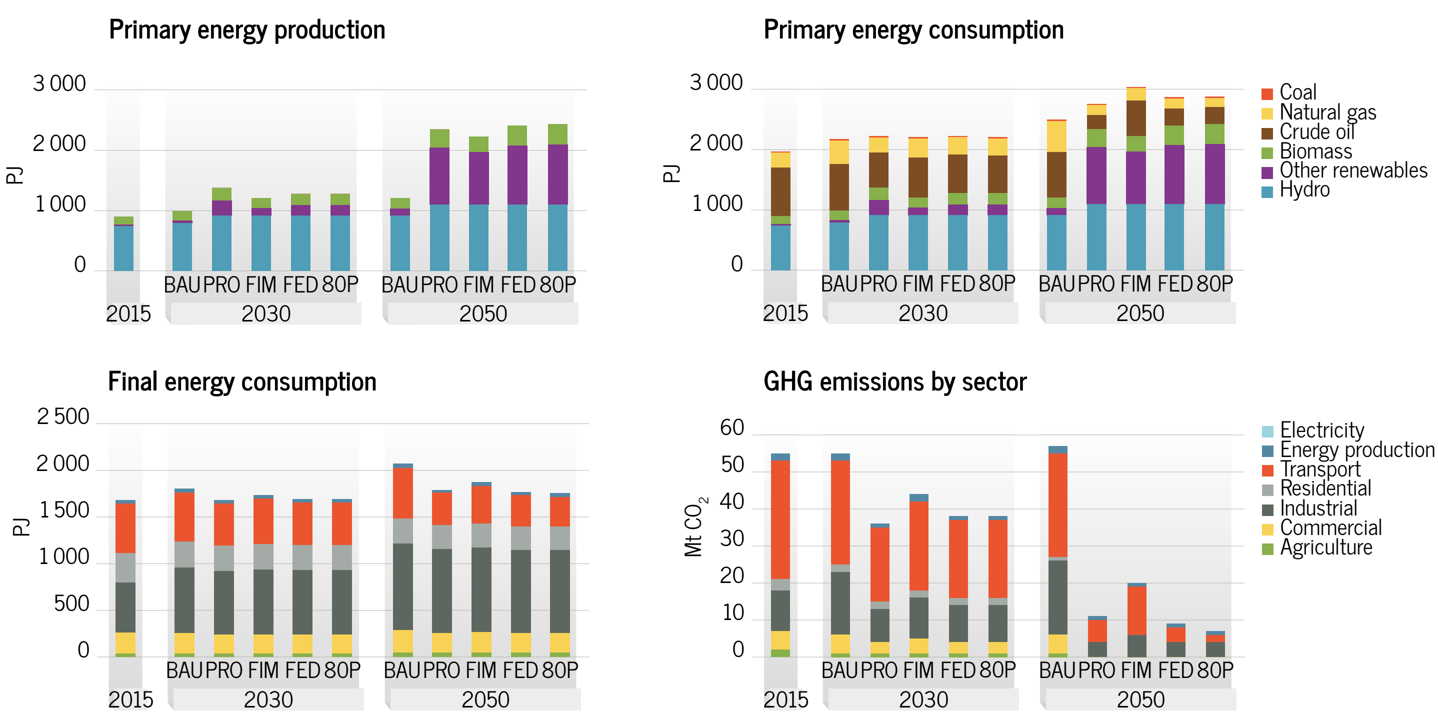
In all scenarios, Quebec's energy production is expected to remain 100% renewable. In BAU, production growth is slow, dominated by hydroelectricity. While GHG reduction scenarios see a significant growth in other renewables for 2030, their overall share remains small at around 15%. By 2050, however, all GHG reduction scenarios see the fraction of other non-hydro renewables rise above 50%, while supporting a slight increase in absolute hydro production.

Even though 47% of Quebec's energy consumption is already decarbonised, Quebec emissions should decrease by slightly more than the national average for both FED and 80P by 2050 (83% and 87%, respectively) suggesting that there is considerable relatively low hanging fruit for Quebec's decarbonization.

In addition, some reduction could be achieved at even lower cost through purchases on the California carbon market, reducing the real local transformations to be made (FIM). Following the federal predictions of 25% of reductions bought from California, Quebec could likely turn to this option to compensate for its lack of action, buying up to 16 of the 20 MtCO_2e pledges for 2030.

As in Ontario, all sectors will have to contribute to reach the 2030 GHG reduction targets, except for FIM, where most of the reduction comes from purchased credits. However, by 2050, all space heating and most agricultural activities will have to be low-carbon, leaving some emissions only for oil refining, industry and transportation.

Figure 8.6 – Quebec's energy profile



8.1.7 New Brunswick

Primary energy production in New Brunswick is largely dominated by renewable sources. In all scenarios, however, these are insufficient to support demand even though GHG reductions scenarios suggest a production dominated by wind and solar.

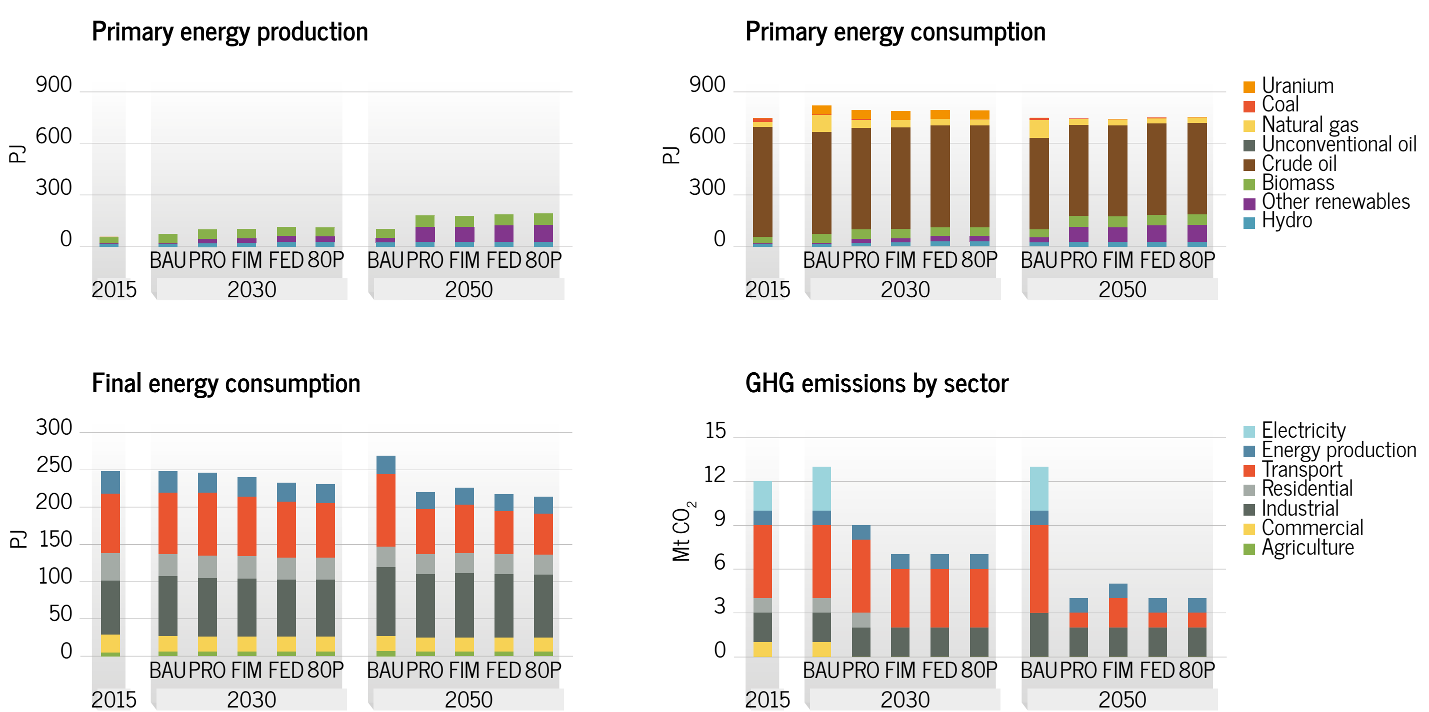
Between 2005 and 2016, New Brunswick reduced its emissions by 24% (5% with respect to 1990), both through moving to renewable energy sources and through the collateral effects of closing two papers mills in the earlier part of this decade, while maintaining a small oil production.

In the absence of strong new programs, however, BAU sees a slight increase in GHG emissions over time, mainly linked to industrial energy demand. In 2030, compared to PRO, GHG emission reductions are more important under the federal reduction regime, as even scenario FIM projects a 1 $MtCO_2e$ additional reduction in comparison to PRO. This is even more pronounced in FED and 80P, with a gap of over 2 $MtCO_2e$ compared to PRO, suggesting that some tension between provincial and federal measures is to be expected, at least for the coming years, if national reduction efforts are to be "allocated" to each jurisdiction taking only provincial reduction costs into consideration.

This gap narrows considerably for 2050, as New Brunswick's targets are in line with FED and 80P, leading to a reduction of about 67% with respect to current emission levels, less than for some other provinces, mainly due to the transformation that has already taken place. While electricity should be the first sector to decarbonise in all scenarios, agriculture and space heating follow closely, as in most other provinces, with transport taking more time to transform significantly. By 2050, all GHG reduction scenarios roughly advance the same solution, with emissions dominated by the use of fossil fuels in industry and transport, as well as the running of oil refineries.

With provincial targets in line with federal ones, the PRO scenario leads to relatively low marginal costs for GHG reductions of \$36/t in 2030 and \$650/t in 2050, well below national levels in FED, suggesting that it should be relatively easy for New Brunswick to work under a national reduction objective without affecting its conventional oil production.

Figure 8.7 – New Brunswick's energy profile



8.1.8 Nova Scotia

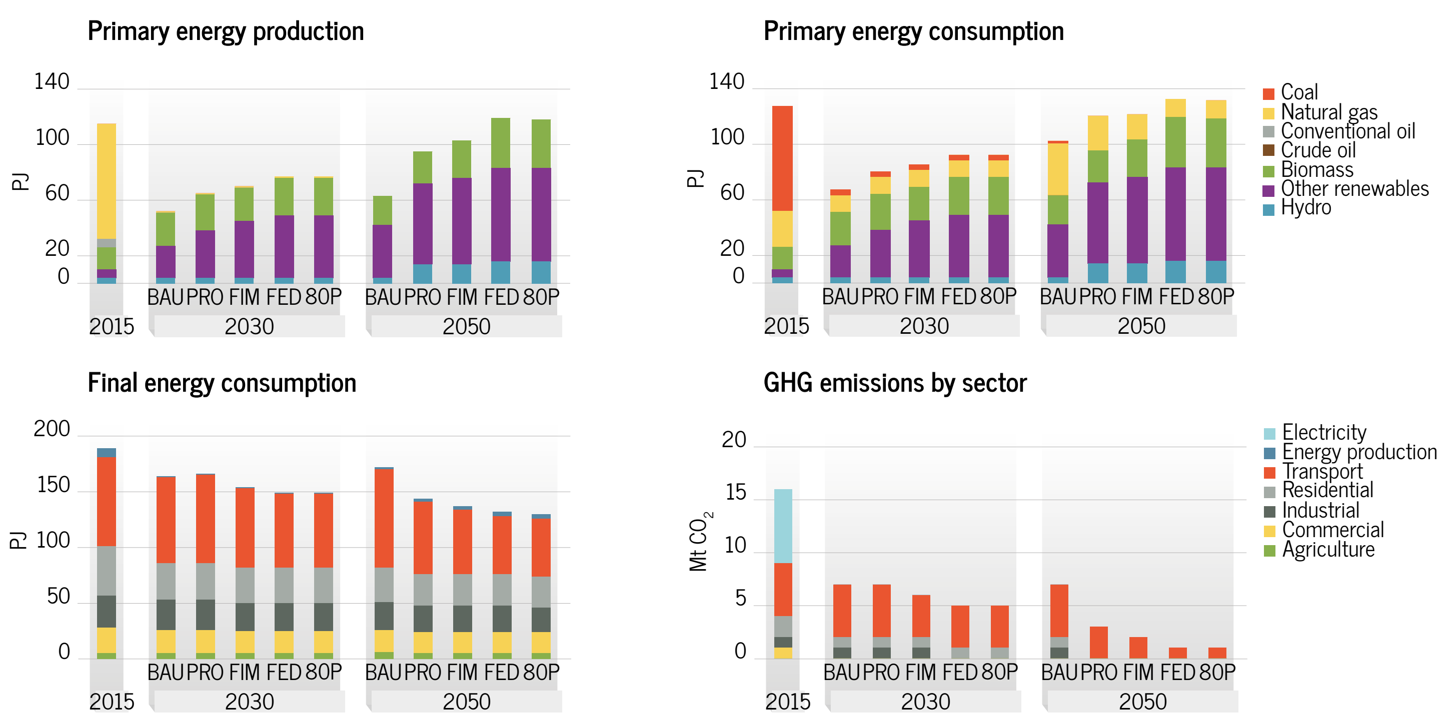
With its coal plants due to be shut down or at least used more sparingly, Nova Scotia is one of the only provinces to see its reference emissions (BAU) fall off significantly over the next few years, more than halving between now and 2030. With this transformation, Nova Scotia is therefore well ahead of its own plan and should be very close to the national targets (FED) in 2030.

