Positioning Canada's Electricity Sector in a Carbon Constrained Future

Report of the Standing Senate Committee on Energy, the Environment and Natural Resources

The Honourable Richard Neufeld, Chair
The Honourable Paul J. Massicotte, Deputy Chair

March 2017

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Canada

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Members

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The Honourable Paul J. Massicotte, Deputy Chair

and

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The Honourable Rosa Galvez
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Ex-officio members of the Committee:

The Honourable Senators Peter Harder, P.C. (or Diane Bellemare) and Claude Carignan, P.C. (or Yonah Martin).

The committee would like to recognize the following Senators who are no longer serving members of the committee whose contribution to the study was invaluable:

The Honourable Senator Grant Mitchell
The Honourable Senator Pierrette Ringuette

Other Senators who have participated from time to time in the study:

The Honourable Senators: Ataullahjan, Bellemare, Dean, Johnson (retired), Martin, McIntyre, Omidvar, Raine, and Runciman.

Parliamentary Information and Research Service, Library of Parliament:
Sam Banks and Marc LeBlanc, Analysts.

Senate Committees Directorate:
Maxime Fortin, Clerk of the Committee
Brigitte Martineau, Administrative Assistant

Order of Reference

Extract from the *Journals of the Senate*, Thursday, March 10, 2016:

The Honourable Senator Neufeld moved, seconded by the Honourable Senator Frum:

That the Standing Senate Committee on Energy, the Environment and Natural Resources be authorized to examine and report on the effects of transitioning to a low carbon economy, as required to meet the Government of Canada's announced targets for greenhouse gas emission reductions. Recognizing the role of energy production, distribution and consumption in Canada, the committee shall be authorized to:

(a) identify and report on the impact transitioning to a low carbon economy will have on energy end users, including Canadian households and businesses;

(b) identify and report on the most viable way the following sectors — electricity, oil and gas, transportation, buildings and trade-exposed energy intensive industries — can contribute to a low carbon economy in meeting Canada's emission targets;

(c) examine and report on cross-sector issues and undertake case studies, if necessary, on specific programs or initiatives aimed at reducing greenhouse gas emissions;

(d) identify areas of concern and make any necessary recommendations to the federal government that will help achieve greenhouse gas emission targets in a manner that is sustainable, affordable, efficient, equitable and achievable.

That the committee submit interim reports on identified sectors, cross-sector issues and case studies and submit its final report no later than September 30, 2017, and that the committee retain all powers necessary to publicize its findings until 180 days after the tabling of the final report.

After debate,

The question being put on the motion, it was adopted.

Charles Robert

Clerk of the Senate

The committee has held 35 hearings and heard from 91 witnesses consisting of government officials, electricity utilities, industry representatives, energy experts, university students, major energy users and environmental organizations. Committee members conducted site visits and had fact finding meetings in Vancouver, Kitimat and Prince George, British Columbia, Calgary, Alberta, Estevan, Saskatchewan, Sarnia and Hamilton, Ontario and Montreal and Varennes, Quebec.

Executive Summary

Many Canadians could soon be paying higher electricity bills as the country tries to meet reduction targets for its greenhouse gas (GHG) emissions —especially those in provinces that rely on fossil fuel generation.

The electricity sector is among the first to reduce emissions, dropping 33% from 2005 to 2014. It is expected to further reduce by 56% from 2014 to 2030, contributing more to emission reductions than any other sector of the Canadian economy.

The Standing Senate Committee on Energy, the Environment and Natural Resources is studying what it will cost ordinary Canadians and businesses to meet Canada's GHG reduction targets. The committee will make any necessary recommendations to the federal government that will help achieve its GHG reduction commitments in a manner that is sustainable, affordable, efficient, equitable and achievable.

The committee is examining the effect Canada's GHG reduction targets will have on five sectors of the Canadian economy: electricity, oil and gas, transportation, buildings, and trade-exposed, emission-intensive industries that are mostly heavy industries that compete in international markets such as steel and cement manufacturing.

This first interim report addresses the electricity sector. The committee's final report is expected to be released at the end of 2017 and will include recommendations to the federal government.

An increase in costs is one of the likely consequences arising from Canada's shift to a low-carbon economy and its bid to meet its commitments under the United Nations Framework Convention on Climate Change, often referred to as the Paris Agreement.

Canadians can be proud that the country's electricity systems are over 80% non-emitting and among the cleanest in the world. However, electricity systems across the country require modernization and renewal as many existing assets are reaching the end of their life. The country is facing a turning point where clean power sources are broadening and reliable low-cost thermal stations such as coal are retiring. The challenge is to keep electricity affordable while ensuring reliability. This is not an easy task.

As a means to achieve deep decarbonization, governments are turning to electricity to play a greater role in the economy through electrification of vehicles, buildings and industrial processing, but in some cases the technology is not yet cost effective. Governments are also looking to increases in energy efficiency and smart grid applications and expansion of interprovincial/territorial electricity trade. However, this is constrained by the high cost of transmission infrastructure.

Federal government involvement in Canada's electricity sector is limited. Provincial and territorial governments decide how to provide power within their jurisdictions and how to pay for

it. However, the federal government has many policy tools and powers to influence the nation's electricity systems. The report raises questions and discusses federal policy options, which range from using stringent regulatory measures, carbon pricing, incentives and technology funding programs.

Another significant challenge facing Canada is the uncertainty created by the 2016 United States presidential election. The new administration has already signalled likely changes in U.S. trade, energy and climate change policies, including a significant reduction in corporate income taxes.

The new administration's goals pose serious challenges for Canada in maintaining competitiveness while pursuing GHG emission reductions that typically increase business costs.

In December 2015, Canada along with 194 countries reached an agreement in Paris to address climate change. Canada faces a herculean task — the elimination of 219 megatonnes of GHG emissions — to meet its reduction target under the Paris Agreement. To put it in context, if all the cars, trucks, planes, trains and ships were to disappear from Canada by 2030, we would still fall far short of meeting our GHG reduction commitments.

The committee believes Canadians should have a real understanding of what will be necessary to meet GHG reduction targets. The prospect of higher electricity rates is a reminder of the real dollars-and-cents costs ordinary Canadians will face in the transition to a lower-carbon economy.

Addressing Climate Change

Climate change is an immense, pressing and complex global challenge. It is a destabilizing threat to global health and security that could define the next century more than any other. For several decades, many countries including Canada have pushed difficult decisions needed to curb greenhouse gas (GHG) emissions into the future. Clearly, this is not an easy problem to fix. However, the problem will not simply go away and it can no longer be kicked to future generations.

Everyone shares the atmosphere, which means addressing climate change requires an ambitious level of global co-operation. On 12 December, 2015, Canada and 194 other countries party to the United National Framework Convention on Climate Change reached an agreement in Paris to limit global average temperatures increases to less than 2 °C and to pursue efforts to achieve 1.5 °C above preindustrial levels.[1] To many, this was a pivotal moment in the effort to address climate change because both developed and developing countries were part of the agreement and together they represented most of the world's emissions.

Since the Paris Agreement, the United States elected a new administration which will likely change the direction of U.S. trade, energy and climate change policies. The United States is Canada's largest trading partner. Both countries share highly integrated economies where goods move freely across the border often in shared supply chains.

Climate change is occurring as global energy demand is growing. The International Energy Agency estimates that global energy use will increase nearly one third by 2040 due to increased demand from emerging economies.[2] Also, current low prices for oil are challenging policy efforts to switch to cleaner fuels. Meanwhile, some countries are grappling with a protracted and slow global economic recovery where many households around the world are more worried about retaining or finding a job than tackling climate change, especially since its worst consequences will not be felt for several decades, if not a century, into the future.

Canada's Emission Commitment

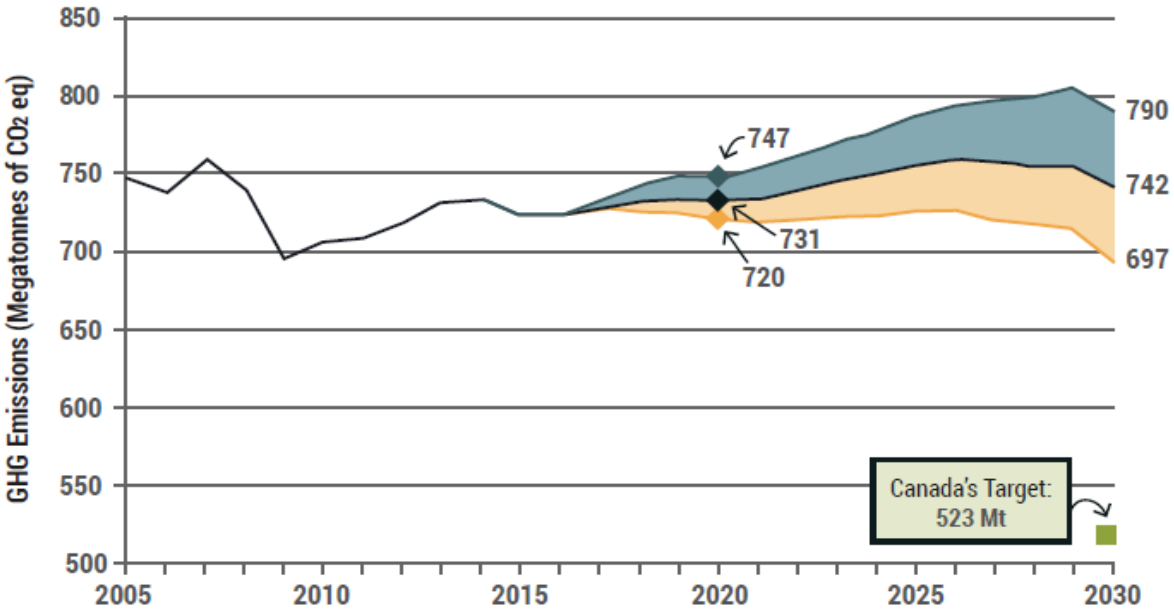
GHGs are not an ordinary pollutant. They are embedded in almost every activity, product and service and are supported by long-lived capital infrastructure.[3] Addressing climate change will require a rapid and substantial retooling of energy systems that have supported economies for nearly a century. Unlike the past, it is a transition chiefly driven by public policy and it will not be cost-free.

Canada's emission target submitted to the Paris Agreement is 30% below 2005 levels by 2030. The 2030 target is a minimum target. Deeper reductions are anticipated to reach the Paris Agreement's ambition of 80% reduction from 2005 levels by the second half of the century.[4]

In the wake of the Paris Agreement, federal, provincial and territorial governments have committed to working together to reduce emissions. In December 2016, Canada's First Ministers released the Pan-Canadian Framework on Clean Growth and Climate Change with the exception of Saskatchewan and Manitoba which did not adopt the Framework.[5] The Framework builds on previously announced initiatives such as a national minimum benchmark price on carbon emissions and an acceleration of the phase-out of traditional coal-fired electricity units.

The following projections (Figure 1) include the latest forecasts for gross domestic product (GDP) and oil and gas prices and production. They also include new federal, provincial and territorial government measures that have legislative or funding certainty as of 1 November, 2016.

Figure 1: Canada's Emissions Projections in 2020 and 2030 (MT CO_2 eq)



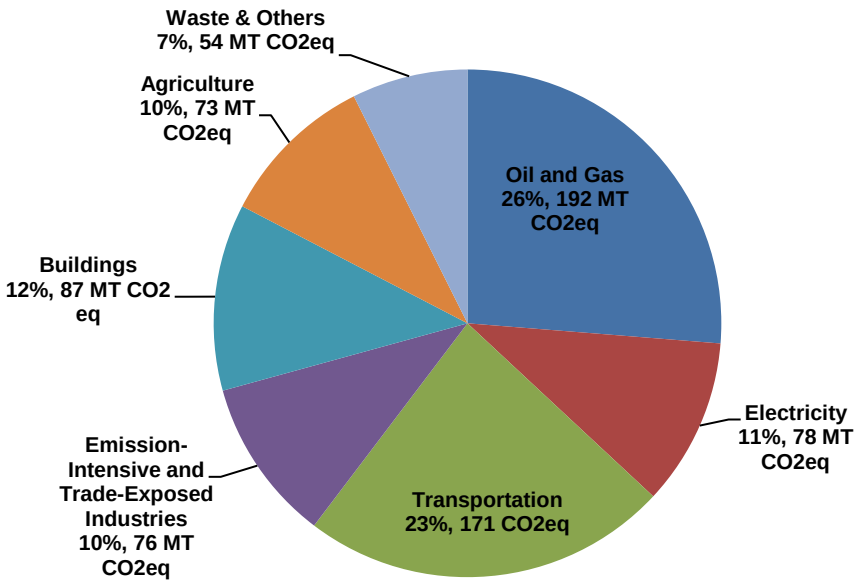
Note: Megatonne of Carbon Dioxide Equivalent: MT CO_2 eq.
Source: Environment and Climate Change Canada, Canada's 2016 Greenhouse Gas Emissions Reference Case

Legend: Emissions projections in three scenarios:

1. High oil and gas prices and high GDP growth – blue line
2. The "reference case" representing business-as-usual oil and gas prices and GDP growth – black line
3. Low oil and gas prices and low GDP growth – yellow line

Assumptions	High	Reference	Low
Average Annual GDP Growth (2014-2030)	2.3%	1.7%	1.0%
2030 West Texas Intermediate Oil Price (2014 US$/bbl)	111	81	42
2030 Henry Hub Natural Gas Price (2014 US$/GJ)	4.62	3.72	2.89

Figure 2: Canada's Emissions Breakdown, 2014 (MT CO_2 eq)



EMISSIONS PROJECTIONS (REFERENCE CASE) BY ECONOMIC SECTOR –CANADA (MT CO_2 EQ)

	2005	2014	2020	2030
OIL AND GAS	159	192	201	233
ELECTRICITY	118	78	64	34
TRANSPORTATION	171	171	168	157
EMISSIONS INTENSIVE & TRADE EXPOSED INDUSTRIES	88	76	85	97
BUILDINGS	85	87	89	94
AGRICULTURE	70	73	72	74
WASTE & OTHERS	56	54	51	53
TOTAL	**747**	**732**	**731**	**742**
EMISSION TARGET				**523**
DIFFERENCE				**(219)**

Table prepared by the Library of Parliament using data obtained from Environment and Climate Change Canada, Canada's 2016 Greenhouse Gas Emissions Reference Case.

