What Does the Future Hold for Natural Gas?

Considering the role of natural gas and the gas system in Canada's low-emissions future

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Pollution Probe is solely liable and responsible for the contents of this report. All opinions in this report are solely those of Pollution Probe and do not necessarily reflect those of our funders or the participants in the workshop.

About Pollution Probe

Pollution Probe is a national, not-for-profit, charitable organization established in 1969 that exists to improve the health and well-being of Canadians by advancing policy that achieves positive, tangible environmental change. Pollution Probe has a proven track record of working in successful partnership with industry and government to develop practical solutions for shared environmental challenges.

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CHAPTER 1: INTRODUCTION

Canada is establishing aggressive targets to reduce greenhouse gases (GHGs) over the next 30 years as it transitions to a low-emissions sustainable energy system. Achieving these goals while meeting our energy needs in a diverse country and maintaining Canada's competitiveness creates numerous social, technical, economic and environmental challenges. Canada therefore needs to consider the current means of how we produce, source and deliver our energy, what energy supplies and technologies will be necessary for making this transition, and how all existing energy infrastructure could contribute to the transition.

The Generation Energy Council's report for Natural Resources Canada states it clearly: "An energy transition is underway – and will continue to roll out over the course of a generation, roughly between now and 2040. It is the greatest shift of this kind the world has seen in generations."[1]

The natural gas system provides major benefits to Canadians. It is one of the only fuels to supply almost every sector of a modern economy – from industrial processes, to creating fertilizer for agriculture, to generating electricity, to providing space and water heating and fueling trucks and marine vessels.

Natural gas is also currently one of the most cost-effective energy sources for meeting these needs, though this may change with carbon pricing. Another of natural gas's biggest advantages is that it can be stored, which provides the flexibility needed to meet fluctuating seasonal heating needs.

However, natural gas is still a fossil fuel. The GHG emissions from its use have come under increased scrutiny and are subject to legitimate questioning, especially as global trends and government policies point to a low-emissions energy future. What

[1] Generation Energy Council, *Canada's Energy Transition: Getting to Our Energy Future, Together*, July 2018. At https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/energy/CoucilReport_july4_EN_Web.pdf.

is the right role for natural gas and the existing infrastructure in the future as Canada and the rest of the world move toward lower carbon options?

There have been moves both in Canada and internationally to reconsider the role of natural gas. The UK's Committee on Climate Change has said that if the UK is to become net zero by 2050, as the government has said, natural gas consumption will have to decline by 32% by 2050, with increasing use of alternatives in its place.[2] France is looking into moving to 100% "clean gas" (both renewable natural gas and hydrogen) by 2050 (see *case study*, page 17). In Canada, the BC government's CleanBC plan includes shifting residential houses from natural gas space and water heating to electric heat pumps, and to mandate minimum renewable natural gas content, and the Quebec government recently announced plans for increased electrification (see *case study*, page 4). Many municipalities around the world are also putting forward policies to move away from natural gas use.

As part of the Paris Target of holding global warming to 2ºC, the federal government has set a target to reduce emissions by 30% by 2030 and by 80% from 2005 levels by 2050. This would mean that emissions in 2030 would total 523 megatonnes of carbon dioxide equivalent (Mt CO_2e), compared to 716 Mt CO_2e in 2017. To meet the emissions reductions targets the nature and use of natural gas and the gas system itself will need to be changed.

The sector has started to look at how natural gas systems can play a supporting and beneficial role in the low-carbon transition, apart from backing up variable renewable electricity. As a result, governments, gas utilities and other stakeholders are exploring the range of technological, supply and policy options available, their impact on current and future customers, and how utility investment and asset plans will need to change.

The aim of this paper is to provide a common foundation for discussion to examine the potential options for the future use of natural gas and the natural gas system by 2050, including identifying pathways for the natural gas system to contribute to the transition to a low-emissions economy.