However, unless new measures are put in place no further gains are planned for the province. As a result, longer-term emissions should remain far above the most demanding 2050 targets, which would require total emissions of about 1.5 $MtCO_2e$ under the federal targets, about 6 $MtCO_2e$ below BAU and 2.4 $MtCO_2e$ below provincial targets (PRO).

This significant gap means that the province will have to react and realign some of its actions to meet federal targets. Similarly to New Brunswick, the province's 2050 targets are relatively close to the federal targets and yet their marginal costs in the PRO scenario are at $244/t, well below the expected average marginal reduction cost at the national level. This suggests that Nova Scotia relies on a number of reduction options that are particularly advantageous.

Once electricity is decarbonised, Nova Scotia is left with the same dominant sectors as other non-oil producing provinces and will need to take action across the board, as suggested in varying degrees by all GHG reduction scenarios.

Figure 8.8 – Nova Scotia's energy profile



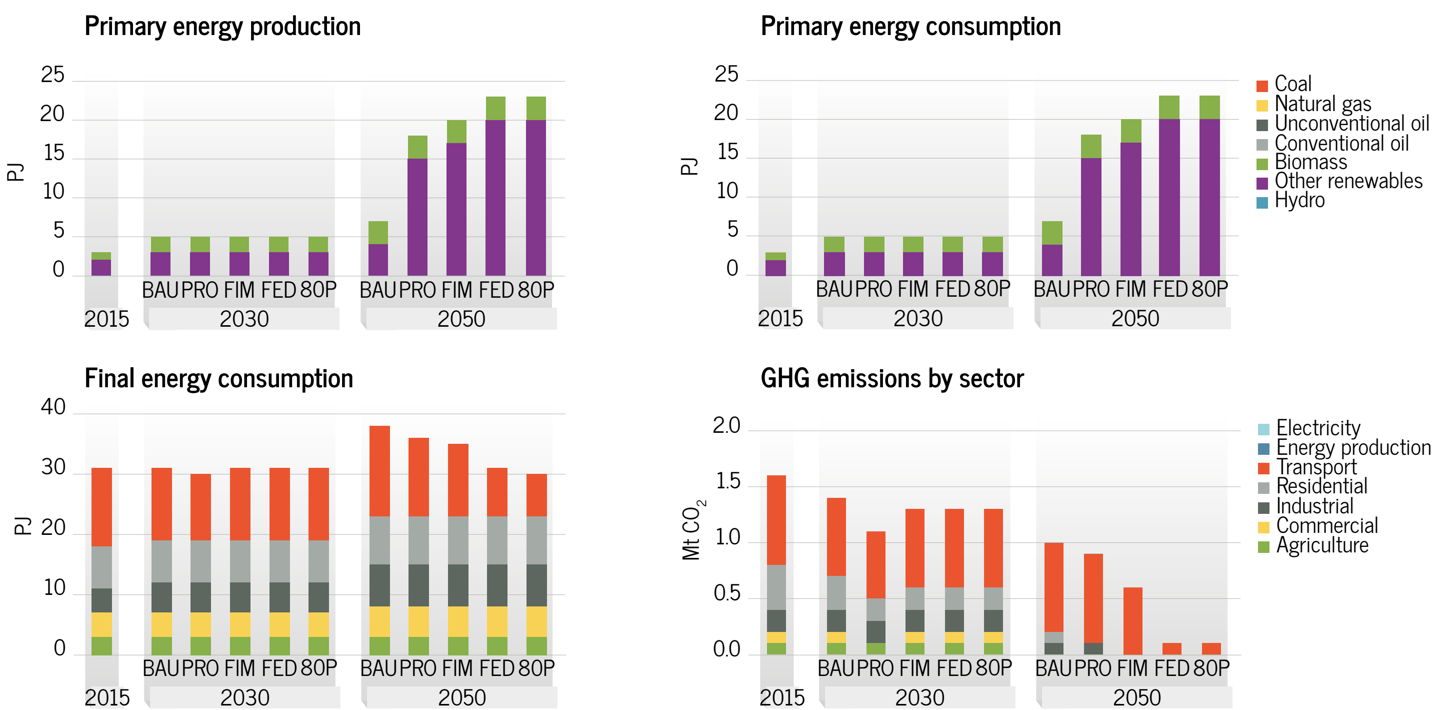
8.1.9 Prince Edward Island

Prince Edward Island has adopted a very ambitious plan to decarbonise its economy, with an already decarbonised electricity generation, supported in part, it must be said, by the coal and nuclear electricity of its neighbours. This allows the province's BAU scenario to show an almost constant reduction in GHG emissions until 2050. Moreover, the absence of a long-term target results in full agreement between PRO and BAU for 2050.

This level is considerably more than the federal goal of 2050, meaning that further efforts will need to take place to satisfy the federal GHG reduction objectives. With little industrial activity, energy transition will primarily affect space heating and transport. These will largely be reduced in equal proportion by 2030 with a total elimination of fossil fuels by 2050 for the most demanding scenarios.

In the absence of an objective for 2050, the peak CO_2 marginal price for Prince Edward Island will be reached by 2030, around $400/t in PRO. There could therefore be a gain for Prince Edward Island to team up with its neighbours that show a significantly lower marginal cost for 2030.

Figure 8.9 – Prince Edward Island's energy profile

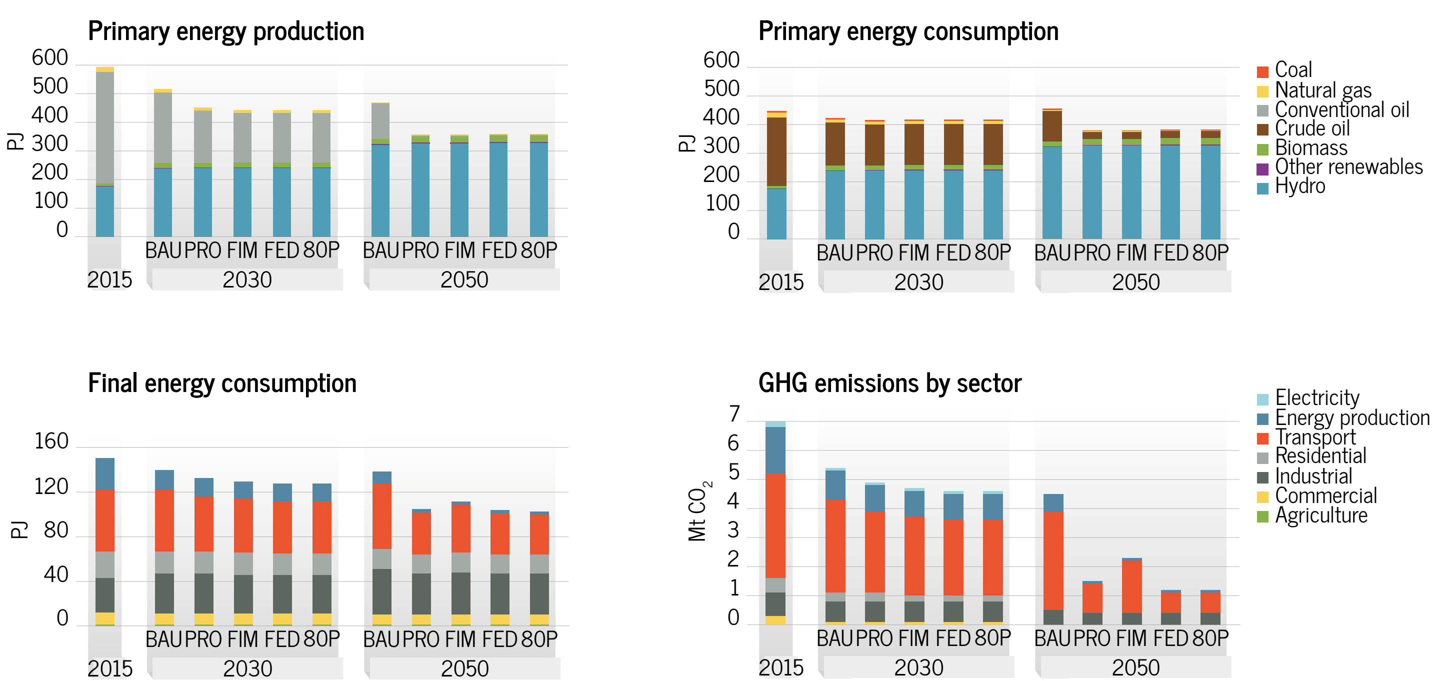


8.1.10 Newfoundland and Labrador

Newfoundland and Labrador is a major energy producer, exporting massively both oil and hydroelectricity. Over the next decades, with electricity from Muskrat Fall becoming available and oil and gas production falling, all scenarios project that an increasing share of energy production will move to renewables, leading to a notable decrease in GHG emissions for 2030, from 22% in BAU to 30%-34% in the three others. For BAU and PRO, the decrease in oil production accounts for almost half of the GHG reductions. Space heating is also expected to cut its emissions by half, the rest coming from transportation. For 2030, differences among the more aggressive scenarios – FIM, FED and 80P — are minor, involving only slight further reductions in transportation and residential heating.

By 2050, all scenarios roughly agree: the only significant sources of GHG emissions should be transport and industry, the rest being electrified, a transformation that thanks to hydroelectricity can be made relatively cheaply in spite of the cost overruns for the Muskrat Fall project. Transport is most sensitive to the reduction goals imposed, and projected emissions vary by a factor of five between 80P and BAU. Yet this effort is far from impossible: for comparable targets in the PRO scenario and in line with FED targets, NATEM computes a marginal reduction cost of $708/t by 2050, very similar to Quebec's $624/t.

Figure 8.10 – Newfoundland and Labrador's energy profile



8.1.11 Northern Canada

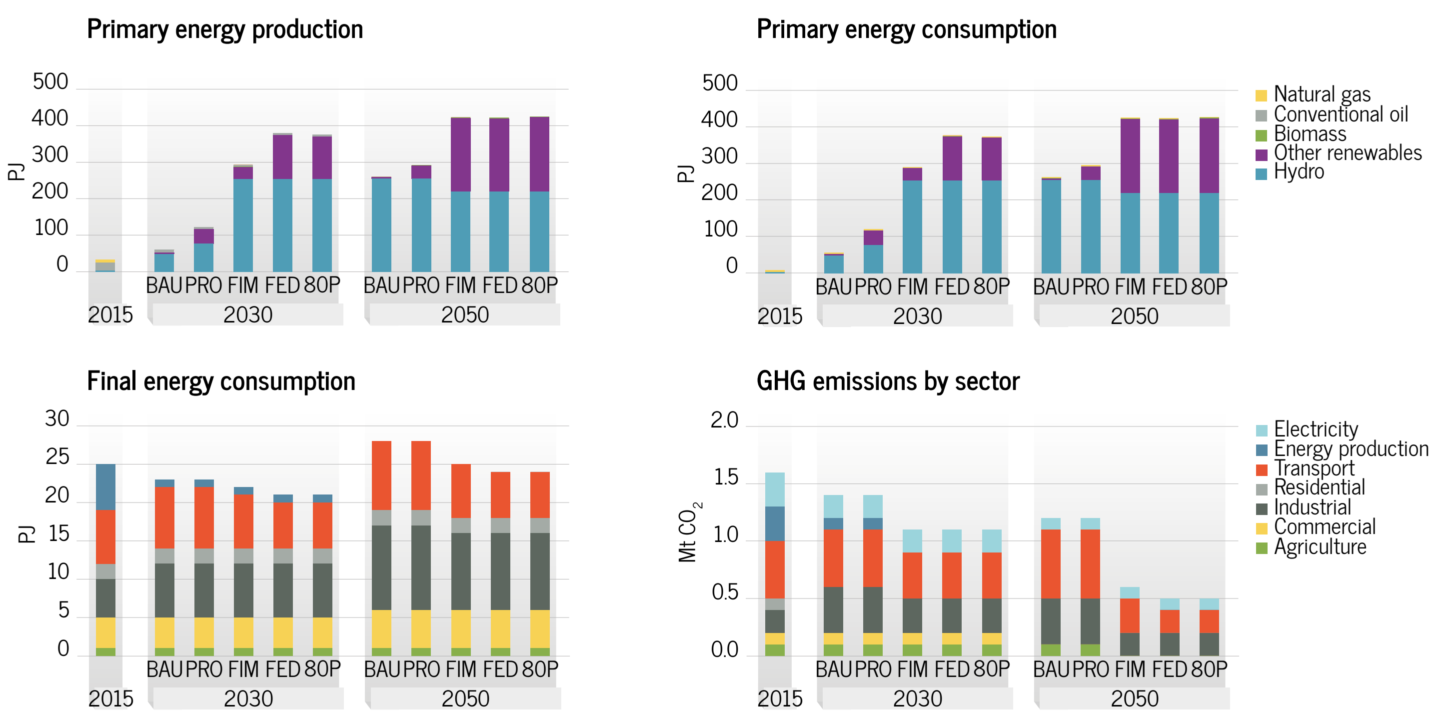
With a small population and large surface areas, Northern Canada, which include the Northwest Territories, Nunavut, and Yukon, is highly dependent on fossil fuels for all its activities. Without very aggressive targets, its business-as-usual scenario is similar to PRO with real emissions largely dependent on mining and other resource exploitation projects that will take place over the coming decade.