Note: **Includes new federal, provincial and territorial government measures that have legislative or funding certainty as of 1 November, 2016.**

The 2030 target is ambitious. According to Environment and Climate Change Canada projections as of November 2016, Canada must reduce annual emissions by 219 megatonnes of carbon dioxide equivalent (Mt CO_2 eq) in order to meet its 2030 target. To put this into context, it is nearly equal to Canada's entire oil and gas industry in 2030, which is projected to be 233 megatonnes.

Achieving the 2030 target will require a herculean shift in how energy is produced and consumed in Canada. For the years beyond 2030, one must imagine a society essentially

transformed and decarbonized. The projections in Figure 1 do not include broader strategies or future measures within existing plans where details are still under development such as federal fuel standards for heavy-duty vehicles, methane reduction regulations and the proposed clean fuel standards and the coal-fired generation phase-out by 2030.

Canadians must do their fair share to address climate change. However, one should keep in mind that Canada's portion of global emissions is relatively small at 1.6 percent.[6] Canada's share is expected to decline as emissions from emerging countries such as China, India, Brazil and Indonesia increase steadily in the future.[7] That being said, every nation's effort to address climate change adds up and collective action will be the only way to meet this challenge. If Canada does not make a concerted effort to meet its own targets then how can we, as an advanced economy, ask other nations to meet theirs? Canada's global reputation and credibility would be damaged if we failed to act.

However, if the U.S. pulls back on its emission reduction goals and the Paris Agreement, it will likely strain global climate change co-operation efforts, making it harder for the rest of the world to implement stringent emission reduction policies. If we are not all in it together, it will make little difference to the atmosphere if Canada meets its targets.

The committee recognizes that there are opportunities created by the clean energy economy, but the transition of the speed and magnitude being considered will affect the lives and pocketbooks of all Canadians and most likely unevenly. ***The question is how much of our welfare are we willing to risk to meet our climate change commitments? On the other hand, how much do we risk in delaying emission reduction policies? If we wait until the future to act, it will likely be more costly to decarbonize since the pace of the transition would have to accelerate.***

Canada's Electricity System

Electric technology is virtually so much a part of our lives, underpinning nearly every activity in society, that it is impossible to imagine the modern world without it. It is used in countless applications from virtually all lighting and appliances to space heating and cooling and communication systems. It has enabled whole industries to emerge. Without electricity, the digital information age would not be possible and every digital application, control system or device commonplace today would not exist.[8]

Put simply, electricity is the flow of trillions upon trillions of agitated electrons and it can be created from virtually any energy source. In most cases, it is produced when a turbine spins a magnet inside a generator. The force applied to the turbine can come from multiple sources such as falling water, fossil fuel or biomass combustion, steam from nuclear fission or blowing wind. No turbines are involved in solar photovoltaic (PV) technology; instead it converts light into electricity using semiconductor material.

Once created, electricity must be consumed or stored; there are few means other than hydro dams to store large amounts of electricity. It can be transported long distances through high voltage wires and delivered directly to homes and businesses along vast distribution systems to power numerous end-uses, literally, with the flick of a switch.

Many people use the terms energy and electricity interchangeably which leaves the impression that all energy sources can be easily mixed and drawn from the same energy pool. This is not the case. Liquid fuels such as gasoline cannot be seamlessly swapped for electricity. These energy sources have different properties and produce useful work such as lifting, lighting, heating and pulling using different technologies.

Electricity Demand

In 2014, Canada consumed approximately 550 terawatt hours (TWh) of electricity, which is roughly 2.5% of global electricity consumption.[9] The industrial sector which includes manufacturing is Canada's largest power user totalling 43% of the country's electricity consumption. Companies in this sector in particular need reliable, firm power because they use large amounts of power usually on a 24-hour basis. An example is a steel manufacturing plant.

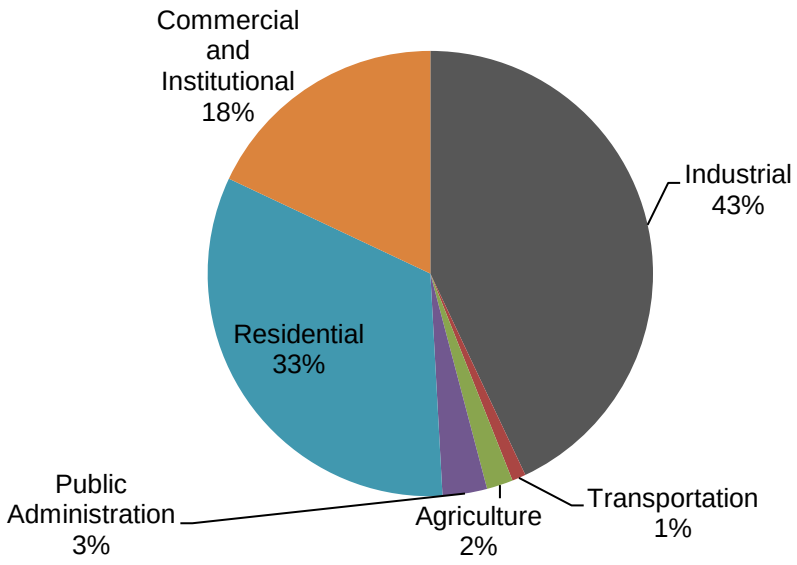
ArcelorMittal Dofasco in Hamilton, Ontario is Canada's leading steel producer.

Photo Credit: ArcelorMittal Dofasco

Households are the second largest consumers of electricity at 33% and the commercial and institutional sector, which includes the service

industry, is 18%. Other industrial activity and the public administration sector account for 8 and 3%, respectively. The agriculture and transportation sectors are not heavy power users, accounting for 2% and 1% of electricity demand. In fact, much of the electricity consumed in the transportation sector is attributed to pipelines.[10]

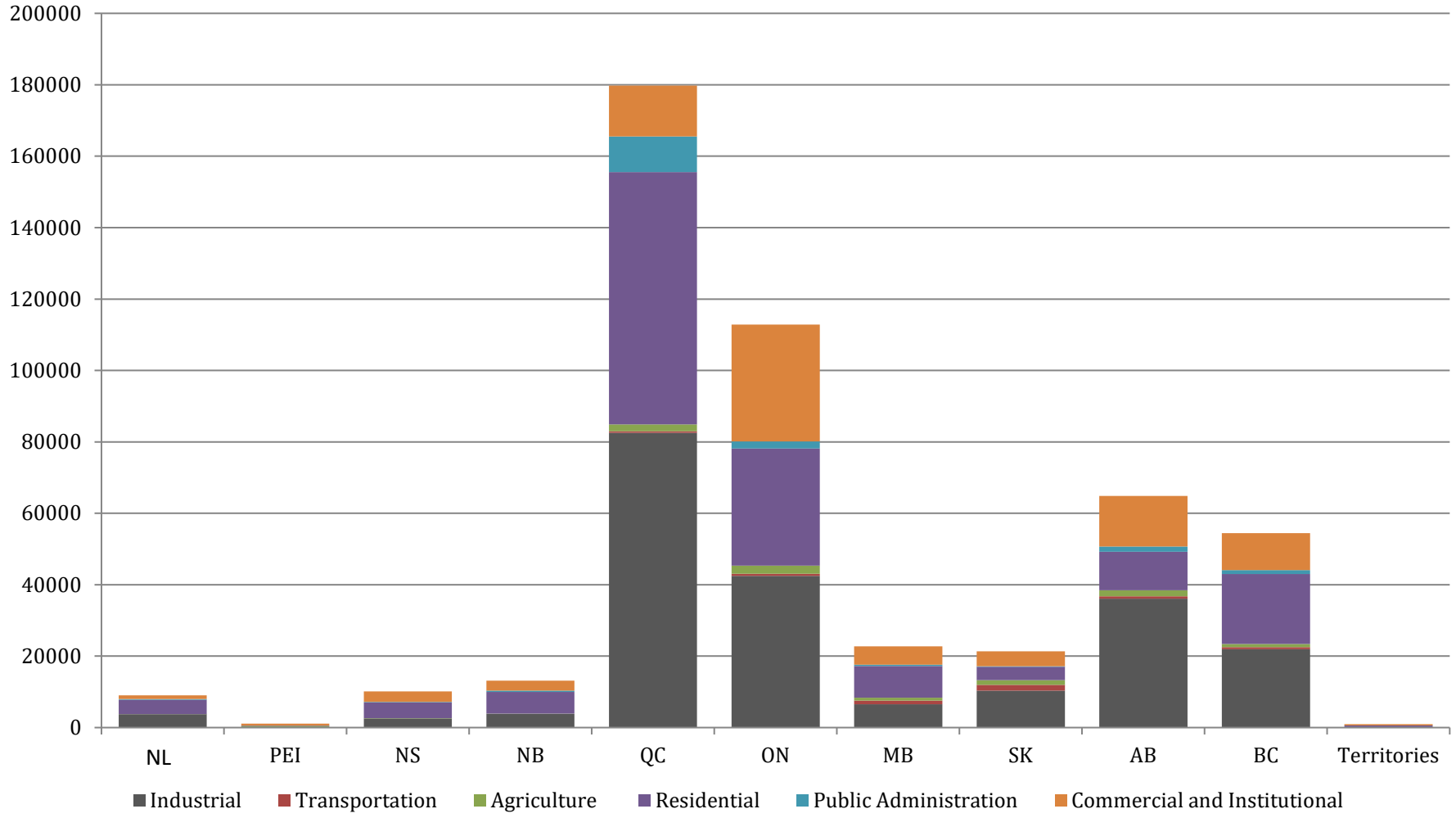
Figure 3: Canada's Electricity Demand by Sector, 2014 (GW/h)



Note: Gigawatt per hour equals GW/h.
Source: Figure prepared by the Library of Parliament using data from Statistics Canada's Report on Energy Supply and Demand 2014 Preliminary.

Quebec consumes the most electricity in Canada, followed by Ontario. The industrial sectors in Quebec, Ontario, Saskatchewan, Alberta and British Columbia consume more electricity than their respective province's residential sector. Of note, the industrial sectors in Alberta and Saskatchewan dominate each province's electricity demand accounting for approximately half of the electricity load. In Ontario, Saskatchewan and Alberta, natural gas is the dominant source of energy for heating homes while in Newfoundland and Labrador, New Brunswick, Quebec and Manitoba it is electricity. Households in British Columbia rely both on natural gas and electricity, while heating oil is prevalent in Nova Scotia, P.E.I., Yukon, the Northwest Territories and Nunavut.

Figure 4: Provincial Electricity Demand by Sector, 2014 (GW/h)



Note: Gigawatt per hour equals GW/h.
Industrial data for P.E.I not available due to confidentiality issue.

Source: Figure prepared by the Library of Parliament using data from Statistics Canada's Report on Energy Supply and Demand 2014 Preliminary.

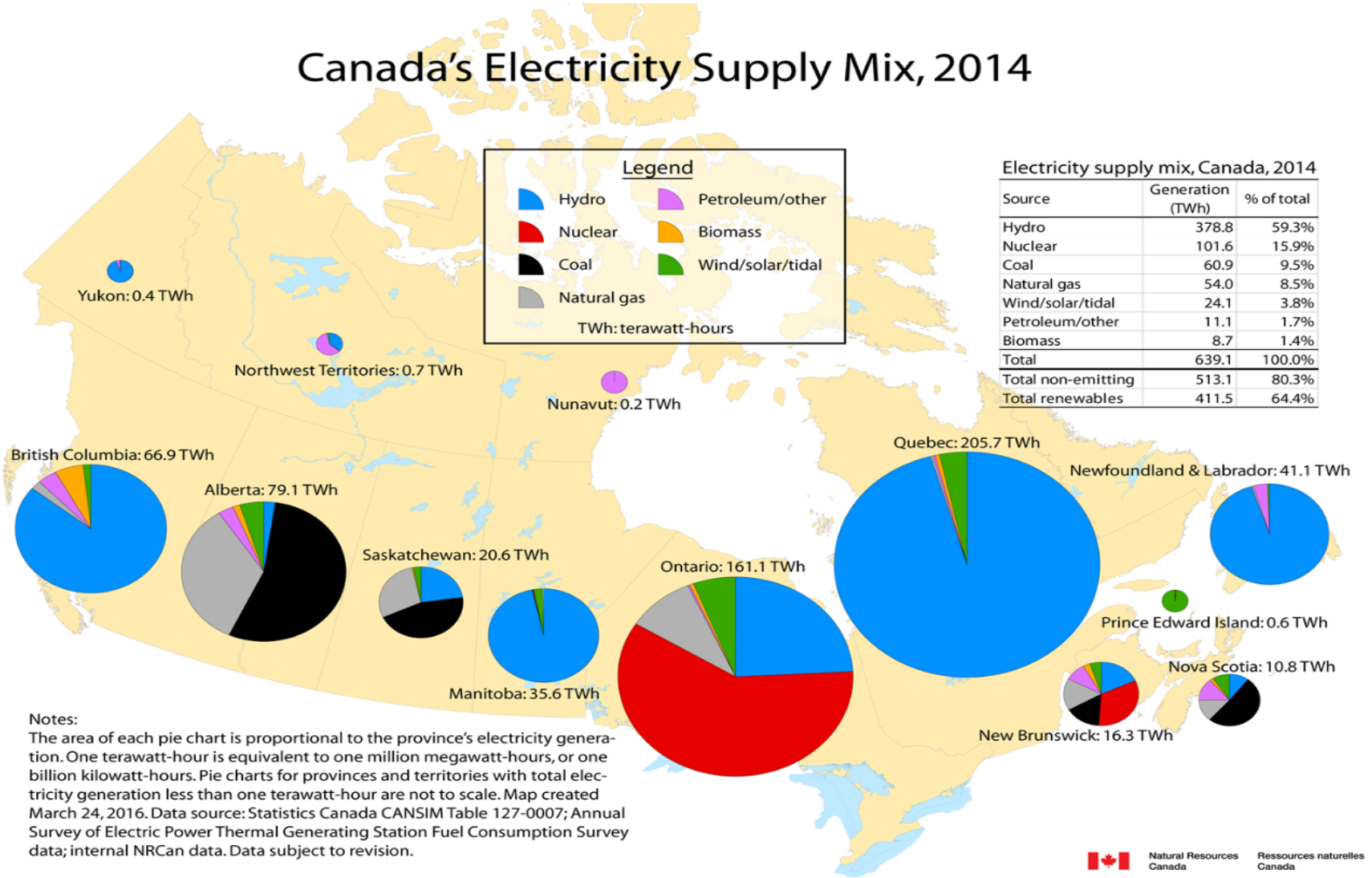
Electricity Supply

Canada is the sixth largest producer of electric power in the world and most of the electricity is produced from clean sources.[11] In 2014, over 80% of the electricity generated in Canada was non-emitting; that is, it came from sources that do not produce GHG emissions. The rest of the power was created from: coal 9.5%, natural gas 8.5% and other petroleum products 1.7%.

Over 80% of Canada's electricity is non-emitting

The bulk of the country's clean power, 59.3%, is created from flowing water – Canada is the second largest producer of hydro power in the world.[12] Nuclear power produced from Canadian-developed technology (CANDU reactors) was responsible for 15.9% of electricity produced in Canada. Nuclear power is considered non-emitting because it produces no direct GHG emissions. Wind energy contributed 3.5% of the total electricity in Canada while biomass and solar/tidal accounted for 1.4% and 0.3%, respectively.

Figure 5: Sources of Electricity Supply in Canada



Electricity supply mix, Canada, 2014

Source	Generation (TWh)	% of total
Hydro	378.8	59.3%
Nuclear	101.6	15.9%
Coal	60.9	9.5%
Natural gas	54.0	8.5%
Wind/solar/tidal	24.1	3.8%
Petroleum/other	11.1	1.7%
Biomass	8.7	1.4%
Total	639.1	100.0%
Total non-emitting	513.1	80.3%
Total renewables	411.5	64.4%

The way electricity is produced varies across the country, largely owing to the differences in resource endowments in each province and territory but also due to policy decisions taken by governments.

Non-Emitting Electricity

Hydro

Hydro is the backbone of Canada's clean energy profile and is expected to play a dominant role in Canada's electricity supply for decades to come. While there are many small hydroelectric stations in Canada, most of the country's installed hydro capacity is sourced from large stations.

Hydro Dam in Saint-Maurice, Quebec

Photo Credit: iStock

For the most part, hydro power provides base-load power, that is, the electricity that is required on a constant basis. Hydro output can vary seasonally depending on precipitation and water levels. Large hydro plants require substantial capital investment but generally have low operating costs.

Jacob Irving, President of the Canadian Council on Renewable Electricity, was enthusiastic about the potential for growth in hydro power throughout the nation. He explained that there is extraordinary potential for developing hydropower capacity across the country, doubling the current output. [13]

Other witnesses such as Don Wharton, Managing Director for Carbon Transition at TransAlta Corporation, countered that it would be difficult to advance new large hydro projects in provinces that have low cost options such as natural gas or other fuels. He said:

> However, there are challenges with the capital requirements of new hydro. Today in Alberta, for example, it is not directly competitive with natural gas and even coal or wind, for that matter. The question is: How do we move toward an increased use of hydro in jurisdictions that have options that are more competitively priced, keeping in mind that we want to keep the costs to consumers as low as possible? I leave that as a question as opposed to a solution, but I wanted to make the committee aware of our views on that. [14]

It should be noted that provinces such as Saskatchewan and Alberta have limited hydro resources and those that are available are located far from demand loads. Each province and territory will have to meet its electricity needs in accordance with its available resources and its ability to draw power from neighbouring jurisdictions.

Chris Sandve, Director of Policy and Reporting at BC Hydro, told the committee that the province's future plans do not include large hydro beyond the existing 1,100 megawatts Site C Clean Energy Project currently under construction. B.C.'s Clean Energy Act requires that at least

93% of electricity generation in the province come from clean or renewable resources, and that 66% of new load requirements be met by conservation measures.[15]

Nuclear

Nuclear reactors produce large amounts of reliable non-emitting electricity. Generally, their installed capacity is comparable to the largest hydro stations. They are best utilized for base-load electricity and not as a dispatchable source of electricity since nuclear plants are less easy to ramp up and down in reaction to changing electricity demand. However, spent nuclear fuel must be managed and stored long-term.

> **CANDU Reactors**
>
> *There are three types of CANDU reactors: CANDU-6 which is currently in operation, the Enhanced CANDU-6, an upgrade of CANDU-6 and the Advanced Fuel CANDU (AFCR), the latest technology in the CANDU fleet. The AFCR is optimized to run on recycled uranium-based fuel from light water reactors as well as thorium based fuel.*

Nuclear reactors require significant up-front cost to build but once built they operate on a low cost fuel model over their lifetime. Canada has an abundance of uranium mostly located in northern Saskatchewan where it is currently being mined. Canadian-made CANDU reactors last up to six decades but by mid-point, large-scale replacement of primary components become necessary. This is called nuclear plant refurbishment.

Nuclear power station located on Lake Ontario in Pickering, Ontario

Photo Credit: bukharova, iStock

There has not been a new nuclear plant built in Canada for over 25 years, although refurbishment projects are akin to a new build. Neil Larlee, Director, Strategic Planning at NB Power, told the committee that nuclear power is likely the strongest option for New Brunswick once existing fossil fuel thermal plants retire by mid-century.[16] The committee was told by Guy Bruce, Vice President, Planning, Environment and Sustainable Development at SaskPower, that Saskatchewan had considered nuclear generation but large nuclear reactors were too big for the province's electricity system. However, the utility is monitoring the development of small modular reactors as a future option:

> Saskatchewan has been looking at the nuclear option for several decades, and it keeps coming back for another review. The last time we looked at it, in 2009, the options looked like the large reactors in the 700 to 1000 megawatt range. Our system is only 4,000 to 4,400 megawatts, so the large reactors are too big for our

> system. We are monitoring the development of what's called small modular reactors. They come in the 50 to 300 megawatt range. This is a technology we're continuing to monitor and to see how it progresses. It's an option we're looking at for the long term. [17]

Small Modular Reactors

Smaller modular reactors offer smaller, compactly-designed, factory-fabricated reactors that can be transported by truck or rail to service markets requiring smaller loads, including resource industries such as the oil sands in Alberta, or in remote off-grid communities.[18] According to the International Atomic Energy Agency, approximately 45 designs are currently under development around the world. Half of these are being prepared for deployment over the next ten years; three, from Russia, China and Argentina, are expected to become operational over the next four years.[19]

Jeff Lyash, President and Chief Executive Officer of Ontario Power Generation, told the committee that small modular reactors are:

> being considered for licensing by the United States Nuclear Regulatory Commission and the Canadian Nuclear Safety Commission. I think the first of those designs is scheduled to clear the licensing hurdle sometime in the next two years and then be targeted for the initial demonstration plants or deployments. In the U.S., I'm aware that the two sites that are actively considering it are the Hanford Site in Washington State and the Oak Ridge National Laboratory in Tennessee — two government-owned nuclear installation sites that would host, perhaps, the first deployment of these small modular reactors. There are also fairly well advanced efforts in China to site the first wave of these.[20]

Wind/Solar

Wind and solar power are a small but expanding feature of many provincial/territorial electricity portfolios. Departing from large traditional centralized power plants, they produce less electricity but are more widely spread over the electricity grid.

Wind and solar power only produce electricity when the wind is blowing and the sun is shining, thus they are considered variable and non-dispatchable. That being said, wind, solar and related technologies are continuously improving. The committee was told that electricity system operators struggle to maintain affordable and reliable

Balancing Electricity

Electricity is essentially a highly perishable commodity. The instant it is produced it must be consumed, exported or stored. Supply must always match demand. Having too little electricity to meet demand is obviously a problem but having too much electricity can be equally difficult to manage.

power as more variable power sources are brought on line. This is particularly the case for provinces with continuous electricity demands from large industrial customers such as in Alberta and Saskatchewan.

Wind Farm

Photo Credit: Senate of Canada

Many witnesses believed that since there is currently no low cost way of storing large amounts of electricity, there were limits on how much variable sources of supply could be introduced into the grid. However, the committee saw progress being made at Hydro-Québec's energy storage laboratory in Varennes, Quebec.

Max Gruenig, President, Ecologic Institute US, pointed out that Germany was able to accommodate over 30% variable renewable power such as wind and solar power into its grid without compromising reliability.[21] However, Don Wharton from TransAlta Corporation argued that it was not possible to replace traditional baseload power such as coal with variable power without relying on backup power:

> …If you take 100 megawatts of coal out of Alberta's system today and you wanted to replace that with wind, that would be fine; you could build 100 megawatts of wind. But in order to maintain reliability, you would also have to have another 100 megawatts of another baseload or reliable or non-intermittent supply in order to ensure you have a reliable system. [22]

The best wind and solar resources are not always near demand loads therefore it can require additional transmission lines which can add to the cost of these power sources. Sometimes these resources are out of sync with electricity demand; for example, strong winds occurring when the temperature is mild and light winds when it is cold.

Biomass Generation

Biomass generation is commonly powered by direct combustion of wood, wood waste or spent pulping liquor. Pulp and paper facilities are by far the largest users of biomass generation; they use it to produce heat and self-supply electricity, and any excess power is often sold into the grid.

Ontario has converted two of its coal plants to burn biomass. The committee was told that several other provinces and territories are

Electricity through Biogas

Laforge Holstein is a biomass facility in St André, New Brunswick, which uses organic material such as potato peels, off-grade potatoes and waste grass combined with dairy manure to produce methane from anaerobic digestion. The facility then burns the gas to produce electricity. The facility generates enough electricity each year to run the equivalent of 200 homes.

turning to biomass. In some cases, biomass is an option to displace diesel in remote communities. However, Guy Bruce of SaskPower explained that the economic viability of biomass generation depends on whether the community is close to a sawmill or a pulp and paper facility where wood waste supply can be sourced. [23]

Biomass is also utilized to produce methane (a form of natural gas) through anaerobic digestion from solid landfill waste, sewage, manure, food or agricultural products. The methane produced is called biogas –it can be combusted to make electricity. Jennifer Green, Executive Director of the Canadian Biogas Association, told the committee that there was potential to substantially increase biogas production in Canada. In so doing, it would reduce the amount of biogenic methane currently released in the air from waste sites.[24]

Canfor Pulp Ltd. in Prince George, British Columbia, is considering using what's called Licella technology — an Australian process — to extract biocrude oil from wood chips.

Photo Credit: Canfor Pulp Ltd.

Next Generation Renewables

Underutilized and emerging technologies provide opportunities to harness a new generation of renewable energy in Canada such as offshore wind, geothermal and marine energy. Geothermal generation harnesses thermal energy trapped deep below the earth to make steam. This energy source could provide reliable base load electricity 24 hours a day. Marine technology makes use of the movement of tides, waves and river currents to drive turbines, providing reliable and predictable electricity generation.

As is the case with many emerging energy technologies, there are barriers to deployment, such as high capital and operating costs with lengthy payback periods, uncertain or as yet not fully developed regulatory regimes, lack of specialized supply chains and the general uncertainty related to new technology.

Power in the Bay of Fundy

Canada is home to some of the most abundant sources of ocean current and tidal energy resources in the world. In November 2016, a two MW turbine was deployed in the Bay of Fundy as part of a large scale demonstration project to test the technology. This is enough power to serve 500 homes. The potential for tidal power is immense.