However, following national targets will require a significant restructuring of energy production. For 2030, as for most provinces, the greening of space heating as well as improvements in transportation and electricity supply would be mostly sufficient.

To reach the 2050 FIM to 80P objectives, however, further efforts will have to be made, particularly in the electricity generation, transportation and industrial sectors.

Nevertheless, estimated costs for energy production suggest that this transformation could be beneficial. Indeed, the territories could become major low-carbon energy producers and exporters as early as 2030, particularly in the most aggressive scenarios, with production climbing from about 3 PJ in 2015 to 292 PJ in 2030 and even to 425 PJ in 2050 for FED and 80P, comparable to today's energy requirements for the Atlantic provinces.

Figure 8.11 – Northern Canada's energy profile



8.2 General observations

8.2.1 The contribution of electricity to the transformation

Over the next decades, the electrification of entire provincial energy sectors will lead to significant transformation Canada-wide (see Figure 6.3). Electricity generation, for example, is expected to explode in Northern Canada, from about 1 TWh, produced by hydro, to between 14 and 102 TWh in 2030, depending on GHG emission reductions. This production could even reach 115 TWh (FIM and FED) or 116 TWh (80P) in 2050, 48% of which would come from wind and the rest chiefly from hydro. An increase of roughly equivalent importance is also computed for Prince Edward Island, mainly between 2030 and 2050, with the production, dominated by wind, rising from 0.6 TWh to between 4.6 TWh and 5.5 TWh, in the FIM to 80P scenarios.

While the changes will not be as dramatic, almost all other provinces will see their electricity generation at least double by 2050, as it moves towards low-carbon sources. For example, this is the case in Nova Scotia, which should move primarily to wind by 2030, with a relatively small 20%-30% increase in overall electricity generation, to 12-13 TWh (in FIM to 80P scenarios). This would be followed by a further doubling of the production to 20-22 TWh by 2050 in the FIM to 80P scenarios, mainly to satisfy the transportation and space heating sectors. A similar but more important transformation is needed for New Brunswick, which should triple its electricity generation between now and 2030, from 6 TWh to 17 TWh (PRO and FIM) or 20 TWh (FED and 80P), while eliminating fossil fuels, followed by another significant increase to reach over 30 TWh by 2050.

The same trends are predicted for Saskatchewan and Alberta. In Saskatchewan, electricity generation is expected to double by 2030 and double again by 2050, first largely supported by hydro and fossil fuels and then mainly by wind and hydro. In Alberta, electricity generation remains roughly at the same level as today in 2030, with a considerable decrease in thermal production compensated by imports and a little more wind and solar. By 2050, however, as oil sands are expected to turn to electricity for heat production, the province's total electricity generation with respect to 2030 is expected to be multiplied by around 10 for scenarios FIM to 80P, dominated by wind but with significant contributions from thermal production, including about half from nuclear.

In provinces largely dominated by hydro, electricity already plays an above-average role and production is not expected to increase by as much. For Newfoundland and Labrador, for example, all scenarios (including BAU) plan on more limited increases in electricity generation, from almost 48 TWh today to 64 and 88 TWh, respectively for 2030 and 2050, less than doubling current levels. Similarly, Quebec's electricity generation is expected to increase by at least 37% by 2030, from 206 to 276-310 TWh and then further double by 2050, to 532-563 TWh, depending on the reduction scenario. This overall increase over the period is dominated by wind and solar, but with 96 TWh of new hydro. Similar behaviour is predicted for Manitoba, with production doubling between now and 2030 with a similar increase over the following 20 years to almost 120 TWh in 2050. British Columbia is expected to follow the same pattern, rising from about 75 to 87-99 TWh between now and 2030 and reaching around 200 TWh, principally from wind and hydro, by 2050. For this province as well, the bulk of the increase comes from wind.

With its low cost, electricity from British Columbia, Manitoba and Quebec will also be exported, which explains why Alberta and Ontario's production will decrease until 2030. However, between 2030 and 2050, production explodes in the FIM to 80P scenarios, as demand for electricity increases in the transport and space heating sectors, as well as in the oil and gas production sector in Alberta.

The relative growth estimated for the various renewable electricity sources will depend on both their price and their social acceptability. At the moment, there is strong opposition to hydroelectric developments that might work in favour of wind, even in Quebec. The final choice will partly depend on the spread of rooftop solar and the evolution of battery and other energy storage system prices, as well as on the overall social acceptability of the various technologies.

8.2.2 Integrating provincial transformations into a national movement

A differentiated analysis of the impact of the various scenarios on a provincial level underlines the need to clearly identify transformations that should be implemented, either on a regional or on a national level.

For example, space heating – be it commercial, institutional or residential – appears an easy and early target in almost all provinces. A national program to eliminate the use of fossil fuels for space and water heating could therefore benefit almost the entire country, even Quebec, where the commercial and institutional sector has not yet made the move to low-emission heating. With the additional benefit of direct jobs and investments in the community, such a transformation would receive the support of all provinces, irrespective of their industrial orientation.

Transportation is another sector that should be looked at from a national viewpoint, even though many solutions are local or remain in the hands of the provinces. Nevertheless, expertise, planning, fiscal and financial incentives could be developed at the national level to facilitate a more even transition and ensure the deployment of standards that do not affect interprovincial trade. As the federal government has jurisdiction over airways, railways and waterways, there are a number of actions for moving Canadians and goods towards low-carbon transportation modes that can be oriented by the central government. Rail-based suburban transit, for example, is largely limited by CN and CP resistance, which could be eliminated with the help of more proactive federal legislation.

However, interurban public transportation, biking lanes, toll bridges, road developments, and bonus-malus approaches will be more effective when designed at the provincial level to respect various constraints and values.

Electricity generation will also remain under provincial jurisdiction, although the federal government could provide help and encouragements to thinking regionally. In fact, the federal government also has jurisdiction over interprovincial electricity transmission. Yet the National Energy Board has long been much more interested in pipelines than in electric wires. Clearly, a national plan to sustain the greening of the electric grid through planning and support of cross-provincial interconnections would go a long way to facilitate the development of a stronger green electricity generation sector on which the rest of the energy transition can be based.

8.3 Key trends

As this chapter clearly illustrates, Canada is a very diverse country. This diversity may be most visible in the energy sector, where production and consumption vary so greatly between provinces. In this context, the design of a program oriented to a national perspective remains a challenge. Yet other regions across the planet have demonstrated the benefits of working together on transitions as substantial as the one imposed by the fight against global climate change. **In Canada, there are promising avenues for the federal government to facilitate cooperation on challenges that cut across provinces, notably space heating, transportation, and interprovincial electricity demand management.** Each of these areas is critical to energy transition and to the achievement of objectives for GHG emission reductions.

This chapter also demonstrates that the highest cost of transformation is not where it is often expected. Looking at the GHG reduction distribution with respect to the national target, we see that oil and gas-producing provinces can decrease their emissions more easily than Ontario. This suggests that the opposition to GHG reductions is not simply an economic issue; reducing GHG emissions will therefore require more than simply economic arguments even though they are essential to launch the debate.

In view of the challenges presented here, there is a great need for debate on these issues.

9

The challenges of reducing emissions in the transport sector

Achieving GHG emission reduction targets will require a profound transformation of many economic sectors, with transportation at the forefront due to its share of GHG emissions. It is therefore useful here to devote a chapter to this issue. In the first part of this chapter, we assess the transformation of this sector as demand continues to grow, following historical trends. In the last part, we examine the impact of strongly reducing and even capping demand growth, taking a different approach to reaching overall GHG emission reduction targets.

Highlights

The transportation system remains the sector most resistant to change.

By 2050, demand is expected to grow by 25% for passenger transportation and more than double for freight transportation.

Despite this growth in demand, energy consumption could fall by 40% for passenger transportation and remain the same for freight transportation.

Freight transportation will electrify more than passenger transportation.

Cars and trucks will occupy a smaller share of transportation energy consumption.

Large differences in fuel efficiency disconnect fuel consumption from services rendered with each fuel.

Even with considerable increases in demand, the model manages to find "reasonable" but ambitious solutions for the most aggressive GHG targets.

To assess the impact of demand growth and possible new technologies in the transport sector, a reduced demand scenario is also explored. In this scenario, results suggest that there is not much to gain on the GHG front from curbing demand.

9.1 The transformation of a sector

In some sectors, such as space heating, low-carbon technologies are already established and largely competitive. The challenge for transformation in this case chiefly resides in ensuring that steps are taken in sync with the greening of electricity generation. However, for some industrial transformations, competitive technologies are not yet available and research and technological development are still required. Yet the transition to low-carbon production involves a few key players that can more easily be brought together to drive changes like those already operating in sectors such as pulp and paper and aluminum smelting.

This is not the case in the transportation sector, where a low-carbon transition to some extent involves almost everyone across society. This explains why this sector remains the most change resistant; it continues to rely massively on fossil fuels and most countries have failed to rein in its thirst for energy.

Figure 9.1 – Demand for passenger transportation

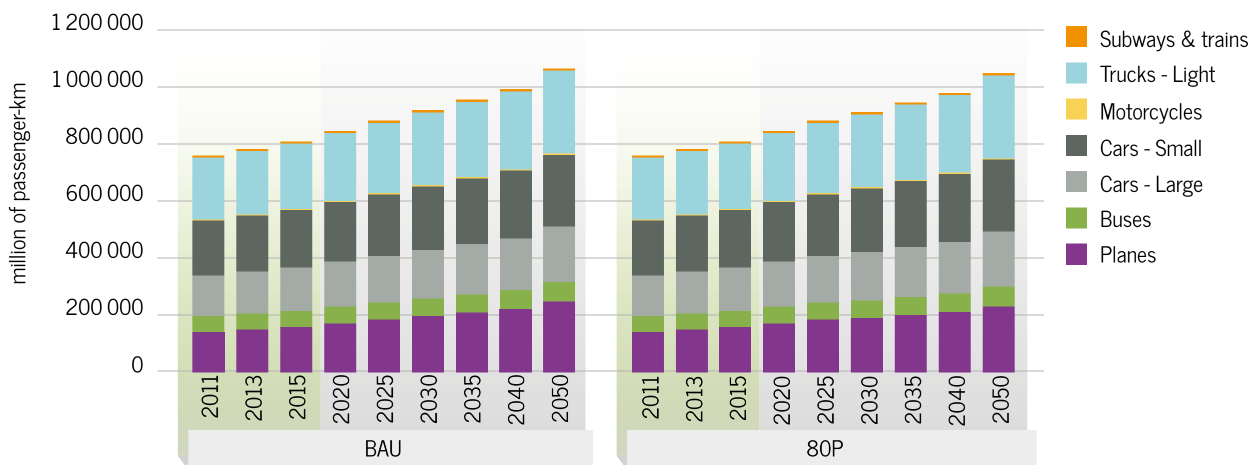
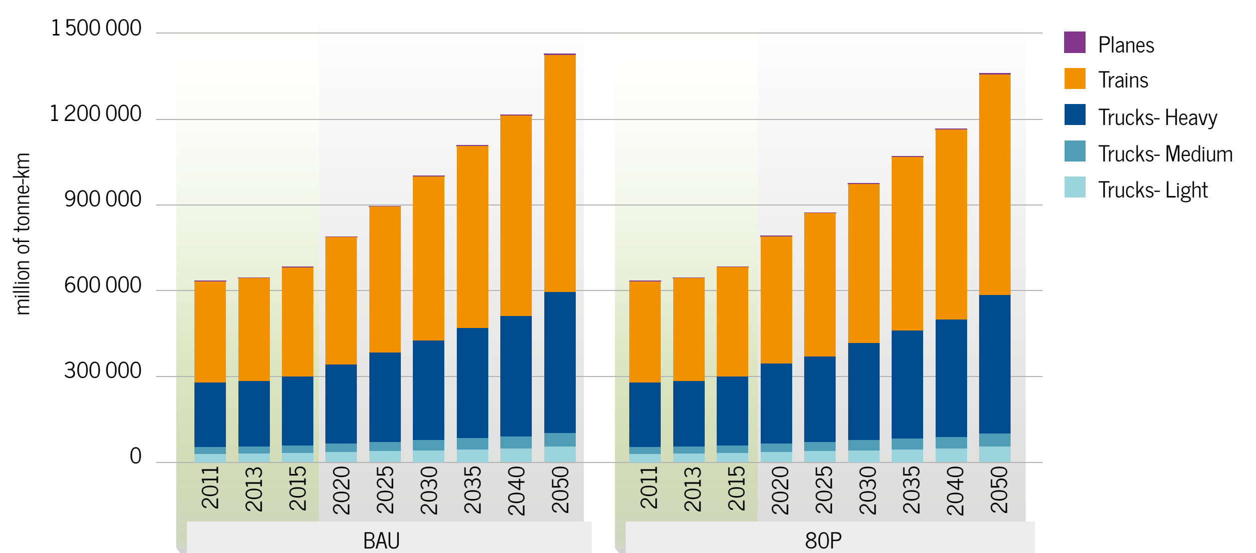


Figure 9.2 – Demand for freight transportation



The challenges of reducing emissions in the transport sector

The basic demand for passenger and freight services is presented in Figure 9.1 and Figure 9.2 for the BAU and 80P scenarios. Following past trends, and in accordance with other projections, we assume that demand will continue to grow at current rates, taking into account the growth of population and the economy, with very little impact from GHG emission reduction policies. In our projections, demand for passenger transportation will increase by about 26% between 2015 and 2050, in both BAU and 80P. The growth will be more marked for freight transportation, where demand will more than double.