Fossil Fuel Generation

What role should fossil fuels play in the future electricity systems of the country? In most cases, fossil fuel generation provides dispatchable and/or baseload electricity at a low-cost. Is closing fossil fuel plants the most cost-effective way to reduce emissions? Are there cost effective clean technology solutions that can be applied to fossil fuel generation? How should the transition away from fossil fuels be managed to maintain reliability and minimize negative economic effects and financial costs to energy consumers?

Natural Gas

Natural gas generation has increased rapidly in recent years and it is predicted to grow in importance as electricity utilities shift away from coal. The National Energy Board forecasts that by 2040 natural gas-fired capacity will nearly double. This is due to historically low natural gas prices and because it is considered the least emitting fossil fuel. Construction of natural gas plants is generally less costly and takes less time to build than comparable alternatives. Natural gas pipeline networks are also well developed in most of the country.[25]

Natural gas is versatile and can serve as base-load and dispatchable power during peak demand. Many consider natural gas a bridge fuel to ease the transition to a low-carbon economy. In committee hearings, electricity utilities and energy experts agreed that without viable, low-cost utility-level storage options to help balance variable renewable power, the country will rely on natural gas for many years to come.[26] However, in the long term, natural gas plants may have to be paired with technologies such as carbon capture and storage to achieve deep decarbonization.

The committee was told that SaskPower is partnering with private companies to help capture methane from oil production to generate electricity.[27] Don Wharton of TransAlta Corporation explained that existing coal plants could be converted to run on natural gas, allowing a transition away from coal without a complete plant shutdown and replacement.[28]

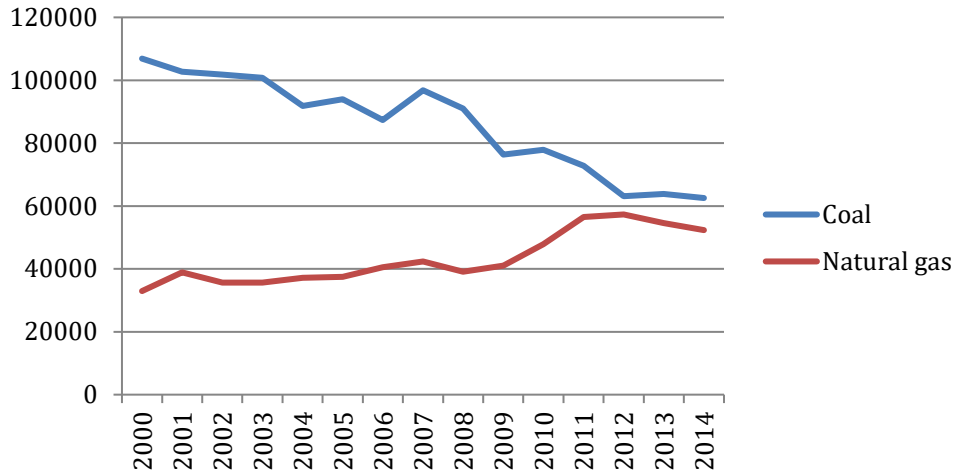
In November 2016, the federal government announced that it was developing performance standards for natural gas-fired electricity to ensure natural gas-fired units are built using efficient technology and the standards will set parameters for boiler conversions from coal to natural gas.[29]

Coal-Fired Generation

Coal-fired generation is one of the most significant contributors to global GHG emissions. In Canada, this type of generation has been decreasing steadily over the last decade, in part due to targeted efforts by provincial and federal governments to address GHG emissions. Ontario phased out its last coal plant in 2014. The federal government introduced coal-fired generation regulations which came into force in 2015 –these regulations apply performance standards that essentially ban the construction of new traditional coal-fired units and accelerate phase out for

existing units.[30] On 21 November, 2016, the federal government announced a further acceleration of the existing timelines, so that traditional coal-fired plants are phased out by 2030.[31] Under Alberta's Climate Leadership Plan announced in November 2015, the province plans to reduce GHG emissions from coal-fired generation to zero by 2030, to be replaced with at least one-third renewable energy sources and two-thirds natural gas.[32]

Figure 6: Canada – Electricity from Coal and Natural Gas (Gigawatt/hours)



Source: Figure prepared by the Library of Parliament using data from Statistics Canada, Electricity generated from fuels, by electric utility thermal plants.

Coal-fired plants provide base load energy and are among the lowest cost generators of electricity. The Alberta Electricity System Operator (AESO) told the committee that Alberta's electricity demand is dominated by the power requirements of its industrial sector. This sector relies on a constant level of reliable power 24 hours a day. Alberta's phase-out of coal-fired plants, which account for nearly half the power needs in the province, creates challenges in maintaining electricity reliability. In emphasizing the importance of electricity reliability, the AESO explained that if a power outage occurs in Fort McMurray in winter, pipelines transporting bitumen can freeze causing months of production downtime and potential health and environment consequences.

The AESO pointed out that Alberta's transition to cleaner electricity will require a significant capital stock turnover in a short period of time, resulting in some capital being stranded. To address this issue, the Alberta government announced on 24 November, 2016 that it was compensating three coal electricity producers in the province over $1 billion for the early shut down of their plants.[33]

Neil Larlee of NB Power cautioned that it would be critical to avoid rate shocks to customers when considering the timing of retirement of thermal assets such as coal plants:

> New Brunswick's only coal station, Belledune Generating Station, is scheduled to retire in 2043 under federal regulations. Should it be required to shut down early, say 2030, this would result in a rate increase of approximately 39 per cent, in addition to planned rate increases, and would have a devastating impact on NB Power's customers and the New Brunswick economy.[34]

Witnesses told the committee that flexibility should be a key feature in developing new federal emission reduction policies. They emphasized the importance of recognizing the unique circumstances of each province, especially those that rely on coal-fired generation. For example, Terry Toner, Director, Environmental Services at Nova Scotia Power Inc, explained "to minimize costs for our customers it is important that utilities have flexibility to manage the retirement of the coal-generating units during this transition to a low-carbon environment." [35]

Coal-fired plants, like Belledune Generating Station in New Brunswick, provide baseload energy and are among the lowest cost generators of electricity.

Photo Credit: NB Power

The federal government provides provinces the option of adopting equivalency agreements where federal regulations would stand down if provincial regimes apply equivalent environmental outcomes. The agreements allow provinces to keep using traditional coal-fired power plants beyond the federal government's phase-out deadline of 2030 if equivalent emission reducing measures are undertaken.

Nova Scotia had entered into an equivalency agreement with the federal government for the existing coal-fired performance standards and on 21 November, 2016, the province expressed an interest in entering into an equivalency agreement for the new coal-fired performance requirements.[36] On 28 November, 2016, the province of Saskatchewan and the Government of Canada reached an agreement in principle to finalize an equivalency agreement for Canada's existing coal-fired regulations.[37]

Diesel Generation

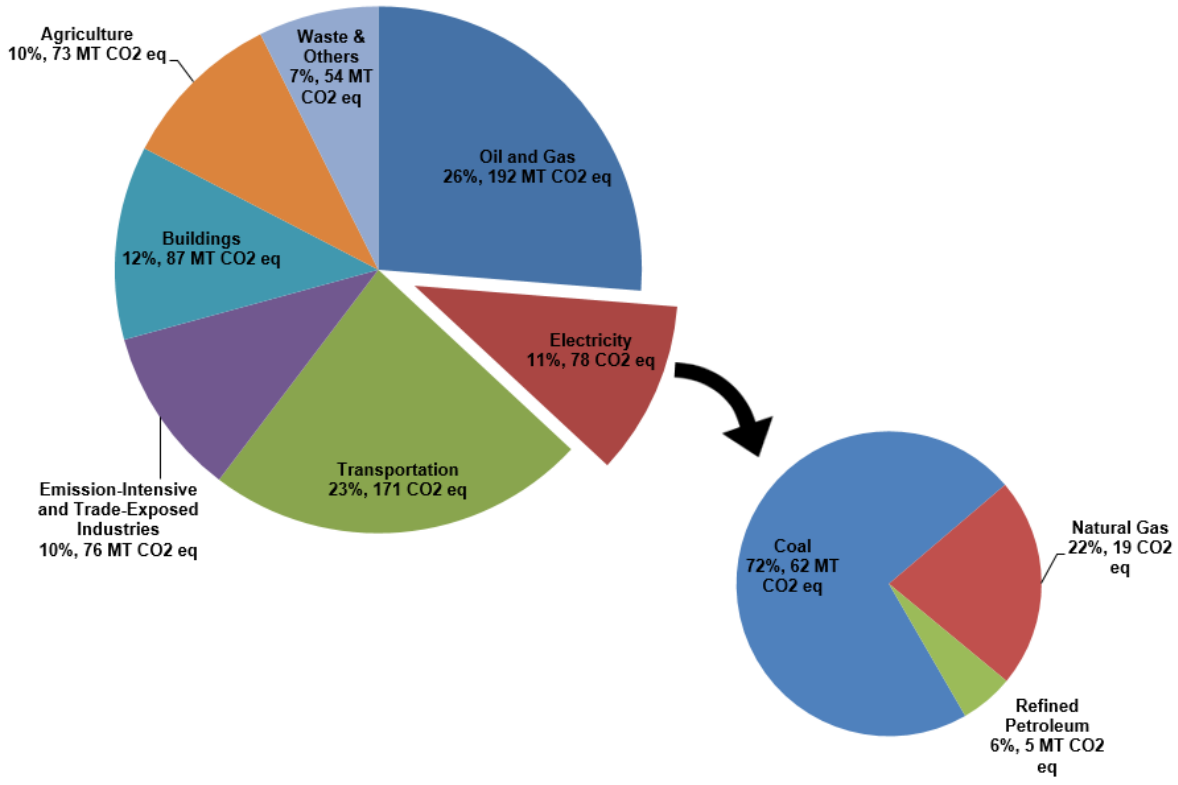
Many northern and remote communities rely on diesel generators for electricity. In many cases, it is the only viable option for electricity for regions that are remote and off-grid. Diesel generation has many environmental disadvantages: it emits GHGs and causes local air and noise pollution. However, it is also relatively low in cost to install and it is dispatchable, scalable, flexible and extremely reliable.

Some witnesses, such as Sergio Marchi, President and CEO of the Canadian Electricity Association, felt that more should be done to address energy systems in northern and remote communities.[38] In 2015, the committee released a report entitled Powering Canada's Territories that outlined many challenges facing the territories.[39] The report found electricity systems were aging, underperforming, at capacity and there was a lack of financial capacity to advance major projects due to small rate and tax bases. The report made recommendations to improve the energy circumstance of the territories including increased federal assistance to upgrade aging diesel generation facilities, to enhance community-solutions and to help with infrastructure investment in qualified territorial energy projects.

Electricity Emissions

Emissions from the electricity sector are mainly carbon dioxide ($C0_2$) molecules released from the combustion of fossil fuels. Canada's electricity sector is responsible for 11% of the country's total emissions. Nearly two-thirds of these emissions come from coal-fired generation followed by natural gas 22%. Refined petroleum such as fuel oil and diesel make up 6% of electricity emissions.

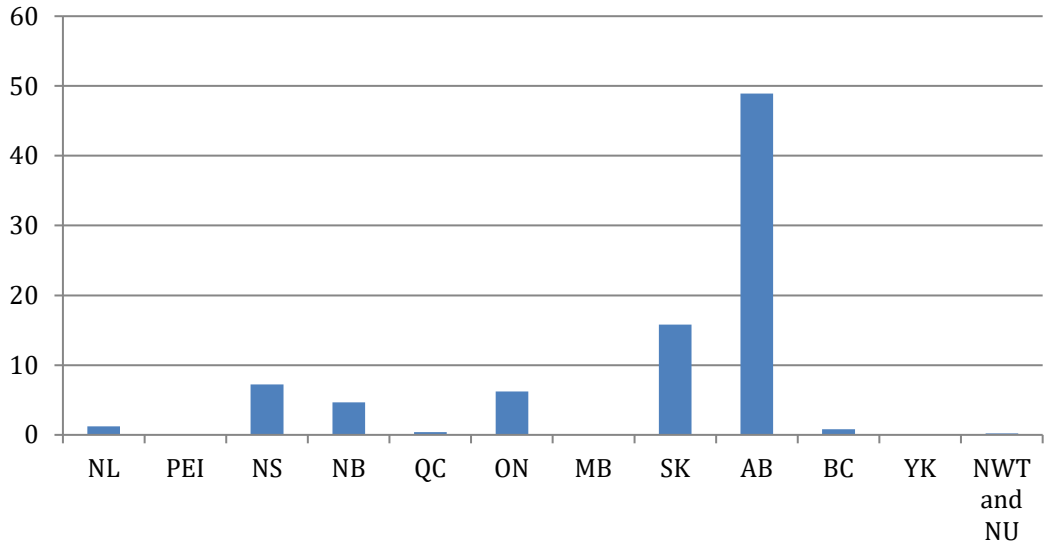
Figure 7: Canada's Emissions Breakdown, 2014 (MT CO_2 eq)



Note: Megatonne of Carbon Dioxide Equivalent: MT CO_2 eq.
Source: Figure prepared by the Library of Parliament using data from Environment and Climate Change Canada, National Inventory Report, Executive Summary, 1990-2014.

Alberta and Saskatchewan's electricity emissions rank the highest in the country. Electricity generation in Nova Scotia and New Brunswick accounts for a large share of each province's total emissions. Northwest Territories and Nunavut deserve special mention since they are characterized by remote, low populated and dispersed communities that rely heavily on diesel generators for electricity and fuel oil for heating. However, their contribution to national emission levels is very minor.