In spite of this growth, total energy consumption will fall for all passenger transportation scenarios (Figure 9.3) and remains relatively steady or even falls slightly for freight transportation in most scenarios (Figure 9.4), both in 2030 and 2050, due mainly to systemic energy efficiency gains.

9.1.1 Passenger transportation

For 2030, all GHG reduction scenarios predict a similar growth in the use of electricity in passenger transportation. From less than 0.01%, it

Figure 9.3 – Final energy consumption for passenger transportation

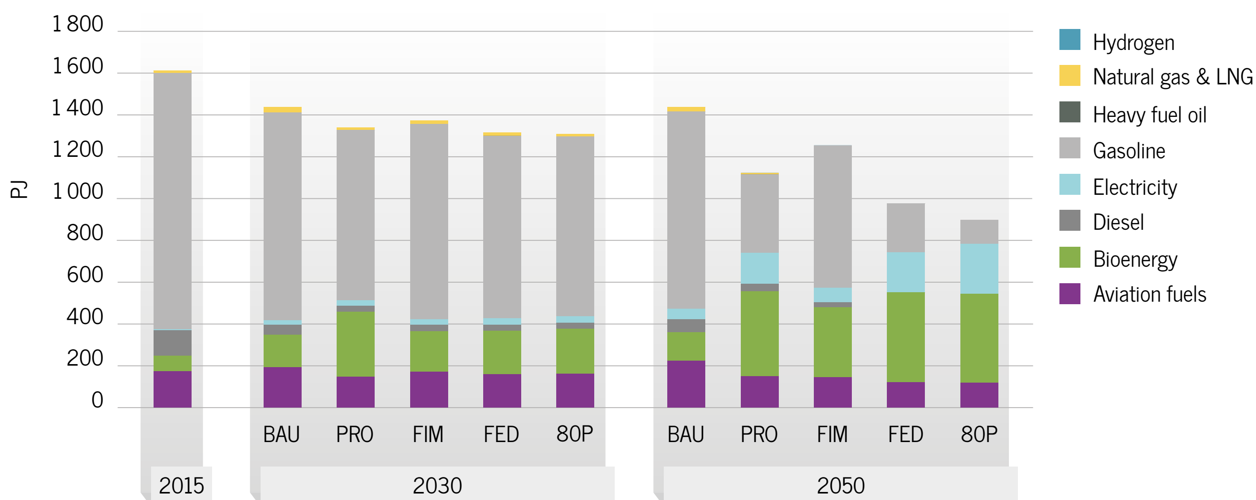
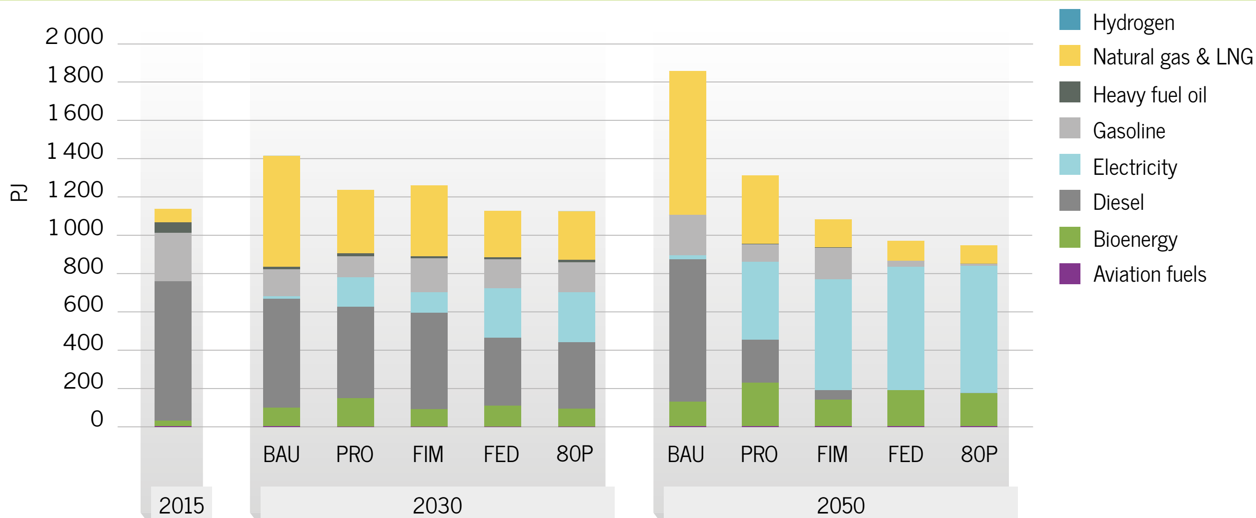


Figure 9.4 – Final energy consumption for freight transportation



is expected to represent between 20 and 30 PJ, or 1.9% to 2.3% of the total energy consumed by this sector, mainly driven by current electrification targets as well as stricter regulations for car and SUV fuel consumption currently in place. In spite of significant growth, electricity is therefore not expected to play a significant role in any scenario for 2030, as most targets adopted imply that only a very small fraction of all vehicles on the road will be electrified. As well, the greening of this sector mainly occurs through gains in fuel efficiency and a growing role for biofuels.

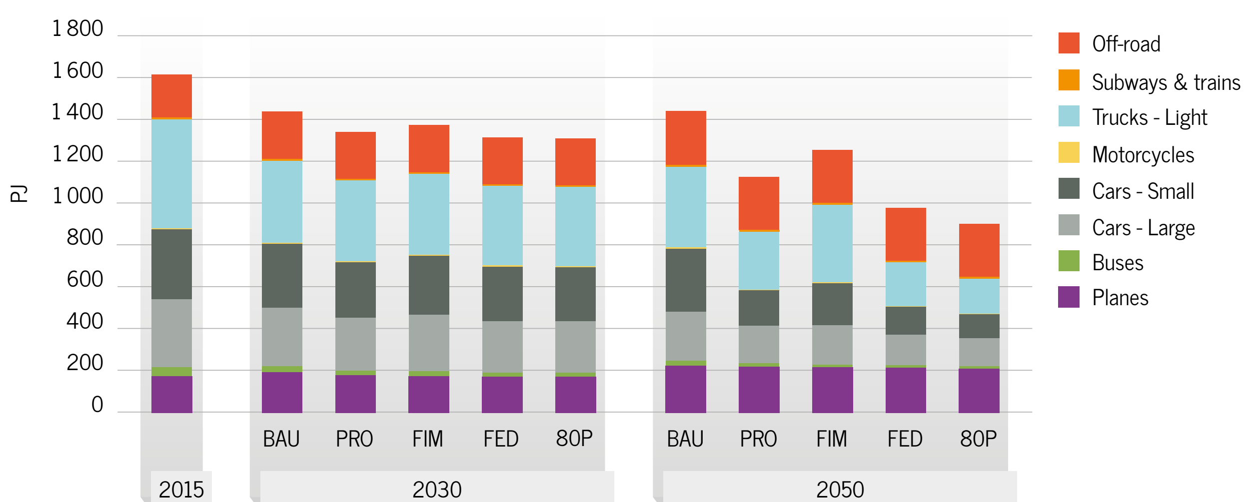
The situation is different for 2050, with a larger number of electric vehicles and with range extenders running on biofuels. These results thus suggest that an early electric transition for the transportation sector is not the most cost-effective approach as Canada embarks on efforts to reduce its GHG emissions. The transportation sector will take time to transform, with a timeline respecting the investment's lifetime; any precipitation will greatly increase costs.

Two other results stand out for 2030. First, the role of natural gas is negligible in all passenger transportation scenarios. Second, bioenergy is growing in absolute value much faster than electricity. In PRO, for example, bioenergy represents 12 times more energy than electricity (310 PJ vs. 26 PJ), and is 7 times the share of electricity (216 PJ vs. 30 PJ) in 80P. Bioenergy continues to grow rapidly between 2030 and 2050. Even though the share of electricity catches up with much more rapid increases between 2030 and 2050, it remains at most half of bioenergy contribution in 2050, depending on the scenario.

For all GHG reduction scenarios, these gains are obtained at the expense of diesel and especially gasoline, the proportion of which varies greatly among scenarios. While the BAU scenario maintains an almost constant total amount of gasoline consumed between 2030 and 2050 (996 PJ vs. 944 PJ), all the other scenarios significantly reduce the use of fossil fuels. In PRO, gasoline represents 61% of all energy consumed in 2030 and only 34% in 2050. For their part, the last two scenarios, FED and 80P, see much deeper changes with gasoline providing 24% or less of the total energy dedicated to moving people around. Given the higher efficiency of electricity, gasoline will mainly be used in hybrid cars as a range extender, strongly reducing the total amount of energy wasted by this sector.

Because of the large differences in efficiency, fuel consumption does not correlate with the service rendered with each fuel (Figure 9.7). While in BAU, internal combustion engines make up more than 90% of displacements in 2030 and more than 80% still in 2050, this percentage drops rapidly as GHG emissions are restricted. In 2030, 80P requires that almost 70% of all kilometres travelled be with hybrid, plug-in hybrid, electric or flex fuel. In 2050, electricity shows considerable gains and makes up the majority of kilometres, when

Figure 9.5 – Energy consumption by mode for passenger transportation



including plug-in hybrids for FED and 80P, even though it represents only about a quarter of the total energy consumed due to the much higher efficiency of electricity. This affects the sector's total energy consumption: while in 2030, 80P requires only 9% less energy than the BAU scenario, this difference rises to 38% in 2050, strongly contributing to energy efficiency gains for Canada.

Figure 9.5 shows how this evolution breaks down in terms of the mode of passenger transportation used. Although several categories remain similar in quantity across all scenarios – planes, buses, and off-road, in particular – cars and trucks come to occupy significantly smaller shares of total consumption in 2050. All GHG emission reduction scenarios show a reduction in consumption for these modes compared with BAU in 2050, with 80P again highlighting the importance of the transport sector in achieving substantial emission reductions. The 2030 results for various scenarios present less diversity, with smaller reductions in these same modes compared with BAU, reflecting the high costs and difficulties of changing the favoured modes of passenger transport in the short run.

Some of the problems tied to reducing emissions from the transport sector stem from the increasing demand (as described in Figure 9.1 for BAU and 80P). The reductions described in Figure 9.5 therefore take place despite a growing demand of 26% (measured in millions of passenger-kilometres).