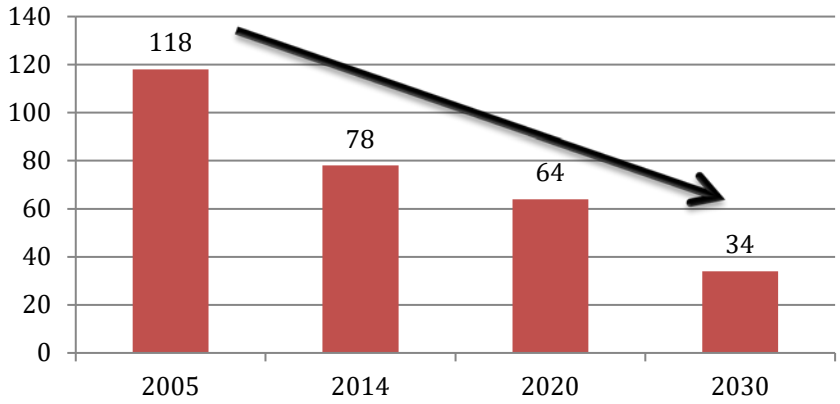
Figure 8: Total GHG Emissions from the Electricity Sector by Province and Territory, 2014 (MT CO_2 eq)



Source: Figure prepared by Library of Parliament using data obtained from Environment and Climate Change Canada, "National Inventory Report 1990-2014: Greenhouse Gas Sources and Sinks in Canada Part 3".

Electricity generation in Canada has become greener. In 2014, the sector accounted for 78 Mt CO_2 eq. From 2005 to 2014, emissions from electricity production reduced by 40 Mt CO_2 eq – this is far more than any other sector. The federal government projects that electricity emission will reduce to 34 Mt CO_2 eq based on existing policies representing a reduction of approximately 56% from existing levels (2014). These reductions will predominantly come from provinces that rely on coal-fired generation such as Alberta, Saskatchewan, Nova Scotia and New Brunswick.

Figure 9: Canada – Historical and Projected Emissions from the Electricity Sector (Mt CO_2 eq)



Source: Figure prepared by Library of Parliament using data obtained from Environment and Climate Change Canada, "Canada's 2016 Greenhouse Gas Emissions Reference Case"

Carbon Capture and Storage (CCS)

Nearly all pathways to long-term decarbonisation, whether globally or in Canada, include the utilization of carbon capture and storage (CCS) technologies. CCS refers to a range of technologies that capture carbon dioxide from fossil fuels. It provides an option to continue to use the abundant supply of fossil fuels to meet growing energy demand without increasing emissions. According to Jeff Erikson, General Manager, Americas Region of the Global CCS Institute, there are approximately 2,000 new coal-fired power plants planned or under construction around the world.[40]

The Institute cites the International Energy Agency (IEA) which projected that the least-cost pathway to achieve Paris Agreement global emission goals would require CCS to capture 4,000 million tonnes per annum (Mtpa) of CO_2 by 2040. However, according to the Institute, current carbon capture capacity for projects in operation or under construction is approximately 40 Mtpa. The Institute argues that CCS is not accelerating at the pace needed to satisfy the ambitions of the Paris Agreement.[41] Mr. Erikson argued that CCS was essential for meeting climate change objectives but its deployment is not inevitable. He is concerned that CCS is being overlooked in favour of renewables and energy efficiency programs in international dialogues. CCS is considered the only option currently available to significantly reduce direct emissions from many industrial processes.

CCS typically involves capturing CO_2 from power plants or other industrial facilities and then piping it for underground storage and/or using it to help flush residual oil from reservoirs in enhanced-oil recovery operations. The feasibility of carbon storage is limited to regions that have the appropriate geological formations, particularly those that have depleted or maturing oil and gas reservoirs.

The committee had an opportunity to visit the Boundary Dam Power Station in Estevan, Saskatchewan, the site of Canada's first large-scale commercial carbon capture and storage facility. The impressive project captures CO_2 produced from one of the units at the coal-fired power station and transports it via pipeline to nearby oil fields where it is used for enhanced oil recovery. The CO_2 not used is injected underground into a layer of brine-filled sandstone. Completed in 2014, it is capable of removing up to one million tonnes of CO_2 per year from the atmosphere or 90% of the emissions from the unit.

SaskPower's Boundary Dam Power Plant in Estevan, Saskatchewan, the site of Canada's first large-scale commercial carbon capture and storage facility.

Photo Credit: Senate of Canada

The federal government's performance standards on coal-fired units do not apply to units that use CCS. While CCS is recognized globally as game changing technology, its biggest obstacle is cost. However, the committee was told that the cost profile of the technology is improving steadily.[42] Officials from SaskPower told the committee that the next generation of CCS would likely be 20-30% less expensive.

Moving Forward: Electricity Generation

The National Energy Board forecasts an increase in Canadian electricity demand of 1% every year over the next 25 years.[43] At the same time, Canada's electricity systems are in need of massive reinvestment, as much of the infrastructure was built three or four decades ago.

Many power stations, transmission and distribution systems need to be replaced, refurbished or modernized. The reinvestment costs were estimated by the Conference Board of Canada in 2012 to be nearly $350 billion from 2011 to 2030[44] -a large capital infusion and job stimulant but one that is also expected to lead to a rise in electricity rates over time.

What Role Should the Federal Government Play?

The federal government does not decide how electricity is generated in Canada. For the most part, these decisions rest with each province and territory. However, the federal government does have many policy tools and powers to influence the nation's power supply.

The federal government provides funding to support clean electricity through multiple avenues including green infrastructure programs and via research funding/grant programs targeted to

clean energy innovation, development and demonstration projects in Canada.[i] Many of these programs are coordinated in partnership with the provinces, territories and municipalities. The federal government also uses the tax system to encourage clean energy technology investment.

The government can exert influence through its procurement of clean electricity sources for its operations. To this point, the federal government announced on 2 November, 2016, that by 2025 all its electricity purchases will be from clean energy sources.[45]

Perhaps most influentially, the federal government has regulatory levers that can impose stringent performance standards on fossil fuel generation such as those currently applied to coal-fired generation. Also, the federal government can set out environmental measures that have a broad economic impact such as the minimum national carbon price announced in October 2016. The minimum price is set at $10 per tonne for 2018 and will increase by $10 per year to reach $50 per tonne by 2022. The revenues collected are to be returned to the provinces and territories.

Key policy questions are: ***How should the federal government work with the provinces and territories to expand support for renewable electricity, energy storage technologies, carbon capture and storage technologies, nuclear power and grid flexibility? Should the government be picking technology winners and losers? What priority areas ought to be the focus of funding? What should be the guiding principles of funding programs?***

How should the federal government use its regulatory powers to accelerate the further transition to clean electricity? The electricity generating portfolios and resources differ in each jurisdiction. How should the federal government account for these differences when developing national emission reduction policies? How will carbon pricing drive investment in clean technologies? What is the financial impact of carbon pricing on Canadian households and businesses? Should carbon pricing be the primary measure to help meet our emission reduction targets? Should we protect our emission-intensive and trade-exposed industries? If so, how?

[i] The 2016 federal Budget announced a $2 billion Low Carbon Economy Trust to fund projects that reduce carbon. The Office of Energy Research and Development (OERD) functions as the Government of Canada co-ordinator of departmental energy research and development activities in priorities areas which include clean electric power generation. The OERD is responsible for the following programs: Clean Energy Fund, ecoENERGY Innovation Initiative, Program of Energy Research and Development (PERD) and Energy Innovation Program.

Electrification of the Economy

A distinct advantage of electricity is that there is neither combustion nor emissions at the point of use. Many witnesses speculated that in the long run, electrification of the economy, through the elimination of multiple sources of combustion such as vehicles, buildings and industrial processing, may be the most cost-effective way to achieve deep decarbonization.[46]

Transportation

Nearly all transportation vehicles are fuelled by liquid petroleum products. The transportation sector is responsible for approximately one quarter of all emissions in Canada. Road transportation including passenger and freight vehicles account for the lion's share of emissions from transportation.

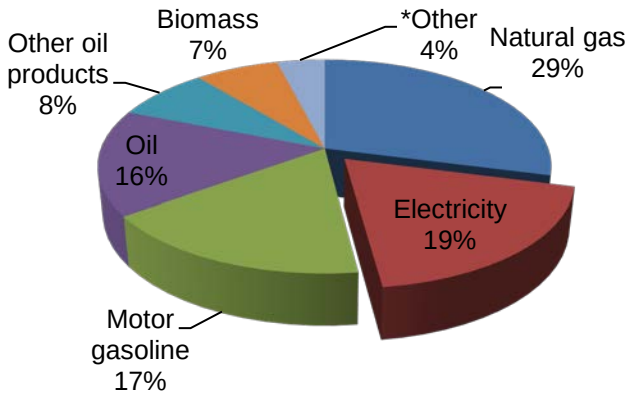
Buildings

The dominant use of energy in buildings is for space and water heating. Most of the non-electricity emissions from buildings in Canada are attributed to natural gas followed to a lesser extent by heating oil.

Industrial

The industrial sector uses large quantities of fuel to convert raw materials into goods and products using heat and motive energy (energy creating movement of machinery). Natural gas is the dominant source of fuel in this sector followed by electric power.

Figure 10: Energy Use in Canada by Fuel Type, 2013



*Other includes coke, coal, coke oven gas, natural gas liquids and steam and waste.

In 2013, electricity accounted for 19% of all energy used in Canada (see Figure 10). Electrification of the economy means substituting natural gas, motor gasoline and other petroleum fuels with clean electricity. It would require a substantial expansion of clean generation and also significant innovation in energy efficiency, and likely a change in behaviour among Canadians.

Advancing Electrification

During committee hearings, Natural Resources Canada officials suggested that clean electricity could be the backbone for deeper decarbonization.[47] ***Are we in the midst of a massive electricity transformation of the economy? If so, should the federal government work with the provinces and territories to pursue a national electrification strategy?*** Such a strategy was endorsed by Sergio Marchi of the Canadian Electricity Association. He argued Canada should first electrify the transportation sector, and then move to buildings and industrial applications.[48] It is seen as a way to leverage the country's abundant renewable and non-emitting electricity and coordinate multiple initiatives from all levels of government under a focused goal.

A charging station for electric cars at Powertech Labs in Surrey, British Columbia.

Photo Credit: Senate of Canada

Some witnesses expressed caution about moving too quickly in a government-led push to electrify the economy. For example, Canadian energy expert Mike Cleland, Senior Fellow, University of Ottawa told the committee:

> I want to leave you with a caution on the use of electricity for heat, either in buildings or industrial sectors. In a recent report from the Council of Canadian Academies, to which I contributed as an expert panel member, we concluded that, over the long run, as buildings achieve extremely high efficiency levels, electricity for space heat will become a viable option. Those sorts of buildings are still rare and will continue to be rare for some time to come. Electric heat in conventional buildings would be achieved only at a carbon-price equivalent that would be economically unwise, to say the least.[49]

Allan Fogwill, President and Chief Executive Officer of the Canadian Energy Research Institute (CERI), told the committee that the Institute studied the impact of electrifying residential, commercial and passenger transportation sectors. The CERI found that electrification of the three sectors would not be enough to reach government emission targets. It found that electricity rates would likely increase by 2 to 3% annually, in addition to the usual electricity rate increases, for the next 30 years. Finally, the CERI found electrification of the three sectors would mean expanding the electricity supply by 2 to 3 times.

Chris Sandve of BC Hydro told the committee that there were further opportunities to electrify the province's upstream oil and gas production to reduce emissions.[50] Professor Pierre-Olivier Pineau of École des hautes études commerciales (HEC) Montréal emphasized opportunities created by switching from heavy trucks to electric trains in the transport of freight.[51]

A key question is to what extent should governments favour electrification to address decarbonization? Electrification necessitates a larger expansion of and investment in clean electricity supply. How will these investments be financed?

Energy Efficiency and Smarter Systems

Energy efficiency and conservation are often referred to as low hanging fruit because it is seen as the most cost effective way to reduce emissions. There is a near inexhaustible supply of fruit, since there are always ways to make the most out of the energy we consume. In so doing, we save money, reduce waste and emissions, and lessen the need to find new energy supplies.

Natural Resource Canada officials told the committee that energy efficiency is expected to contribute approximately 10% of the federal government's emission target and possibly more, depending on future policies.[52] In this regard, improving electricity consumption is expected to play a large part in curbing emissions particularly if an expanded role for electricity is envisioned.

> ***Even if all our energy was clean…***
>
> *Even if all our electricity became non-emitting tomorrow, there would still be a strong argument for energy efficiency. It reduces fuel bills, improves competitiveness, improves consumer welfare, avoids the need for expensive new generation and frees up more clean power for export.*

Energy efficiency is an area of shared jurisdiction among federal, provincial and territorial governments. Generally, the federal government's targeted programs to improve energy efficiency consist of information awareness, workshops, minimum standards and codes, research and development and cost sharing incentives to industrial sectors.

Key questions are how should the federal government build from its energy efficiency policies and programs and how should it coordinate with provincial and territorial governments to improve electricity use? Do government incentive programs to encourage energy efficient purchases and behaviour represent good value for money or do they mostly fund activities that would have occurred anyway? What implications does a new U.S. administration have, if any, for harmonized standards and codes between Canada and the U.S. for energy-using products?

Smarter Systems

Advances in digital applications and technologies have changed the way we interact and do business. The impact has been rapid and transformative, ever-widening our future technological possibilities. Compared to other industries, the electric grid has not kept pace. But things are changing.

The "smart grid" is a digital makeover of the electricity grid. It increases the interface between supply, distribution and consumption. In some places in Canada, smart grids are more advanced than others.

The smart grid facilitates the integration of wind and solar power into the grid. It allows more households and businesses to supply electricity to the grid. It provides real-time monitoring and correction of the electricity system. In the future, smart grids may enable utilities to exploit the storage capacity of household electric vehicle charging stations as a form of "distributed energy" storage to match electricity supply and demand during peak periods. In Ontario, utilities already have voluntary programs allowing them to adjust household thermostats to better optimize system-wide electricity loads.

Neil Larlee, Strategic Planning at NB Power, told the committee that NB Power is investing in a smart grid makeover of the province's electricity infrastructure. However, he explained that customer engagement is proving to be a larger challenge than the technology.[53]

Smart Meters

Smart meters transmit real-time information allowing better tracking of grid problems and enable time-of-use pricing where electricity prices can vary depending on the availability and cost of supply. This can result in consumer cost savings but also in system-wide savings through conservation.

Are smart grids the future of electricity systems? Will Canadians be comfortable with utilities controlling the energy output of their water heaters and household appliances? Is more federal funding needed in this area?

Electricity Trade

Canada does not have a single national electricity market or grid. Provincial and territorial electricity systems have evolved largely independently of each other and for the most part, they are self-sufficient in electricity. The territories are not connected to each other or to adjacent provinces.

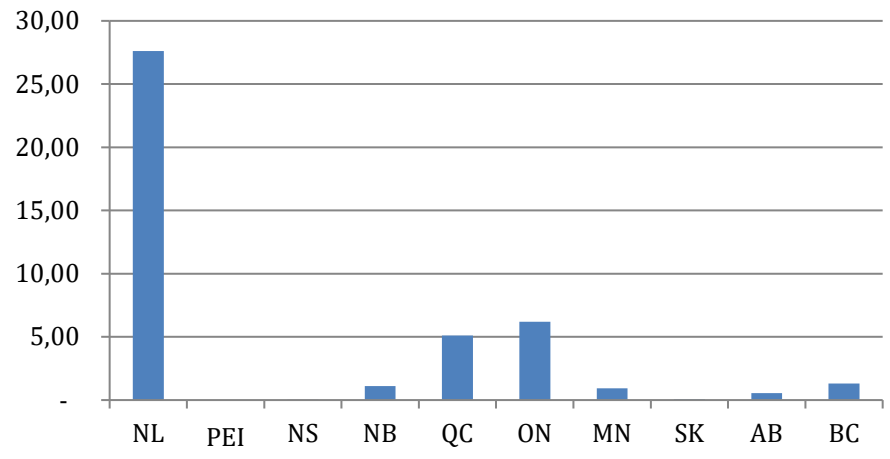
Cost of building transmission lines can be over $1 million per kilometre

As a whole, the provinces have oriented their transmission links with the United States to a greater extent than with each other and these links have much higher transfer capability than interprovincial connections. This has occurred because it is more profitable to supply large U.S. markets. In contrast, the distance between load centres from east-to-west through vast and sparsely inhabited regions serves as a financial barrier to building transmission lines between provinces. According to Guy Bruce of SaskPower, the capital cost of building high voltage transmission lines is "in the order of $1 million plus per kilometre" depending on factors including location and terrain.[54]

Interprovincial/Territorial Trade

In 2014, total interprovincial transfer of electricity was 42.9 TWh; approximately 65% of this amount is Newfoundland and Labrador's Churchill Falls' hydro facility's transfer of its output to Quebec through a long-term agreement. Excluding this transfer, total interprovincial electricity trade was 15.3 TWh, which represents approximately 25% of the international electricity trade between Canada and the United States.

Figure 11: Interprovincial Transfer of Electricity, 2014 (TWh)



Source: Figure prepared by the Library of Parliament using data from Statistics Canada: Table 127-0003, monthly deliveries to other provinces.

During committee hearings, witnesses described increasing electricity movement across Canada not as a form of “east-west” grand grid across the country, but in terms of increased regional interconnections between provinces and territories.[55] As pointed out by Sergio Marchi of the Canadian Electricity Association:

> When you say "east-west," you conjure up a huge tract of land that would make an east-west grid financially unviable. How do you allow for transmission of electricity from one end to the other?...when we talk about east-west I think we need to regionalize that east-west discourse, with Nova Scotia dealing with Ontario and Quebec, or as you said Alberta dealing with British Columbia and Manitoba.[56]

Shorter, regional initiatives between neighbouring provinces would be much more economically viable than a national east-west grid.[57]

Interprovincial/territorial trade is seen as beneficial since it provides more options to leverage different sources of power in order to more efficiently balance supply and demand across jurisdictions. For example, it allows greater ability to offset fossil fuel generation in one province with the clean generation from another. By expanding markets, it also allows for more efficient balancing of loads from variable renewable sources such as wind and solar.

New transmission line projects can attract significant public interest and opposition.

Photo Credit: Senate of Canada

The committee heard that many technical and market-based issues are creating obstacles to expanded electricity trade.[58] For example, Chris Sandve of BC Hydro explained that difference in electricity market systems between British Columbia and Alberta is a challenge to overcome if trade is to expand between the two provinces. [59]

Also, transmission line projects typically span long distances through vast terrain attracting significant public interest and opposition particularly from landowners whose land is affected. As the committee heard from Mike Cleland, “every project, especially big ones with large footprints and more especially ones requiring new transmission, will require the most careful process of public engagement.”[60]

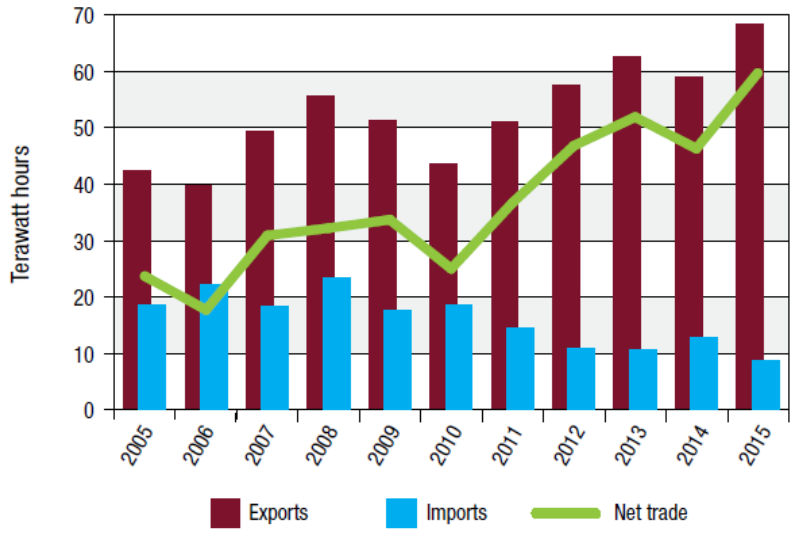
In the 2016 Budget, the federal government announced $2.5 million over two years to support regional dialogues among provinces and territories on the potential for co-operation on electricity trade and transmission.[61]

On 21 November, 2016, the federal government announced its support for using the Canada Infrastructure Bank to finance projects such as viable clean energy and electricity systems between provinces and territories. This could encourage greater transmission links between jurisdictions. ***Should the federal government commit federal funds towards inter-provincial/territorial electricity transmission projects? Are some of these projects the most productive way to spend public funds? How should the federal government balance the benefits of interprovincial/territorial electricity trade with the costs to the public purse? Is increasing electricity trade capacity an effective way to reduce emissions?***

Trade with the United States

Canada is a net exporter of electricity to the United States and this trade has been increasing over the last decade. These electricity exports represent about 2% of total U.S. electricity consumption.[62] However, for the United States markets that rely on Canadian exports, electricity trade is significant. For example, in 2013, Canadian electricity exports accounted for 16% and 13% of New England's and New York's total electricity retail sales, respectively. [63]

Figure 12: Canada's Electricity Trade with the U.S.



Source: Natural Resources Canada Fact Book 2016-17.

Canadian electricity exports offer valuable revenue streams, over $3.1 billion in 2015.[64] Since most of our energy sources are clean, it creates opportunities to displace U.S. fossil fuel generation and reduce emissions continentally. In 2015, about 67% of U.S. electricity generation was sourced from fossil fuel.

Should Canada's contribution to reducing emissions continentally be recognized within its domestic emission targets? After all, we all live in the same atmosphere. Some witnesses strongly endorsed using Canada's clean electricity resources to displace our southern neighbour's fossil fuel generation. Mike Cleland said:

> It may well be that the more cost-effective option could be displacing power generated from fossil fuels in the U.S. That doesn't show up in Canada's numbers, but the planet doesn't care about Canada's numbers. So that's one important perspective. [65]

Balancing Goals: Impact on Households and Businesses

Transition requires change. Provinces and territories are confronting difficult choices in balancing the need to provide low-emitting electricity in a manner that is affordable and reliable.

The committee was told that electricity systems across the country require modernization and renewal as many existing assets are reaching the end of their life. Essentially, the country is facing a turning point where clean power sources are broadening and low-cost thermal stations such as coal are retiring.

> ***It is important to put a human face on all of this***

While there may be many ways to curb and improve electricity use through energy efficiency and demand side management programs, the fact remains that the bulk of the transition will have to be paid for through higher electricity rates and/or higher public spending to stabilize rates and to drive clean generation investment.

This means it will come out of the pocket of the energy consumer and the taxpayer, which is essentially the same pocket. In many parts of the country, households and businesses are already experiencing higher electricity rates as a result of the clean power push. Since electricity is a cost incurred by all businesses and institutions, the rise in electricity rates contributes to rising prices of nearly all goods and services. This situation is likely to be made worse by carbon pricing programs especially if the revenues raised are not recycled to lower income taxes.

As mentioned by Robin Campbell, President of the Coal Association of Canada in discussing a transition to a low-carbon future, it is important to put a human face on all of this.[66] Mr. Campbell told the committee that it was not possible to shut coal plants in Canada without increasing the price of electricity.

Rising energy costs will particularly affect low-income households that are already struggling to make ends meet and are less able to upgrade and purchase energy efficient products, switch fuel use or fund energy retrofits to mitigate higher electricity prices. To address this, many provinces have introduced programs such as tax credits and energy rebates to mitigate the effects of high energy prices.

Competiveness and Carbon Leakages

The committee heard from manufacturers and other heavy electricity users about their concerns over rising electricity rates and the implementation of carbon pricing programs. They have told the committee that the resultant rise in business costs may lead to reduced investment and jobs. It

also jeopardizes the competitiveness of Canadian businesses as they participate on the world stage.

Many industries are unable to pass the full costs to their customers since they trade in competitive and/or globally-priced markets. Further, there is an apprehension that businesses will invest in, or relocate to countries that have fewer emission requirements or use electricity derived from coal-fired plants, thereby negating efforts to reduce global emissions. In so doing, Canada bears the economic cost of lost production and investment with no change in global emissions.[67]

Mathew Wilson, Senior Vice President, National Policy at Canadian Manufacturers & Exporters, explained the impact of "carbon leakage":

> If Canada applies a carbon tax and the investment and production go offshore somewhere else, it's still being produced and in some cases probably produced at higher emissions intensity than it would be done in Canada. There is really no net gain from an environmental perspective overall globally, and in Canada we just lose jobs. [68]

He further told the committee that in several provinces rapidly rising electricity prices were issue number one for manufacturers.[69] These firms rely on stable and affordable supply of electricity to stay in business.

During the committee's fact finding travels, senators heard from many businesses that were concerned about the impact carbon pricing would have on their operations and ability to compete in U.S. markets, especially in light of the new U.S administration.

Moving Forward

In determining the future role of electricity, whether it is in the short, medium or a reimaged long-term future, decision makers must balance a number of policy elements. ***Are solutions technologically feasible and affordable? Will measures help maintain or reinforce the reliability of electricity systems? Do they efficiently and fairly reduce emissions? Will they grow or harm the economy? Will measures affect one region of the country or population cohort more than another? Will measures be publicly acceptable?***

Timelines are short for meeting Canada's emission goals, which means new energy projects must advance promptly. However, all electricity generation projects, including renewable energy, bring with them public opposition particularly if transmission lines are proposed. We need appropriate mechanisms for public engagement that anticipate, manage and address public concerns and local impacts in a way that shortens the lengthy assessment and approval process.

All the areas covered in this report, from advances in clean electricity technologies, grid modernization, demand-side management, electrification and fuel switching, and increasing electricity trade, serve to widen the options for reducing emissions. However, they must be implemented in a way that balances electricity reliability, economic growth, deep emission reductions, affordability and fairness for Canadians. It is critical that the transition to a low-carbon economy be managed to avoid undue hardship. At the end of the day, electricity systems are supported by long-lived capital assets which means the decisions we make today will affect policy options long into the future. It is important to have a vision and get it right, as it is literally the legacy we leave future generations.