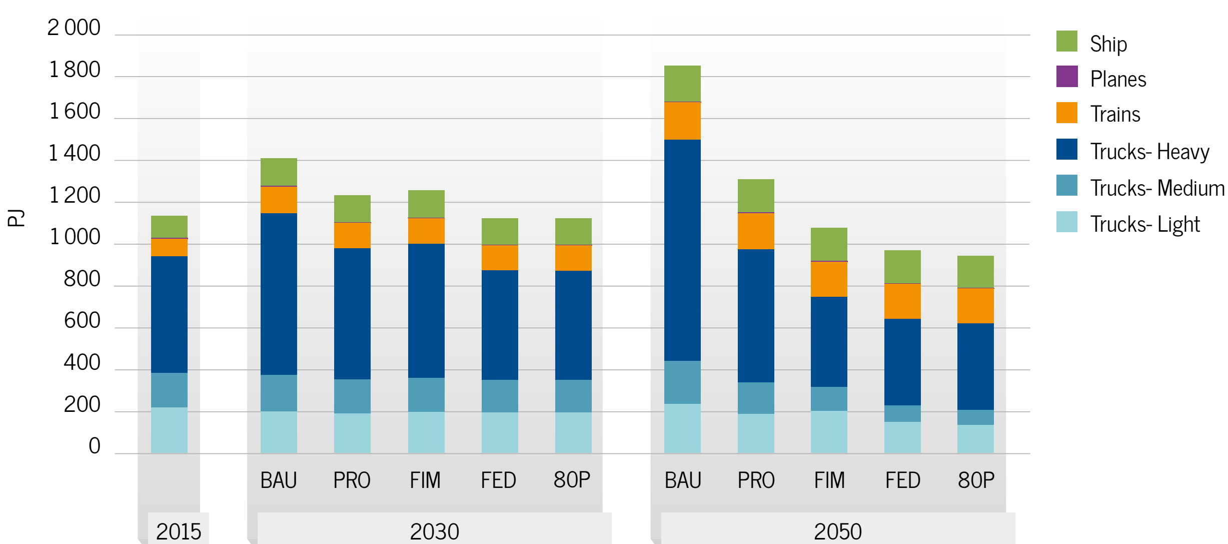
9.1.2 Freight transportation

Demand is expected to more than double for freight transportation over the next 30 years (Figure 9.2), dominated by railroad and road transportation, in line with the continuous growth observed in the last decades – again with few differences across scenarios. However, energy demand is expected to grow more slowly, thanks in part to new efficiency targets that would kick in even in the BAU scenario (Figure 9.4).

Apart from a few points, trends in freight transportation are very similar to those in passenger transportation. In 2030, electricity seems to emerge much more rapidly as it represents almost a quarter of the total energy consumed by this sector in FED and 80P. Results also indicate that natural gas could play a role as a transition fuel in the medium term (at least 21% of demand in 2030) – although only for a short period – as electricity needs to dominate this sector in 2050 to meet targets in all GHG scenarios, reflecting the high emission reduction potential in freight transport.

Except for the BAU scenario, which keeps the share of fossil fuels at 92% in 2050, low-carbon energy is predicted to increase its share to 48% in PRO, and to dominate the other three scenarios, with fossil fuels representing between 12% (80P) and 33% (FIM). Without the deep decarbonization of the freight transportation sector, Canada will be unable to meet

Figure 9.6 – Energy consumption by mode for freight transportation



its GHG emission targets, a trend that is similar across all provinces. We note, in particular, the disappearance of gasoline and especially diesel in the most demanding scenarios, FED and 80P, which contrasts sharply with the 2050 results for BAU.

Figure 9.6 breaks down this consumption by mode of transport. Clearly, the largest energy gains will take place on the road: the evolution of consumption for trucks of all sizes explains the main difference between GHG scenarios and BAU in 2050, as road transportation becomes electrified, multiplying by three to four the energy efficiency associated with this sector and leading to a much smaller overall energy demand in 2050, especially in FIM to 80P.

9.2 Technological developments in the passenger transportation sector

Figure 9.7 presents the expected mix of technologies used for passenger transport. For 2030, internal combustion engine (ICE) vehicles see their share decrease rapidly in terms of passenger-kilometres served, largely due to the rapid expansion of hybrid and flex fuel vehicles. While electric vehicles play a larger role than today, they remains marginal overall.

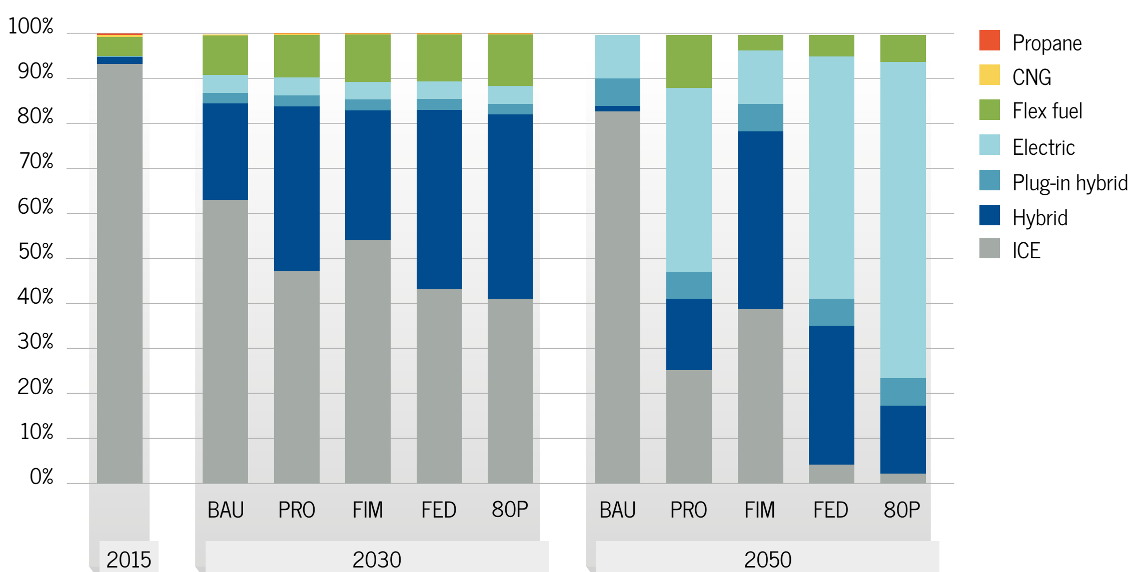
Pathways are much more diverse for 2050. For example, FED and 80P stand out with a large proportion of purely electric displacements; for these two scenarios, ICEs all but disappears. The main difference between these two scenarios consists of an increase in electric vehicles at the expense of hybrids in 80P, which highlights the central role of electric vehicles in order to achieve that volume of emission reductions in a context where demand is increasing (as described in Figure 9.1).

Less aggressive scenarios underline this difference: while PRO sees a large share of pure electric, FIM converges towards dominance by hybrid vehicles. This difference represents both a balance between the various targets and the current estimates of the evolution of prices over the next decades.

9.3 Challenges to transforming the transportation sector

It is remarkable that even with the inclusion of a considerable increase in demand for both passengers and freight, the NATEM model manages to find "reasonable solutions" in the

Figure 9.7 – Technology shares to meet passenger demand



transportation sector for the most aggressive GHG targets – reasonable, but clearly very ambitious.

For example, reaching federal targets (FED) requires that more than half the kilometres travelled by passengers in 2050 be with clean energy and that ICEs be almost banned by 2050, barely 30 years from now. The transformation may be even more profound in the freight sector, where only 20% of the energy would be allowed to be from fossil fuels by 2050 to respect provincial or federal targets.

Even though these scenarios might appear challenging, they are in line with the decision by a number of countries, including China, France and the United Kingdom, to ban new sales of ICE vehicles by 2040. It is therefore possible to envision passenger transportation in 2050 as very similar to that today, except for the dominance of zero-emission vehicles. With prices for electric vehicles already falling rapidly as their availability increases, it is easier than ever, from a technical point of view, to envisage such a transition. It is harder to see this transition from an economic perspective. However, at the moment, Canada is not a significant actor in the design and construction of personal electric vehicles. A complete transition away from ICE vehicles could therefore lead to increasing Canada's commercial imbalance with its trading partners.

As determined by our various scenarios, the transformation of the freight sector will require a strong and directed approach from governments, in order to support new technologies, some of which could necessitate important new heavy infrastructure, such as catenary lines on highways or railway electrification. Because such infrastructure needs standards, planning and considerable investments, rapid actions are required. Since trade is mainly with the USA and Mexico, any transformation of freight transportation would gain from an integrated approach and Canada should push for establishing committees with its trading partners to explore the best way to transform freight transportation on a continental scale. Depending on the direction taken, Canada could well come out ahead, as it can rely on a number of industries that are very active in the production of heavy transportation equipment and vehicles.

9.4 Transport-based alternative scenario

For the main scenarios, we choose to remain very conservative in terms of the demand evolution in the transportation sector, maintaining previous trends and adopting a business-as-usual underlying model, which does not impose any significant change in Canadians' habits. Yet as the number of vehicles on the road increases faster than the population and cities become ever more congested, this hypothesis is likely to face some serious constraints. In fact, a number of cities around the world have made it a priority to decrease the use of cars and move citizens to alternative modes of transportation, be they active (walking, cycling) or public (buses, subways, trams and trains).

With the rapid progress of autonomous vehicles, it is becoming easier to contemplate the optimization of the car and truck fleet and usage – for example, a car today spends an average of 23 hours parked, a very inefficient use of the second costliest budget item in most Canadian households (Statistics Canada 2018g). Of course, if nothing is done, the arrival of autonomous vehicles could very well increase congestion, as the share of empty cars jumps from zero today, to 10%, 20% and even 50%, with cars roaming by themselves to avoid paying parking or to be ready to pick up their owners at any moment. However, with appropriate regulations, incentives and investments, these vehicles can very well facilitate access to rapid, frequent and high-quality public transport that can collect passengers from larger regions even in low-density areas.

A similar transformation could take place in freight transportation. Current estimates predict that the volume of goods moved around the country will double over the next 30 years. This steep increase reflects the anticipated growth of the consumption of material goods by Canadians. It could be argued that, as the world slowly shifts to ways of life that have a lower environmental impact, the current projections are overstated and that growth in the freight sector will be slower, particularly as it is optimized with the help of autonomous vehicles and better management.

Many unknowns remain as to the quantity of transportation services Canadians will need over the next decades as the sector undergoes a profound transformation. For lack of a clear picture, we consider a scenario where the growth of transportation services is strongly curtailed:

- a flat growth curve for passenger transportation (Figure 9.8) to simulate increased car-sharing leading to a smaller number of vehicles and a significant move in urban areas toward active or public transportation modes;
- a growth reduced by two thirds for freight that would result from both better management and a slowdown in goods consumption (Figure 9.9).

Figure 9.10 and Figure 9.11 compare the evolution of energy consumption for passengers and freight

Figure 9.8 – Demand assumptions for passenger transportation

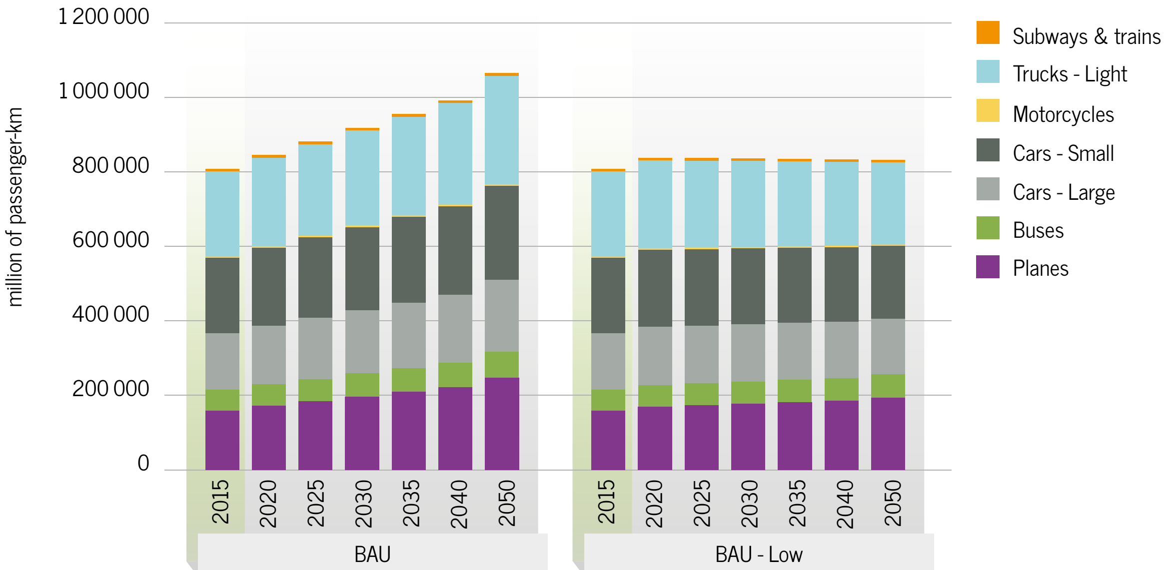


Figure 9.9 – Demand assumptions for freight transportation

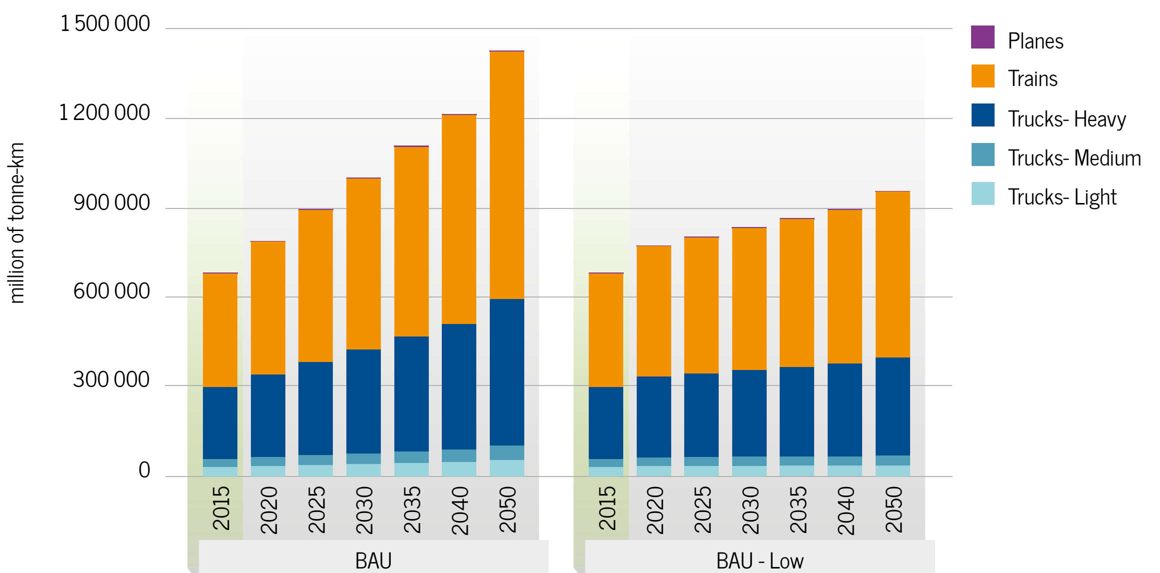


Figure 9.10 - Final energy consumption for passenger transportation under different demand assumptions