Appendix A – List of Witnesses

March 22, 2016

- *Environment and Climate Change Canada:*
  - Dan McDougall, Assistant Deputy Minister, Strategic Policy Branch;
  - Derek Hermanutz, Director General, Economic Analysis Directorate, Strategic Policy Branch;
  - Mike Beale, Assistant Deputy Minister, Environmental Stewardship Branch.

April 12, 2016

- *National Energy Board:*
  - Jim Fox, Vice President, Integrated Energy Information and Analysis;
  - Shelley Milutinovic, Chief Economist.

April 14, 2016

- *Natural Resources Canada:*
  - Jeff Labonté, Director General, Energy Safety and Security;
  - Niall O'Dea, Director General, Electricity Resources Branch;
  - Marc Wickham, Director, Science and Technology Programs, Innovation and Energy Technology Sector, Office of Energy Research and Development;
  - Drew Leyburne, Director General, Energy Policy Branch;
  - Patricia Fuller, Director General, Office of Energy Efficiency;
  - Paula Vieira, Director, Transportation and Alternative Fuels Division;
  - Laura Oleson, Director, Demand Policy and Analysis, Office of Energy Efficiency, Energy Sector;
  - Debbie Scharf, Director, Equipment Division.

April 19, 2016

- *Canadian Council on Renewable Electricity:*
  - Jacob Irving, President, Canadian Hydropower Association.

April 21, 2016

- *Canadian Nuclear Association:*
  - John Barrett, President and Chief Executive Officer.

May 3, 2017

- *Ecologic Institute US:*
  - Max Gruenig, President.

- *TransAlta Corporation:*
  - Don Wharton, Managing Director for Carbon Transition.

May 5, 2016

- *Canadian Electricity Association:*
  - Sergio Marchi, President and CEO;
  - Devin McCarthy, Director, Generation and Environment.

- *Capital Power:*
  - Martin Kennedy, Vice President, External Affairs.

- *Nova Scotia Power Inc.:*
  - Terry Toner, Director, Environmental Services.

- *Canadian Biogas Association:*
  - Jennifer Green, Executive Director;
  - Kevin Matthews, Director;
  - Donald Beverly, Director.

May 10, 2017

- *As an individual:*
  - Andrew Leach, Associate Professor, Alberta School of Business, University of Alberta;
  - Mike Cleland, Senior Fellow, University of Ottawa.

- *HEC Montréal:*
  - Pierre-Olivier Pineau, Professor, Chair in Energy Sector Management.

May 12, 2016

- *Association of Major Power Customers of BC:*
  - Brian Wallace, Counsel;
  - Carlo Dal Monte, Director, Energy, Catalyst Paper Corporation;
  - Karina Brino, President and CEO, Mining Association of BC.

May 17, 2016

- *SaskPower:*
  - Mike Marsh, President and Chief Executive Officer;
  - Guy Bruce, Vice President, Planning, Environment and Sustainable Development.

- *BC Hydro:*
  - Chris Sandve, Director of Policy and Reporting.

May 19, 2016

- *Transport Canada:*
  - Ellen Burack, Director General, Environmental Policy;
  - Jim Lothrop, Director General, Sustainable Transportation Stewardship.

May 31, 2016

- *National Airlines Council of Canada:*
  - Marc-André O'Rourke, Executive Director;
  - Teresa Ehman, Chair, Environment Subcommittee.
  - *Green Aviation Research and Development Network:*
  - Sylvain Cofsky, Executive Director;
  - Fassi Kafyeke, Senior Director, Strategic Technology and Advanced Product Development, Bombardier Aerospace.

June 2, 2016

- *Ontario Power Generation:*
  - Jeff Lyash, President and Chief Executive Officer.

- *NB Power:*
  - Neil Larlee, Director, Strategic Planning.

June 9, 2016

- *Canadian Hydrogen and Fuel Cell Association:*
  - Eric Denhoff, President and Chief Executive Officer.

- *Renewable Industries Canada:*
  - Andrea Kent, President.

- *Canadian Automated Vehicles Centre of Excellence:*
  - Barrie Kirk, Executive Director.

September 27, 2016

- *Association of Canadian Port Authorities:*
  - Wendy Zatylny, President;
  - Debbie Murray, Director, Policy and Regulatory Affairs.

- *Conference Board of Canada:*
  - Louis Thériault, Vice President, Public Policy.

September 29, 2016

- *Canadian Natural Gas Vehicle Alliance:*
  - Bruce Winchester, Executive Director.

- *Pollution Probe:*
  - Steven McCauley, Acting Chief Executive Officer.

October 18, 2016

- *Electric Mobility Canada:*
  - Chantal Guimont, President and Chief Executive Officer.

- *Canadian Trucking Alliance:*
  - Jonathan Blackham, Policy and Government Affairs Assistant.

October 20, 2016

- *Coal Association of Canada:*
  - Robin Campbell, President.

October 25, 2016

- *VIA Rail Canada:*
  - Yves Desjardins-Siciliano, President and Chief Executive Officer;
  - Pierre Le Fèvre, Senior Advisor to CEO and Chief Executive Officer;
  - Bruno Riendeau, Director, Safety and Environment.

- *Railway Association of Canada:*
  - Michael Bourque, President and Chief Executive Officer;
  - Michael Gullo, Director, Policy, Economic and Environmental Affairs.

October 27, 2016

- *Canadian Vehicle Manufacturers' Association:*
  - Mark Nantais, President.

- *Fertilizer Canada:*
  - Garth Whyte, President and Chief Executive Officer;
  - Clyde Graham, Senior Vice President.

November 1, 2016

- *Canadian Manufacturers & Exporters:*
  - Mathew Wilson, Senior Vice President, National Policy;
  - Nancy Coulas, Director, Energy and Environment Policy.

- *CMC Research Institutes, Inc.:*
  - Richard Adamson, President.

November 3, 2016

- *Canadian Urban Transit Association:*
  - Alex Maheu, Director, Public Affairs;
  - Jeff Mackey, Policy Analyst.

- *Hydro-Québec:*
  - Louis Beauchemin, Senior Director, Subsidiary Management;
  - France Lampron, Director, Transportation Electrification.

November 24, 2016

- *Sustainable Development Technology Canada:*
  - Leah Lawrence, President and Chief Executive Officer.

- *Alberta Innovates:*
  - John Zhou, Vice President, Clean Energy.

November 29, 2016

- *C.D. Howe Institute:*
  - Benjamin Dachis, Associate Director, Research.

December 1, 2016

- *PTAC Petroleum Technology Alliance Canada:*
  - Soheil Asgarpour, President.

December 6, 2016

- *Council of Canadian Academies:*
  - Eric M. Meslin, President and Chief Executive Officer;
  - Eddy Isaacs, Scientific Advisory Committee Member.

- *In Situ Oil Sands Alliance:*
  - Richard Sendall, Chairman;
  - Patricia Nelson, Vice Chair.

December 8, 2016

- *Federation of Canadian Municipalities:*
  - Clark Somerville, President;
  - Dallas Alderson, Manager, Policy and Research.

- *As an individual:*
  - Mark Jaccard, Professor, Simon Fraser University.

December 13, 2016

- *Canada West Foundation:*
  - Trevor McLeod, Director of the Centre for Natural Resources Policy.

December 15, 2016

- *Canadian Energy Research Institute:*
  - Allan Fogwill, President and Chief Executive Officer.

January 31, 2017

- *Global CCS Institute:*
  - Jeff Erikson, General Manager, Americas Region.

February 2, 2017

- *Institute for Oil Sands Innovation:*
  - Qi Liu, Scientific Director.

- *Emissions Reduction Alberta:*
  - Steve MacDonald, Chief Executive Officer.

February 16, 2017

- *Canada Mining Innovation Council:*
  - Carl Weatherell, Executive Director and Chief Executive Officer.

- *As an Individual:*
  - Jennifer Winter, Assistant Professor, School of Public Policy, University of Calgary.

February 28, 2017

- *Chemistry Industry Association of Canada:*
  - Bob Masterson, President and Chief Executive Office;
  - David Podruzny, Vice-President, Business and Economics.

- *Petroleum Services Association of Canada:*
  - Mark A. Salkeld, President and Chief Executive Officer.

March 2, 2017

- *Forest Products Association of Canada*:
  - Robert Larocque, Vice President, Climate Change, Environment and Labour;
  - Kate Lindsay, Director, Environmental Regulations and Conservation Biology.

- *Mining Association of Canada:*
  - Brendan Marshall, Vice President, Economic and Northern Affairs.

Appendix B – Fact-Finding Missions – List of Witnesses

Western Canada – October 2-7, 2016
(Vancouver, Kitimat and Prince George, British Columbia, Calgary, Alberta and Estevan, Saskatchewan)

- *Alberta Electric System Operator:*
  - Miranda Keating Erickson, Vice President Operations;
  - Angela Anderson, External Relations Advisor.

- *ARC Financial Corp.:*
  - Peter Tertzakian, Chief Energy Economist and Managing Director.

- *Canada's Oil Sands Innovation Alliance:*
  - Dan Wicklum, Chief Executive Officer.

- *Canfor Pulp Ltd.:*
  - Martin Pudlas, Vice President, Operations;
  - Peter Lovell, General Manager;
  - Robert Thew, Manager, Strategic Capital and Energy.

- *CanmetENERGY:*
  - Cécile Siewe, Director General, Devon Research Center;
  - Jinwen Chen, Director, Hydrocarbon Conversion;
  - Michael Layer, Senior Program Manager.

- *Legislative Assembly of Saskatchewan:*
  - Lori Carr, Member of the Legislative Assembly.

- *Pembina Institute:*
  - Chris Severson-Baker, Managing Director.

- *Petroleum Technology Research Centre:*
  - Norm Sacuta, Communications Manager.

- *Powertech Laboratories:*
  - Madhvi Ramnial, Manager, Client Engagement and Business Development;
  - Angela Das, Senior Manager, Advanced Transportation;
  - Jeff Turner, Project Manager, Electric Vehicles and Energy Systems;
  - David Facey, Legal Counsel;
  - Frankie Nash, Policy Analyst.

- *Rio Tinto:*
  - Blair Dickerson, Vice President;
  - Richard Prokopanko, Director of Government Affairs;
  - Gareth Manderson, General Manager;
  - Kevin Dobbin, Manager Communications and Communities, BC Works;
  - Manny Arruda, Casting Coordinator, BC Works;
  - Alain Bouchard, Business Partner HSE;
  - Graham Caven, Reduction PTA Trainer, BC Works;
  - Carolyn Chisholm, Principal Advisor, Vice President Canada Office;
  - Marion Egan, Executive Assistant, BC Works;
  - Joe Velho, Coordinator, BC Works.

- *SaskPower:*
  - Howard Matthews, Vice President, Power Production;
  - Sandra Beingessner, Executive Co-ordinator, Executive Offices;
  - Dave Jobe, Director, Carbon Capture and Storage;
  - Mike Zeleny, Tour Ambassador, Carbon Capture and Storage.

- *Seven Generations Energy Ltd.:*
  - Alan Boras, Director, Communications and Stakeholders Relations.

- *University of Calgary:*
  - Dan McFadyen, Program Director, School of Public Policy;
  - Robert Mansell, Academic Director, School of Public Policy;
  - Shantel Jordison, Manager, Extractive Resource Governance Program.

- *University of Northern British Columbia:*
  - Daniel Weeks, President;
  - Daniel Ryan, Interim Vice President, Academic and Provost;
  - Geoffrey Payne, Interim Vice President, Research;
  - Tim Tribe, Vice President, Advancement;
  - Robert Knight, Vice President, Finance and Business Operations;
  - Chris Buse, CIRC Project Lead;
  - Stephen Déry, Canada Research Chair in Northern Hydrometeorology;
  - Kevin Ericsson, Chief Engineer;
  - David Claus, Assistant Director, Facilities Management.

- *Vancouver Fraser Port Authority:*
  - Duncan Wilson, Vice President, Corporate Social Responsibility;
  - Carrie Brown, Director, Environmental Programs;
  - Evangeline Englezos, Director, Community and Aboriginal Affairs;
  - Christine Rigby, Environmental Specialist, Air Emissions.

Ontario – November 14-17, 2016
(Sarnia and Hamilton, Ontario)

- *ArcelorMittal Dofasco:*
  - Sean Donnelly, President and Chief Executive Officer;
  - Tony Valeri, Vice President, Corporate Affairs;
  - Henry Wegiel, Director, Trade and Government Relations;
  - Ian Shaw, Manager, Energy Management;
  - Jim Stirling, General Manager, Environment;
  - Richard Do Couto, Specialist, Corporate Responsibility;
  - Tom Kuhl, General Manager of Primary Manufacturing Technology;
  - Dan Evans, Reliability Coach;
  - Errol Hilado, Process Reliability Specialist.

- *BioAmber:*
  - Mike Hartmann, Executive Vice President;
  - Ann Waddell, Vice president, Government Affairs.
  - Fabrice Orecchioni, Chief Operations Officer.

- *Bioindustrial Innovation Canada:*
  - Sandy Marshall, Executive Director.

- *Biox Corporation:*
  - Alan Rickard, Chief Executive Officer;
  - Courtney Quinn, Vice President, Finance;
  - Ryan Doell, Operations Manager;
  - Bozena Millivojevic, Production Manager.

- *Canadian Fuels Association:*
  - Lisa Stilborn, Vice President, Ontario Division;
  - Erin Brophy, Communications Manager.
- *CanmetMATERIALS:*
  - Philippe Dauphin, General Manager;
  - Mark S. Kozdras, Program Manager, Automotive Materials;
  - Hitesh Jain, Manager, Business and Contracts.