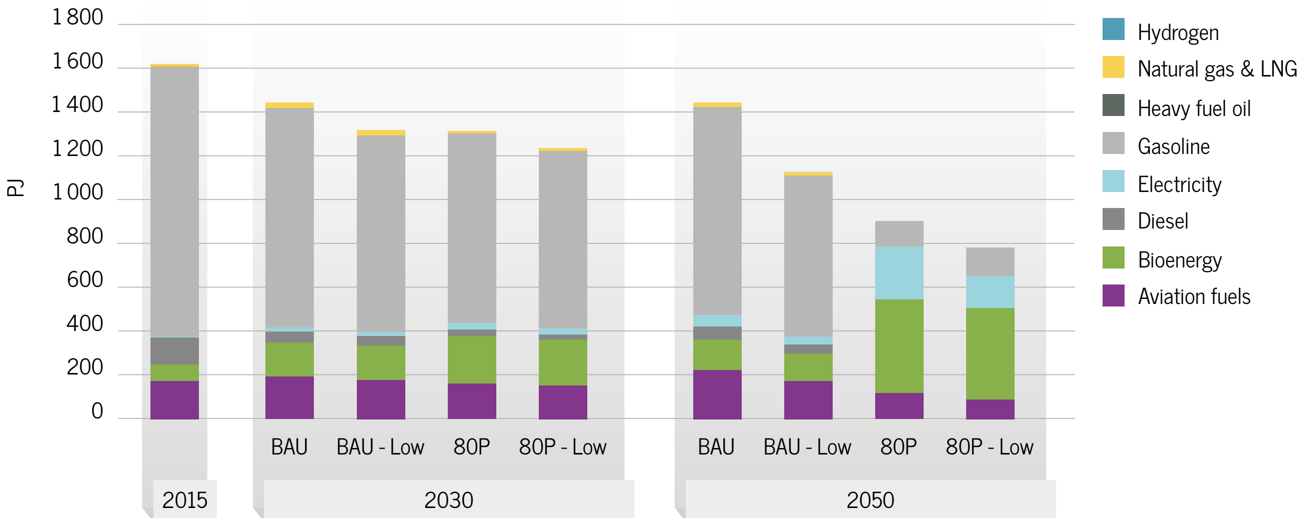
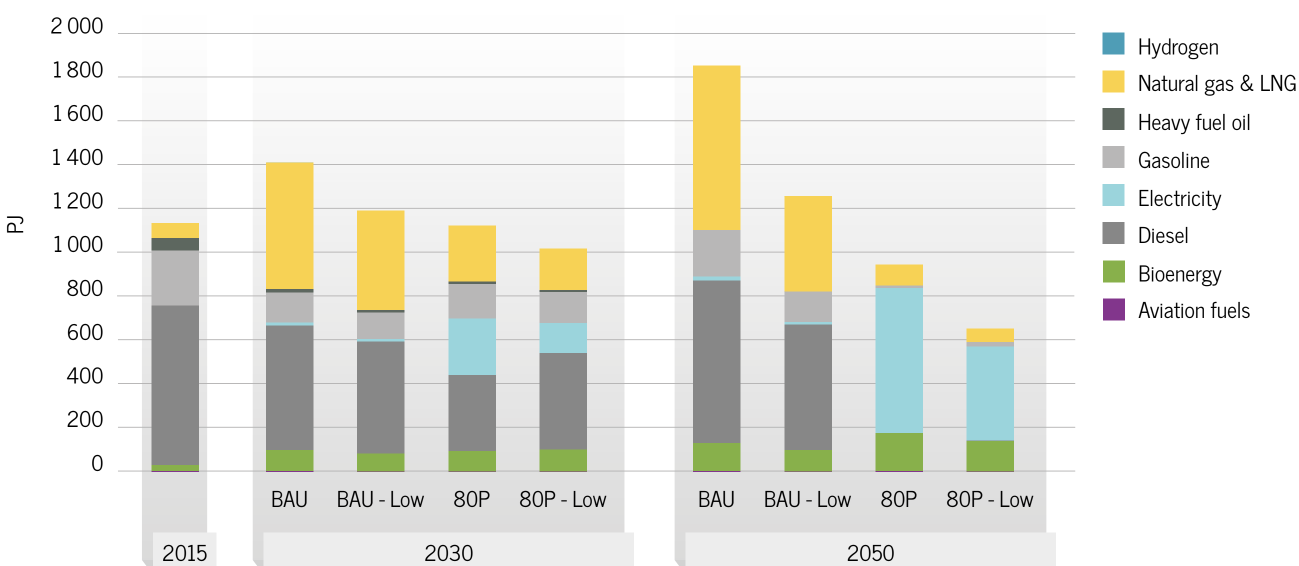
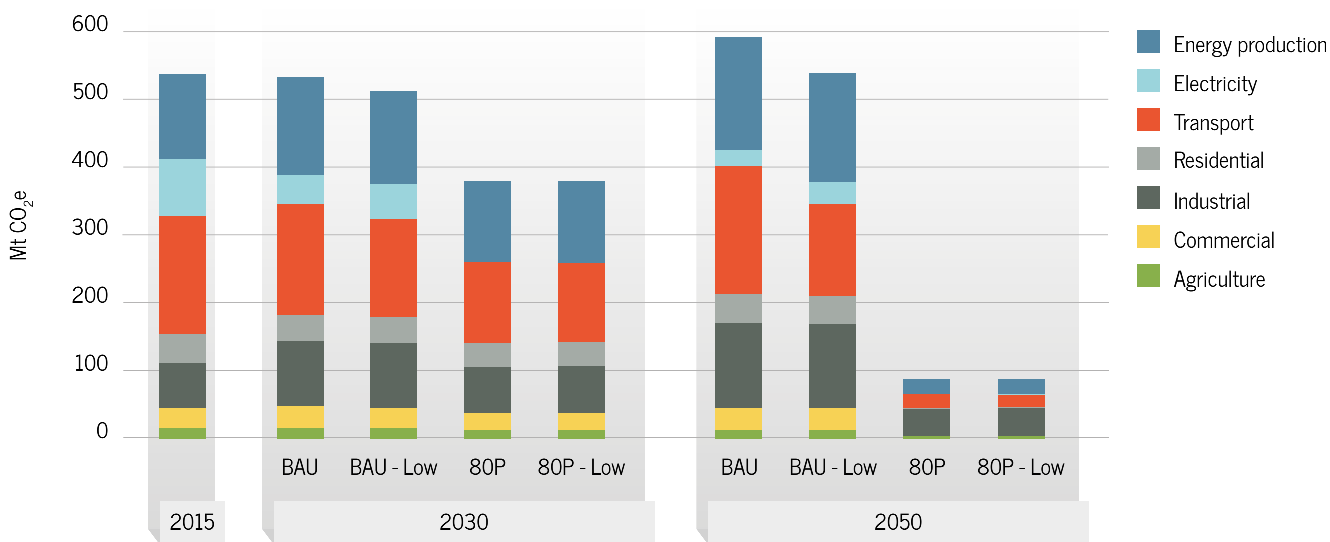


Figure 9.11 – Final energy consumption for freight transportation under different demand assumptions



between the BAU and 80P scenarios developed on both the business-as-usual growth in demand and the reduced growth variant (BAU-Low and 80P-Low). In passenger transportation, the difference in energy demand between the current trend and the low demand growth variants is mainly associated with a reduction in the use of fossil fuels in 2030. This supports the previous observation that low-carbon technologies, such as electricity, will not be significant game changers in passenger transportation over the next decade, unless there is a strong push through legislation or regulation. By 2050, in the BAU-Low case, the reduction in demand will proportionally affect all energy sources, reducing fossil fuels slightly more (-23 %) than renewables (-15 %), while for 80P, bioenergy remains almost untouched as demand for electricity decreases by almost 40%.

Figure 9.12 – GHG emission by sector



A similar picture emerges for freight transportation. Between now and 2030, for the BAU-Low scenario, the reduction in demand primarily leads to a reduction in the use of natural gas and LNG, which are more expensive energy solutions, while for 80P, the share of electricity falls faster. The same trend is observed for 2050: demand for natural gas is expected to be 40% lower in BAU-Low than in BAU, and 35% lower in 80P-Low than in 80P, a reduction similar to that of electricity in this case, with biofuel demand reduced by only 20%.

More interesting perhaps is the effect of the reduced demand for transportation on GHG emissions per sector and on the marginal cost of reduction. For BAU, because of the absence of constraints, reduced demand leads to GHG emission reductions of 20 and 53 MtCO_2e in the transportation sector for 2030 and 2050 respectively, with only minor adjustments in the other sectors (Figure 9.12). If no GHG limit is imposed, then acting on demand can have a noticeable impact.

For the 80P scenario, which is constrained by GHG emissions, we see very little transfer of the potential GHG gains to other sectors. As transportation is the most expensive sector to transform, the reduction in demand serves primarily to reduce investments in this sector, leaving GHG emissions untouched both by 2030 and 2050. Reducing demand does not therefore lead to reduced GHG emissions in this scenario, but instead affects the marginal costs of reduction, which falls from $1055/t to $920/t in 2050 with reduced demand for transportation. While this difference is notable, it represents a 13% reduction in marginal cost, a difference that could also be easily overcome by technological improvements.

9.5 Key trends

The profound transformation of the transportation sector is unavoidable in any GHG reduction scenario. Interestingly, our model suggests that this transformation can be achieved without restricting the displacement of either persons or goods, even allowing for continuous growth in this sector, following the trends observed over the last decades.

This hypothesis is likely too optimistic (or pessimistic, depending on one's point of view). However, it demonstrates strongly that **a substantial transformation of this sector is possible without affecting freedom of movement**.

If we include somewhat more aggressive or cost-efficient measures to decrease the overall demand for transport, we note that without additional constraints on GHG emissions, these are reduced proportionally to the demand. However, when strict limits on GHG emissions are imposed, the reduced demand largely helps to diminish the cost of meeting these targets, a cost that can also be affected by technological improvements when other aspects such as city transportation and citizens' quality of life are not included.

There are many paths leading to a similar low-carbon future for this sector. These paths depend on other social objectives such as health, congestion and quality of life, and leave much room for each city and province to find the answer that is most appropriate to its own goals.

10

Towards the GHG targets: the energy challenge

In this Outlook, we evaluate how the various plans and objectives, mainly tied to GHG reductions, set forward by provincial and federal governments could affect Canada's energy future. The transition of the Canadian energy sector has started, both on the consumption and on the production front: unconventional gas has become the main energy-producing activity in British Columbia; Ontario has closed its coal plants; and wind power has become the largest source of new electricity generation across the country, as Canadians have opted for ever larger vehicles and battery-operated objects of all kinds.

In this evolving world, the country's energy future remains an open question, dependent on internal and external choices and trajectories, and cannot be easily predicted. However, it is possible to estimate the challenges and the impacts of decisions and orientations on this system and to facilitate reflections, debates and planning. To this end, we analyze various energy pathways using global cost optimization that takes into account recent technological developments and price evolution.

These pathways suggest that while the goals set by the various governments are more attainable than ever, they involve profound transformations that will affect all Canadians.

10.1 Supporting trends

The energy system transformation needed to reach the various GHG reduction targets adopted by the provincial and federal governments is extensive. Yet two interrelated external factors could contribute to accelerating the transition and reducing its cost, as is already evidenced by the reference scenario.

First, a remarkable trend has emerged over the last two decades, showing **the slowdown in the growth of energy demand** across almost all sectors of the economy, even with a growing population and economy. This trend is largely due to constant improvements in energy efficiency, the displacement of expenses towards services that are less energy demanding and the growing role of renewable energies in electricity generation. Since the demand curves used in this Outlook are based on historical growth rates, it is therefore very possible that its evolution remains overestimated. Investments required to meet domestic demand could then be significantly less than assumed by the various scenarios presented here, facilitating the move towards a low-carbon economy.