- *Chemistry Industry Association of Canada:*
  - Bob Masterson, President and Chief Executive Officer;
  - David Podruzny, Vice President, Business and Economics
  - Erika Adams, Director, Communications.

- *City of Hamilton:*
  - His Worship Fred Eisenberger, Mayor;
  - Andrew Grice, Director, Water and Wastewater Operations;
  - Geoff Lupton, Director, Energy, Fleet and Traffic;
  - John Mater, Director, Corporate Assets and Strategic Planning;
  - Dan Chauvin, Director, Woodward Upgrades;
  - Dan McKinnon, General Manager, Public Works;
  - Mark Bainbridge, Acting Director, Hamilton Water
  - Greg Crone, Strategic Initiatives and Policy Advisor;
  - Frank Gazzola, Superintendent, Energy Engineering;
  - Plamen Nikolov, Senior Project Manager, Capital Works.

- *Imperial:*
  - Brian M. Fairley, Sarnia Refinery Manager;
  - George E. Vincent, Senior Regulatory Affairs Advisor;
  - Dave Luecke, Sarnia Chemical Plant Manager;
  - Jon Harding, Community Affairs and Aboriginal Relations Advisor.

- *McMaster University:*
  - Ishwar Puri, Dean Faculty of Engineering;
  - Rob Baker, Vice President Research;
  - Nick Markettos, Acting Director, McMaster Institute for Transportation and Logistics;
  - Altaf Arain, Director, McMaster Centre for Climate Change;
  - Gillian Goward, Acting Associate Dean Research and External Relations;
  - Lori Dillon, Manager, Research Communications;
  - Alex Lawson, Executive Advisor, Public Affairs;
  - Kristen Munro, Manager, Public Affairs;
  - Ali Emadi, Director of MacAUTO;
  - Saeid Habibi, Professor, Mechanical Engineering;
  - Megan Wood, Team Lead, McMaster Engineering EcoCAR3 Team;
  - Theo Abraham, Communications Manager, McMaster Engineering EcoCAR3 Team.

- *NOVA Chemicals:*
  - Rob Thompson, Regional Manufacturing Director;
  - Ken Faulkner, Director of Government Relations;
  - Meaghan Kreeft, Communications Consultant.

- *Sarnia-Lambton Chamber of Commerce:*
  - Shirley de Silva, President and Chief Executive Officer;
  - Monica Shepley, Manager of Advocacy and Policy Development;
  - Mark Lumley, Chairman, Board of Directors;
  - Michael Kooy, 1st Vice Chair;
  - Peter Smith, Co-Chair, Energy Committee;
  - Alex Palimaka, Board Member;
  - Cathy MacLellan, Vice President Human Resources and Outreach, Ubiquity Solar;
  - Ed brost, President, Je&M Consulting Ltd.;
  - Maike Luiken, Bluewater Technology Access Centre;
  - Joe Lasowski, CF Industries.

- *Sarnia-Lambton Economic Partnership:*
  - George Mallay, General Manager.

- *Shell:*
  - Helen Bennett, Emerging Regulatory Policy Issue Advisor.

- *Union Gas:*
  - Sarah Van Der Paelt, Director, Distribution Business Development and Strategic Accounts.

- *Suncor Energy:*
  - Michael Kandravy, Director, Fuels Quality and Regulatory Affairs;
  - Michael Southern, Manager, Government Relations.

- *Western Sarnia-Lambton Research Park:*
  - Tom Strifler, Executive Director;
  - Katherine G. Albion, Commercialization Centre Director;
  - Victoria Townsend, Research Engineer and Project Manager;
  - Stephen Reaume, Coordinator;
  - Mike Nesdoly, Manager, Applied Research and Innovation.

Quebec – February 7-8, 2017
(Montreal and Varennes, Quebec)

- *AQPER (Association québécoise de la production d'énergie renouvelable) :*
  - Jean-François Samray, President and Chief Executive Officer

- *CanmetENERGY:*
  - Gilles Jean, Managing Director;
  - Lisa Dignard, Director, Integration of Renewable and Distributed Energy Resources R&D Program;
  - Éric Soucy, Director, Industry R&D Program;
  - Chantal LeRoy, Acting Director, Building R&D Program;
  - Amélie Richard, Commercialisation Officer.

- *City of Laval:*
  - Stéphane Boyer, City Councillor;
  - Ian Dessureault, Environment Services.

- *Écotech Québec:*
  - Denis Leclerc, President and Chief Executive Officer;
  - Marie-Hélène Labrie, Vice-President of the Board;
  - Élise Laferrière, Vice-Presidente, Partnerships and Operations.

- *Gaz Métro:*
  - Stéphanie Trudeau, Principal Vice-President, Regulations, Clients and Communities;
  - Frédéric Krikorian, Director, Sustainable Development, Public and Governmental Affairs.

- *Hydro-Québec's Research Institute:*
  - Jérôme Gosset, Director;
  - Jean-Pierre Tardif, Advisor – Communications and Marketing.

- *McGill:*
  - Jim Nicell, Professor & Dean of Engineering;
  - Subhasis Ghoshal, Director, Trottier Institute for Sustainability in Engineering and Design;
  - Lauren Penney, Manager, Trottier Institute for Sustainability in Engineering and Design;
  - Benoit Boulet, Associate Dean, Research & Innovation
  - François Bouffard, Associate Professor;
  - Yixin Shao, Professor;
  - Jeff Bergthorson, Associate Professor.

- *Union des producteurs agricoles :*
  - Pierre Lemieux, Second Vice-President;
  - Daniel Bernier, Research and Agricultural Policy Advisor – Environment.

[1] United Nations Framework Convention on Climate Change, The Paris Agreement.
[2] International Energy Agency, World Energy Outlook 2016 –Executive Summary.
[3] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 10 May, 2016 (Mike Cleland, Senior Fellow, University of Ottawa, as an individual).
[4] Canadian Intergovernmental Conference Secretariat, First Ministers' Meeting – Vancouver Declaration on clean growth and climate change, Vancouver, British Columbia, 3 March, 2016.
[5] Government of Canada, Pan-Canadian Framework on Clean Growth and Climate Change.
[6] Environment and Climate Change Canada, Global Greenhouse Gas Emissions, figure is based on 2012 global emissions.
[7] Ibid.
[8] Pollution Probe, Primer on Energy Systems in Canada, 12 January, 2011.
[9] Figures were sourced from Statistics Canada's CANSIM Table 128-0017 includes producer generated consumption and the International Energy Agency's Electricity Information. Figures were rounded.
[10] Statistics Canada, Supply and demand of primary and secondary energy in natural units, CANSIM Table 128-0017.
[11] Natural Resources Canada, Energy Fact Book 2016-17.
[12] Ibid.
[13] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 19 April, 2016 (Jacob Irving, Canadian Hydropower Association, Canadian Council on Renewable Electricity).
[14] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 3 May, 2016 (Don Wharton, Managing Director for Carbon Transition, TransAlta Corporation).
[15] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 17 May, 2016 (Chris Sandve, Director of Policy and Reporting, BC Hydro).
[16] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, , 42nd Parliament, 2 June, 2016 (Neil Larlee, Strategic Planning, NB Power).
[17] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 17 May, 2016 (Guy Bruce, Vice President, Planning, Environment and Sustainable Development, SaskPower).
[18] Canadian Nuclear Association, *Canadian Nuclear Factbook 2015*.
[19] International Atomic Energy Agency, *Small Modular Reactors Offer Option for Near-Term Nuclear Power Deployment*, 16 September, 2015.
[20] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 2 June, 2016 (Jeff Lyash, President and Chief Executive Officer, Ontario Power Generation).
[21] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 3 May, 2016 (Max Gruenig, President, Ecologic Institute US.
[22] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 3 May, 2016 (Don Wharton, Managing Director for Carbon Transition, TransAlta Corporation).
[23] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 17 May, 2016 (Guy Bruce, Vice President, Planning, Environment and Sustainable Development, SaskPower).
[24] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 5 May, 2016 (Jennifer Green, Executive Director, Canadian Biogas Association).
[25] Senate, Standing Committee on Energy, the Environment and Natural Resources, 1st Session, Evidence, 42nd Parliament, 12 April, 2016 (Jim Fox, Vice President, Integrated Energy Information and Analysis, National Energy Board).
[26] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 10 May, 2016 (Mike Cleland, Senior Fellow, University of Ottawa, as an individual).
[27] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 17 May, 2016 (Mike Marsh, President and CEO, SaskPower).
[28] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 3 May, 2016 (Don Wharton, Managing Director for Carbon Transition, TransAlta Corporation).
[29] Government of Canada, Government of Canada accelerates investments in clean electricity.

[30] The following was extracted from NEB's Canada's Energy Future 2016 report: "Under new federal regulations, *Reduction of Carbon Dioxide Emissions from Coal-Fired Generation of Electricity Regulations* (Reduction Regulations), coal plants are required to meet an annual average emissions-intensity standard of 420 tonnes of CO_2 per GWh during a calendar year. This performance standard applies to coal facilities commissioned after 1 July 2015 and units that have reached the end of their useful life. Temporary exemptions are available if units are designed, or can be retrofitted, to permit integration with [carbon capture and storage] technology, provided certain implementation milestones are met."

[31] Government of Canada, Government of Canada accelerates investments in clean electricity.

[32] Alberta Government, Climate Leadership.

[33] Alberta Government, Phasing out coal pollution.

[34] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 2 June, 2016 (Neil Larlee, Strategic Planning, NB Power).

[35] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence,1st Session, 42nd Parliament, 5 May, 2016 (Terry Toner, Director, Environmental Services, Nova Scotia Power Inc.).

[36] Government of Canada, Backgrounders, The Government of Canada announces approach with Nova Scotia on pricing carbon pollution and coal phase-out equivalency agreement.

[37] Government of Canada, "Saskatchewan, federal government work together on equivalency agreement", News Release, 28 November, 2016.

[38] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 5 May, 2016 (Sergio Marchi, President and CEO, Canadian Electricity Association).

[39] Senate, Standing Committee on Energy, the Environment and Natural Resources, *Powering Canada's Territories*, Final Report, 2nd Session, 41st Parliament, 17 June, 2015.

[40] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 31 January, 2017 (Jeff Erikson, General Manager, Americas Region, Global CCS Institute).

[41] Ibid.

[42] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 17 May, 2016 (Mike Marsh, President and CEO, SaskPower).

[43] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 12 April, 2016 (Jim Fox, Vice President, Integrated Energy Information and Analysis, National Energy Board).

[44] Conference Board of Canada, Investment in Electricity Infrastructure Generates Employment and Economic Growth, 13 February, 2012.

[45] Government of Canada, "Federal Government to significantly reduce its own greenhouse gas emissions", News Release, 2 November 2016.

[46] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 10 May, 2016 (Mike Cleland, Senior Fellow, University of Ottawa, as an individual).

[47] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 14 April, 2016 (Niall O'Dea, Director General, Electricity Resources Branch, Natural Resources Canada).

[48] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 5 May, 2016 (Sergio Marchi, President and CEO, Canadian Electricity Association).

[49] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 10 May, 2016 (Mike Cleland, Senior Fellow, University of Ottawa, as an individual).

[50] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 17 May, 2016 (Chris Sandve, Director of Policy and Reporting, BC Hydro).

[51] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 10 May, 2016 (Pierre-Olivier Pineau, Professor , HEC Montréal).

[52] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 14 April, 2016 (Jeff Labonté, Director General, Energy Safety and Security, Natural Resources Canada).

[53] Senate, Standing Committee on Energy, the Environment and Natural Resources, 1st Session, Evidence, 42nd Parliament, 2 June, 2016 (Neil Larlee, Strategic Planning, NB Power).

[54] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 17 May, 2016 (Guy Bruce, Vice President, Planning, Environment and Sustainable Development, SaskPower).

[55] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 5 May, 2016 (Sergio Marchi, President and CEO, Canadian Electricity Association).
[56] Ibid.
[57] Ibid.
[58] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 17 May, 2016 (Chris Sandve, Director of Policy and Reporting, BC Hydro).
[59] Ibid.
[60] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 10 May, 2016 (Mike Cleland, Senior Fellow, University of Ottawa, as an individual).
[61] Government of Canada, 2016 Federal Budget, Advancing Regional Electricity Cooperation.
[62] Natural Resources Canada, Energy Fact Book 2016-17.
[63] United States Energy Information Administration, U.S.-Canada electricity trade increases.
[64] Statistics Canada, Canadian International Merchandise Trade Database, Table 908-0027.
[65] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 10 May, 2016 (Mike Cleland, Senior Fellow, University of Ottawa, as an individual).
[66] Senate, Standing Committee on Energy, the Environment and Natural Resources, 1st Session, Evidence, 42nd Parliament, 20 October, 2016 (Robin Campbell, President, Coal Association of Canada).
[67] Ecofiscal Commission, Provincial Carbon Pricing and Competitiveness Pressures, 18 November, 2015.
[68] Senate, Standing Committee on Energy, the Environment and Natural Resources, Evidence, 1st Session, 42nd Parliament, 1 November, 2016 (Mathew Wilson, Senior Vice President, National Policy, Canadian Manufacturers and Exporters).
[69]Ibid.