Second, the energy transition will also be helped by a general tendency to **increase the role of electricity** in the life of Canadians. At the moment, the share of electricity in Canadians' energy basket varies greatly across provinces, from as low as 13% in Alberta to 39% in Quebec. Yet, as Canada moves toward its GHG targets, and as the cost of renewable electricity generation falls and services are more and more integrated with information technologies, electricity is expected to play a growing role across the country, irrespective of current use levels. Since electricity generally provides more efficient services than fossil fuels, electrification will contribute to reducing overall primary energy consumption over the next decades, as can be seen in the various scenarios presented here.

Naturally, this electrification will not take place at the same rate across all sectors. Although, in terms of percentage, transport will likely be the fastest growing sector for electricity use, heat production for buildings, water and industrial processes will be responsible in absolute numbers for most of the demand over the coming years, chiefly because technologies are largely already available and relatively cheap. Moreover, while a sizeable share of the electrified transport material is imported, building-related modifications contribute more to the local economy, decreasing their net costs to the Canadian economy.

This growing role for electricity will develop just as distributed energy production becomes more competitive, particularly in the Canadian markets where electricity prices are high, increasing pressure on current infrastructure. To enable Canadians to enter the electricity generation market on a large scale, while ensuring that all consumers have access to the energy they need, utilities will have to transform their grid, developing new pricing schemes and supporting innovation in a sector that has been largely static for decades and likely significantly expand energy exchanges with their neighbours. As the rest of the world faces essentially the same challenges, Canadian utilities can either adopt a wait-and-see attitude or move aggressively to transform their business, developing an expertise that could be highly valuable around the world.

10.2 The barriers

Significant barriers that impede or work against the transition are also present in Canada. Three stand out today.

First is **the weight of Canada's oil and gas production** that represents a major export sector and supports the economy across the country. Even though most of this production is targeted for export, GHG emissions associated with extraction and transport affect Canada's GHG goals disproportionally with respect to other oil- and gas-producing nations, placing considerable environmental and political pressure on this industry. Moreover, as Canada contributes to developing and adopting low-carbon emission technologies, the reduction of the oil and gas sector appears to be more and more possible.

Yet Canada's oil and gas future is linked to domestic decisions only to a very limited extent; in fact, it depends on the evolution of the worldwide demand, which sets prices. Should demand for fossil fuels from the rest of the world continue to grow, Canada will certainly expand its production of non-conventional oil and gas. However, if the rest of the world moves on a path dominated by electrification and reduction in fossil fuel demand, Canada's energy sector is unlikely to be able to compete with cheaper alternatives. The future of Canada's oil and gas sector will therefore be determined both by general orientations regarding GHG emissions and technological developments abroad, particularly in emerging economies. Nonetheless, how fast and how deep this transformation will be remains to be seen. Yet movements from major investments funds, such as the *Caisse de dépôt et placement du Québec*, which now factor in climate change risks in their investments, suggest that oil and gas is on the way out (CDPQ 2018).

To prevent Canada from finding itself at odds with the rest of the planet, a situation it cannot benefit from, it must prepare for job losses in the sector and support the emergence of new industries that will not be energy centric. This transformation is challenging, but as a major energy exporter Canada has very little leverage on the decisions made in the rest of the world.

Second, as highlighted by the various scenarios examined in this Outlook, there is considerable incompatibility between the provincial and federal targets, which can lead to tensions between the various levels of government and confusion in the industry and among citizens and investors. There is therefore a strong need for governments supporting GHG reductions to work together to reduce the incoherence and to support actions that will leverage the various efforts to transform the economy effectively, especially since the marginal costs associated with deep decarbonization have decreased significantly even in relation to evaluations made only a few years ago.

Although Canada places considerable weight on buying carbon credits from the United States in its latest report to the UN, this option is unlikely to deliver the expected reduction as this solution demands a lot from California, which will already find it difficult to reach its own reduction goals, especially with Ontario pulling out of this market. While the market is an efficient tool to act at the margin and provide a uniform price for GHG emissions, it is not built to support the 25% imbalance expected by the federal government (see the conclusion in Chapter 3). With an imbalance that high, prices would soon reach the ceiling fixed by the WCI and, instead of delivering guaranteed reductions, would simply turn into a tax system at a level well below marginal costs for reaching the expected targets. While this mechanism is built into the WCI carbon market in order to prevent disproportionate hardship to its emitters, its use is a worst-case scenario that would limit its ability to provide adequate price levels unless negotiations are undertaken to significantly raise this ceiling.

Finally, **Canada GHG reduction efforts are facing considerable political uncertainties:** even though the science cannot be contested, GHG reduction efforts across Canada remain highly dependent on short-term electoral transitions, at both provincial and federal levels, and on US politics.

While health care and education for example are somewhat protected from sizeable swings following each election, in most provinces climate change issues remain politicized to a level that is not seen in most developed economies including, on some level, the United States, where states are often bound by regional agreements and structures that maintain orientation through political cycles. This is the case with the RGGI in the US North East. The lack of comparable agreements and structures in Canada creates considerable uncertainty for investors and public administrations that hesitate to make the bold moves needed to profoundly transform Canada's energy sector.

For instance, in spite of legally approved GHG reduction objectives for Ontario, the election of the Conservative Party led by Doug Ford, with an expected protracted battle with the federal government, has already begun to dampen GHG reduction efforts in this province, in addition to adding support to other opposing provinces like Saskatchewan.

The deep divide between provincial and federal targets and objectives is likely to create tension and increase the costs of transforming the Canadian economy. As the rest of the world moves forward, there is a strong need for the various levels of government to work towards common or at least compatible targets that will facilitate investments and cost-reducing measures.

10.3 Transport: the key sector

Transport is among the demand sectors most affected by the energy transition. All GHG-reduction scenarios suggest that the move away from fossil fuels will be slow. Moreover, both passenger and freight transportation are likely to continue to rely on very diverse energy sources by 2050, dominated by electricity and biofuels, but with fossil fuels remaining for some specific applications such as aviation. For ground transportation, modelling favours electric over combustion engines with fuels serving largely for range extenders.

A more specific analysis of the transport sector shows that it will require sustained targeted attention from governments and the private sector since the transformation will take place over decades and involve considerable investments. However, this opens the door to Canada's active participation in the development of intellectual property associated with this transformation.

To mimic some of the profound technological transformations that are expected to occur in the transportation sector, we considered a scenario where demand is flat for passenger transportation and growth is considerably reduced for freight, as explained in chapter 9. Remarkably, while a reduced demand decreases the marginal cost of GHG reduction by 2050, it largely remains within the uncertainty of the model, falling from \$1055/t to \$920/t for 80P. These results suggest that, contrary to what could have been expected, the GHG emission gains achieved by restricted access to transportation services are small, while affecting both citizens and the private sector. A more astute strategy should therefore target the development of alternative approaches that will provide the same or better services more efficiently.

10.4 Acting now

Climate change remains a fact, whether or not it is accepted by politicians and citizens. Moreover, many countries are integrating this reality much more significantly than Canada, gaining economic advantages for both today and tomorrows' economy and adapting to changes, decreasing the need for costly reengineering in the decades to come.

While this Outlook shows that the GHG reduction targets are attainable, Canada is not on track to deliver them. Most provinces lag behind their own timeline, and the federal government has yet to announce programs that will ensure the transformation needed to reach the next milestone set for 2030 in Canada's 7th National Communication and 3rd Biennial Report to the United Nations Framework Convention on Climate Change (Canada 2017d). This document shows that, with current measures, Canada can at best deliver internally only about 43 percent (96 $MtCO_2e$) of the legislated reductions of 221 $MtCO_2e$ (see Figure 5.6 and Table 5.28, p. 153).

As Canada dithers on this issue, there is a need for the scientific, business and social communities, as well as governments, to develop approaches that will link the abstract GHG reductions with direct lifestyle improvements for the population, be they in health, education, transport or job prospects. For the transformation to provide the best leverage to improve Canada's economy and the life quality of its citizens, it is important to get moving and build on a long-term vision that will facilitate investments and orient the transformation. While the Pan-Canadian Framework (Canada. 2017a) signed at the end of December 2016 provides a very general first step to align the various efforts, a more detailed approach developed with the support of the general public is essential to set a transition that can survive election cycles (SCD 2017).

At the moment, very little is offered in terms of short-term advantages for citizens to support the energy transition. For example, apart from setting a minimum price on carbon, the PCF has yet to put in place programs that will benefit Canadians directly.

Moreover, while the experience in Prince Edward Island, as it moves to renewable energy, has received considerable support from its population, this has not been the case in Ontario over the last few years, where the move to renewable energy has led to considerably higher prices. This has served as a deterrent to citizens to back efforts to manage and encourage the energy transition. This situation is unfortunate as this experience, if well managed, could have delivered lower prices, while allowing more Ontarians to participate directly in energy production. Yet experiences in Germany, the United Kingdom and Sweden show that in order to garner cross-party support, it is essential for the energy transition to demonstrate clear and concrete advantages to a large segment of society.

Achieving such a consensus requires Canadians to move beyond discussions on carbon pricing and pipelines, and directly address the transformative potential of the energy transition, a potential with benefits that go beyond the sole impact on the energy sector. Correctly implemented, this transition can be leveraged to ensure a better quality of life, including better jobs, better health and a better environment. We hope that this Outlook will initiate more positive discussions on this transition and help identify the pathway Canadians want to take for this crucial journey.

Appendix A – References for Table 3.1

Canada

Canada. 2017. Government of Canada sets ambitious GHG reduction targets for federal operations (news release). Government of Canada: Treasury Board of Canada Secretariat. Online, https://www.canada.ca/en/treasury-board-secretariat/news/2017/12/government_of_canadasetsambitiousghgreductiontargetsforfederalop.html

Canada. 2017. Regulations Respecting Reduction in the Release of Methane and Certain Volatile Organic Compounds (Upstream Oil and Gas Sector). Government of Canada. Online, http://www.gazette.gc.ca/rp-pr/p1/2017/2017-05-27/html/reg1-eng.html (accessed February 15 2018)

Canada. 2018. Achieving a Sustainable Future: A Federal Sustainable Development Strategy for Canada. Government of Canada. Online, http://fsds-sfdd.ca/index.html#/en/detail/all/goal:G05 (accessed February 25 2018)

Alberta

Alberta. 2012. Renewable Fuels Standard Regulation (Climate Change and Emissions Management Act). Province of Alberta.

Alberta. 2017. Climate Leadership Plan: Progress Report. Alberta Government.

British Columbia

British Columbia. 2018. Climate Action Legislation. Government of British Columbia. Online, https://www2.gov.bc.ca/gov/content/environment/climate-change/planning-and-action/legislation (accessed February 10 2018).

British Columbia. 2018. Renewable & Low Carbon Fuel Requirements Regulation. Government of British Columbia. Online, https://www2.gov.bc.ca/gov/content/industry/electricity-alternative-energy/transportation-energies/renewable-low-carbon-fuels (accessed February 10 2018)

Manitoba

Manitoba. 2011. Ethanol General Regulation 165/2007. Manitoba.

Manitoba. 2016. Biodiesel Mandate for Diesel Fuel Regulation. Manitoba.

Manitoba. 2015. Manitoba's Climate Change and Green Economy Action Plan. Manitoba.

Manitoba. 2016. The Efficiency Manitoba Act. The Legislative Assembly of Manitoba.

Manitoba. 2017. A Made-in-Manitoba Climate and Green Plan: Hearing from Manitobans. Manitoba.

New Brunswick

New Brunswick. 2016. Transitioning to a low-carbon economy: New Brunswick's Climate Change Action Plan. Province of New Brunswick.

New Brunswick. 2017. Update on New Brunswick Climate Change Actions. Province of New Brunswick.

Newfoundland and Labrador

Newfoundland and Labrador. 2007. Provincial Energy Plan. Newfoundland and Labrador.

Newfoundland and Labrador. 2011. Climate Action Plan. Newfoundland and Labrador.

Newfoundland and Labrador. 2011. Energy Efficiency Action Plan. Newfoundland and Labrador.

Nova scotia

NEB. 2016. Canada's Renewable Power Landscape: Energy Market Analysis. National Energy Board.

Nova Scotia. 2017. Environmental Goals and Sustainable Prosperity Act 2015-17 Progress Report. Nova Scotia.

Nova Scotia. 2009. Toward a Greener Future: Nova Scotia's Climate Change Action Plan. Nova Scotia Environment.

Northwest Territories

Northwest Territories. 2001. A Greenhouse Gas Strategy for the Northwest Territories 2011-2015. Northwest Territories: Environment and Natural Resources.

Nunavut

Canada. 2015. Nunavut: Environment Profile. Government of Canada. Online, https://www.canada.ca/en/environment-climate-change/corporate/briefing/nunavut-environment-profile.html (accessed February 28 2018)

Ontario

NEB. 2016. Canada's Renewable Power Landscape: Energy Market Analysis. National Energy Board.

Ontario. 2005. Ethanol in Gasoline regulation 535/05. Government of Ontario.

Ontario. 2014. Greener Diesel – Renewable Fuel Content Requirements for Petroleum Diesel Fuel Regulation 97/14. Government of Ontario.

Service Ontario. 2014. Low Carbon Transportation Fuels in Ontario: Amendments to Ethanol in Gasoline (O. Reg. 535/05) and Greener Diesel - Renewable Fuel Content Requirements for Petroleum Diesel Fuel (O. Reg. 97/14) Regulations. Online, http://www.ontariocanada.com/registry/view.do?postingId=25687&language=en (accessed February 15 2018)

Ontario. 2016. Ontario's Five Year Climate Change Action Plan 2016-2020. Government of Ontario.

Ontario. 2016. Climate Change Mitigation and Low-carbon Economy Act, 2016, S.O. 2016, c.7. Government of Ontario.

Prince Edward Island

Prince Edward Island. 2016. Provincial Energy Strategy 2016/17. Prince Edward Island.

Quebec

MDDELCC. 2018. Engagements du Québec: Nos cibles de réduction d'émissions de GES. Québec : Développement durable, environnement et lutte contre les changements climatiques. Online, http://www.mddelcc.gouv.qc.ca/changementsclimatiques/engagement-quebec.asp (accessed January 31 2018)

Québec. 2016. L'énergie des Québécois: Source de croissance. Politique énergétique 2030. Gouvernement du Québec.

Saskatchewan

Saskatchewan. 2005. The Ethanol Fuel (General) Regulations. Regina, Saskatchewan.

Saskatchewan. 2011. The Renewable Diesel Act. Regina, Saskatchewan.

Saskatchewan. 2017. Prairie Resilience: A Made-in-Saskatchewan Climate Change Strategy. Government of Saskatchewan.

Yukon

Yukon. 2012. Climate Change Action Plan: Progress Report. Yukon Government.

Appendix B – Definitions

Primary energy:
Energy form that has not been subjected to any human engineered conversion process (e.g. crude oil, coal, hydro resources, wind energy, biomass, etc.). It is energy contained in raw fuels received as input to a system. The use of primary energy as a measure ignores conversion efficiency.

Primary energy production:
Extraction or production of primary energy in the country. It includes primary energy that is used domestically and exported.

Primary energy consumption:
Consumption of primary energy in the country. It includes primary energy produced in the country and imported. A synonym often used is Total Primary Energy Supply (TPES).

Secondary energy:
Resulting energy from conversion of primary sources of energy (e.g. electricity from coal, petroleum products from crude oil, biofuels from forest residues, etc.).

Final energy consumption:
All energy supplied to the final consumer for all energy uses, usually disaggregated into final end-use sectors (e.g. agriculture, commercial, industrial, residential, transport, energy production, etc.).

Bioenergy:
Energy content in biomass feedstock, biogas and waste, including solid biomass, liquid biofuels and biogas.

Other renewables:
Renewable sources of energy excluding hydroelectricity, including mainly wind, solar and geothermal.

Energy-related emissions:
GHG emissions produced by activities requiring the consumption of fuels.

References

Alberta. 2018a. Carbon levy and rebates. Alberta Government. Online, https://www.alberta.ca/climate-carbon-pricing.aspx#p184s7

Alberta. 2018b. Renewable Electricity Program. Alberta Government. Online, https://www.alberta.ca/renewable-electricity-program.aspx (accessed January 18 2018)

Alberta. 2018c. Capping oil sands emissions. Alberta Government. Online, https://www.alberta.ca/climate-oilsands-emissions.aspx (accessed January 18 2018)

BC Hydro. 2016. New eDrive electricity rate for LNG facilities. BC Hydro.

Billette de Villemeur, Etienne and Pierre-Olivier Pineau. 2016. Integrating Thermal and Hydro Electricity Markets: Economic and Environmental Costs of Not Harmonizing Pricing Rules (August 30, 2016). The Energy Journal (2016). Available at SSRN: https://ssrn.com/abstract=2832334British Columbia. 2016. Climate Leadership Plan. Government of British Columbia.

British Columbia. 2017a. Tax Rates on Fuels: Motor Fuel Tax Act and Carbon Tax Act. British Columbia: Ministry of Finance.

British Columbia. 2017b. Budget 2017 September Update. Government of British Columbia.

British Columbia. 2018a. British Columbia's Revenue-Neutral Carbon Tax. Government of British Columbia. Online, https://www2.gov.bc.ca/gov/content/environment/climate-change/planning-and-action/carbon-tax (accessed February 2 2018).

British Columbia. 2018b. Low Income Climate Action Tax Credit. Government of British Columbia. Online, https://www2.gov.bc.ca/gov/content/taxes/income-taxes/personal/credits/climate-action?keyword=low&keyword=income&keyword=climate&keyword=action&keyword=tax&keyword=credit (accessed February 2 2018).

British Columbia. 2018c. Motor Fuel Tax & Carbon Tax. Government of British Columbia. Online, https://www2.gov.bc.ca/gov/content/taxes/sales-taxes/motor-fuel-carbon-tax?keyword=motor&keyword=fuel&keyword=tax (accessed February 2 2018).

British Columbia. 2018d. Becoming Carbon Neutral – B.C.'s Provincial Public Sector. British Columbia: Ministry of Environment and Climate Change Strategy.

British Columbia. 2018e. Clean Energy Vehicle Program. Government of British Columbia. Online, https://www2.gov.bc.ca/gov/content/industry/electricity-alternative-energy/transportation-energies/clean-transportation-policies-programs/clean-energy-vehicle-program (accessed February 2 2018).

Canada. 2016. The Government of Canada accelerates investments in clean electricity (news release, November 21). Government of Canada.

Canada. 2017a. Pan-Canadian Framework on Clean Growth and Climate Change. Government of Canada. Online, https://www.canada.ca/en/services/environment/weather/climatechange/pan-canadian-framework.html (accessed March 15)

Canada. 2017b. Taking action to phase out coal power. Government of Canada: Environment and Climate Change Canada.

Canada. 2017c. Powering Past Coal Alliance Declaration. Government of Canada.

Canada. 2018a. Output-based pricing system regulatory framework. Government of Canada.

Canada. 2018b. Technical paper: federal carbon pricing backstop. Government of Canada.

Canada. 2018c. Carbon pricing: regulatory framework for the output-based pricing system.

Canada. 2018d. Clean fuel standard – Regulatory Framework, December 2017. Government of Canada.

Canada. 2018e. Greening Government Strategy. Government of Canada: Treasury Board of Canada Secretariat.

Canada. 2018f. Achieving a Sustainable Future: A Federal Sustainable Development Strategy for Canada. Government of Canada. Online, http://fsds-sfdd.ca/index.html#/en/detail/all/goal:G05 (accessed February 25 2018)

Canadian Fuels Association. 2018. Fuels Industry – Fuel Production. Canadian Fuels Association. Online, http://www.canadianfuels.ca/The-Fuels-Industry/Fuel-Production/ (accessed February 27 2018)

CARB. 2018. Summary of auction settlement prices and results (Feb. 2018). California Air Resource Board. Online, https://www.arb.ca.gov/cc/capandtrade/auction/auction.htm

CDPQ. 2018. Investissement durable 2017, Caisse de dépôt et placement du Québec , Montréal, avril 2018.

Department of Finance Canada. 2018. Legislative and Regulatory Proposals Relating to the Greenhouse Gas Pollution Pricing Act and Explanatory Notes. Government of Canada: Department of Finance.

ECCC. 2017a. Proposed methane regulations: A significant step in addressing climate change in Canada. Government of Canada: Environment and Climate Change Canada.

ECCC. 2017b. Canada's 7th National Communication and 3rd Biennial Report to the United Nations Framework Convention on Climate Change. Government of Canada: Environment and Climate Change Canada.

ECCC. 2018. National and Provincial/Territorial Greenhouse Gas Emission Tables. Government of Canada: Environment and Climate Change Canada. Online, http://donnees.ec.gc.ca/data/substances/monitor/national-and-provincial-territorial-greenhouse-gas-emission-tables/?lang=en (accessed March 1 2018)

Flanagan, Erin, Bora Plumptre, Duncan Kenyon and Karen Tam Wu. 2017. State of the Framework: Tracking implementation of the Pan-Canadian Framework on Clean Growth and Climate Change. Calgary: The Pembina Institute.

Hughes, J. David. 2018. Canada's Energy Outlook: Current realities and implications for a carbon-constrained future. Online, https://energyoutlook.ca/

IEA. 2011. World Energy Outlook. Paris: International Energy Agency.

IEA. 2018. Canada Balance (2015). Paris: International Energy Agency. Online, https://www.iea.org/Sankey/#?c=Canada&s=Balance (accessed February 22 2018)

MDDELCC. 2017. *Bilan mi-parcours du Plan d'action 2013-2020 sur les changements climatiques.* Quebec: Développement durable, environnement et lutte contre les changements climatiques.

MDDELCC. 2018. The zero-emission vehicle (ZEV) standard. Quebec: Développement durable, environnement et lutte contre les changements climatiques. Online, http://www.mddelcc.gouv.qc.ca/changementsclimatiques/vze/index-en.htm (accessed March 8 2018)

NEB. 2017. Canada's Adoption of Renewable Power Sources. Energy Market Analysis (May). National Energy Board.

NRCAN. 2018a. Energy facts. Government of Canada: Natural Resources Canada. Online, http://www.nrcan.gc.ca/energy-facts (accessed February 22 2018)

NRCAN. 2018b. Fuel Consumption Taxes in Canada. Government of Canada: Natural Resources Canada. Online, http://www.nrcan.gc.ca/energy/fuel-prices/18885 (accessed March 8 2018)

OECD. 2017. OECD Environmental Performance Reviews: Canada 2017. Paris, Organisation for Economic Co-operation and Development.

OEE. 2018. Comprehensive Energy Use Database. Government of Canada: Natural Resources Canada, Office of Energy Efficiency. Online, http://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/menus/trends/comprehensive_tables/list.cfm (accessed February 10 2018)

Ontario. 2017. 2017 Long-term Energy Plan. Ontario: Ministry of Energy. Online, https://news.ontario.ca/mei/en/2017/10/2017-long-term-energy-plan.html (accessed March 1 2018)

Ontario. 2018a. Electric Vehicle Incentive Program (EVIP). Ontario: Ministry of Transportation. Online, http://www.mto.gov.on.ca/english/vehicles/electric/electric-vehicle-incentive-program.shtml (accessed March 2 2018)

Ontario. 2018b. Electric vehicle charging incentive program. Ontario: Ministry of Transportation. Online, http://www.mto.gov.on.ca/english/vehicles/electric/charging-incentive-program.shtml (accessed March 2 2018)

Ontario. 2018c. Electric Vehicle Chargers Ontario (EVCO). Ontario: Ministry of Transportation. Online, http://www.mto.gov.on.ca/english/vehicles/electric/electric-vehicle-chargers-ontario.shtml (accessed March 2 2018)

SCD. 2017. Re-Energizing Canada: Pathways to a Low-Carbon Future. Sustainable Canada Dialogues. Online, http://www.sustainablecanadadialogues.ca/en/scd/energy.

SCNR. 2017. Strategic Electricity Interties. Standing Committee on Natural Resources, December 2017, 42th Parliament, 1st Session. https://www.ourcommons.ca/DocumentViewer/en/42-1/RNNR/report-7/

Statistics Canada 2018a. CANSIM Table 128-0016: Supply and demand of primary and secondary energy. Government of Canada: Statistics Canada.

Statistics Canada 2018b. CANSIM Table 134-0001: Refinery supply of crude oil and equivalent. Government of Canada: Statistics Canada.

Statistics Canada 2018c. CANSIM Table 051-0001: Estimates of population, by age group and sex for July 1, Canada, provinces and territories. Government of Canada: Statistics Canada.

Statistics Canada 2018d. CANSIM Table 127-0006: Electricity generated from fuels, by electric utility thermal plants. Government of Canada: Statistics Canada.

Statistics Canada 2018e. CANSIM Table 127-0007: Electric power generation, by class of electricity producer. Government of Canada: Statistics Canada.

Statistics Canada 2018f. CANSIM Table 127-0008: Supply and disposition of electric power, electric utilities and industry. Government of Canada: Statistics Canada.

Statistics Canada 2018g. CANSIM Table 203-0022: Survey of household spending (SHS), household spending, Canada, regions and provinces, by household income quintile. Government of Canada: Statistics Canada.

TEFP. 2016. Canada's Challenge & Opportunity – Transformations for Major Reductions in GHG Emissions. Trottier Energy Futures Project. Online, http://iet.polymtl.ca/tefp.

WDI. 2018. World Development Indicators. World Bank: World Development Indicators.