This paper will focus only on the downstream natural gas industry – i.e., the transmission, storage and distribution of natural gas using a network of local distribution pipelines and its commercial, institutional and residential uses. Industrial users of gas outside the oil and gas sector, some of whom are directly connected to the gas transmission networks, will also be considered. The upstream production of natural gas and electricity generation, while important, are not considered here.

To understand the issues and barriers around the transition in the downstream gas sector, Pollution Probe convened a workshop in spring 2019 with over 40 stakeholders from across Canada, including representatives from gas distributors from across Canada, electrical utilities, all levels of government, regulators, and the businesses and financial sectors. Following on from that, a public webinar was also held to gather more feedback.

We also need to consider if Canada could even achieve its emissions reduction targets without using the gas system in some fashion due to the need to supply heat and the amount of electricity generation that would need to be built in order to meet the energy services currently provided by natural gas. Numerous studies have shown that using the gas system to provide energy services may be one of the most cost-effective and practical ways to reduce emissions throughout the entire energy system.

Timelines are also important, and it may be difficult or expensive to build the needed new infrastructure in time to meet Canada's 2030 and 2050 targets. As a result, at the very least the costs could potentially be much higher to meet our targets without using the gas system, making durable progress and public buy-in difficult to achieve.

To discuss what role natural gas and the gas system can play in the clean energy transition, we first provide context on where gas is used in Canada now, and consider regional differences in energy profiles. As we examine solutions, we look into how the gas system can be used as efficiently as possible. While efficiency is a large part of any transition, alone it is unlikely to get us the required reductions in emissions. As such, we will also examine potential low-carbon gases and

[2] Committee on Climate Change, *Net Zero: The UK's contribution to stopping global warming*, May 2019. At https://www.theccc.org.uk/wp-content/uploads/2019/05/Net-Zero-The-UKs-contribution-to-stopping-global-warming.pdf.

what they can mean for the gas system. Finally we discuss the barriers to moving to a lower emissions gas system and potential opportunities for the future.

Case Study: Climate change policies in Canada

There are a mix of federal and provincial climate change policies in Canadas.

Federal policies

Pan-Canadian Framework

In the Pan-Canadian Framework on Clean Growth and Climate Change (PCF), the federal government has set targets of reducing greenhouse gas (GHG) emissions by 30% by 2030 and by 80% by 2050 from 2005 levels. Achieving these targets and successfully lowering emissions will require a number of changes and investments across the energy sector.

There are a number of components within the PCF, including methane regulations and the phasing out of coal-fired power. The two key elements for this paper are the federal carbon pricing system and the Clean Fuel Standard.

Federal carbon pricing

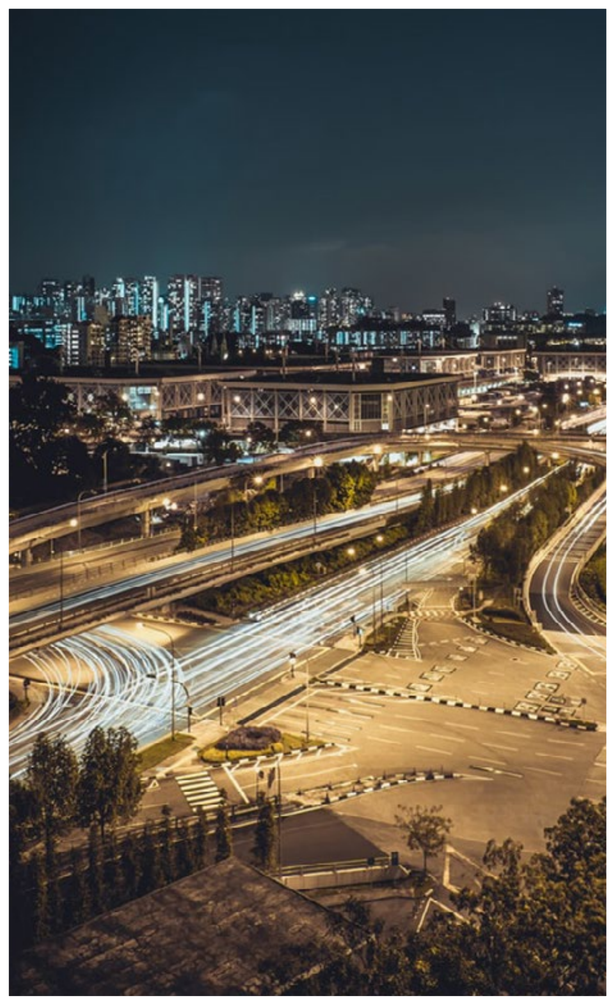
The federal carbon pricing system that applies to provinces and territories that do not have a comparable carbon pricing system has two parts:

- a trading system for large industry, known as the output-based pricing system
- a regulatory charge on fuel based on the carbon content.

The federal carbon price started at $10 per tonne in 2018, and will rise by $10 per year to reach $50 per tonne in 2022.[3]

Clean Fuel Standard

The Clean Fuel Standard (CFS) aims to reduce the GHG footprint of fuels. The CFS is a performance-based policy and is intended to incentivize the use of low-carbon energy sources such as renewable fuels, including renewable natural gas, hydrogen and electricity, depending on the jurisdiction profile. This is achieved by setting lifecycle GHG intensity requirements for liquid, gaseous and solid fuels that become stricter over time. “Regulated parties,” suppliers of fossil fuels including utilities, will need to comply with the CFS through lowering the GHG emissions profile of their fuels, by investing in technologies that lower their current GHG profile, substituting for low-GHG fuels, or through fuel switching to a lower GHG fuel stream in some cases, such as transportation. Suppliers can also purchase credits on a CFS credit market to meet their targets. The CFS is expected to come into force in 2022 for liquid fuels, and regulations for gaseous and solid fuels are still under development and are expected to come into force in 2023.[4]



[3] Government of Canada, *How we’re putting a price on carbon pollution*. At https://www.canada.ca/en/environment-climate-change/services/climate-change/pricing-pollution-how-it-will-work/putting-price-on-carbon-pollution.html.

[4] Government of Canada, *Clean Fuel Standard,* March 2019. At https://www.canada.ca/en/environment-climate-change/services/managing-pollution/energy-production/fuel-regulations/clean-fuel-standard.html.

Provincial and territorial policies

Some provinces and territories have introduced their own complementary climate change policies. Below are two examples.

CleanBC

CleanBC is the BC government's action plan that aims to reduce climate pollution while promoting the development of jobs and economic opportunities for people, businesses and communities. The plan prioritizes shifting from fossil fuels to cleaner electricity, such as hydropower, and other renewable energies, enhancing energy efficiency solutions, and having BC be a destination for low-carbon investments and industry.

The BC government has set a 40% reduction target by 2030 from 2007 levels, increasing to 60% by 2040 and 80% by 2050. In addition, the government is promoting the electrification of upstream gas production and setting a target of 15% of natural gas supplied to come from renewable gas by 2030.[5]

Politique énergétique 2030

The Quebec government has set ambitious 2030 targets, including:

- increase energy efficiency by 15%
- reduce petroleum products consumption by 40%
- increase renewable energy output by 25%
- increase bioenergy production by 50%.

Based on the government's targets, Transition énergétique Quebec, the Quebec energy transition agency, has established interim 2023 targets that include reducing fossil fuel use in heating.[6] The newly elected government recently went further, announcing plans to increase electrification, including for heating and in industry.[7]

[5] BC Government, *CleanBC*, March 2019. At https://cleanbc.gov.bc.ca/.
[6] Transition énergétique Québec, *Energy Transition Master Plan*, 2019. At https://transitionenergetique.gouv.qc.ca/en/energy-transition-master-plan.
[7] Philip Authier, "François Legault presents electric vision of Quebec's green future," *Montreal Gazette*, May 26, 2019. At https://montrealgazette.com/news/quebec/francois-legault-presents-electric-vision-of-quebecs-green-future.

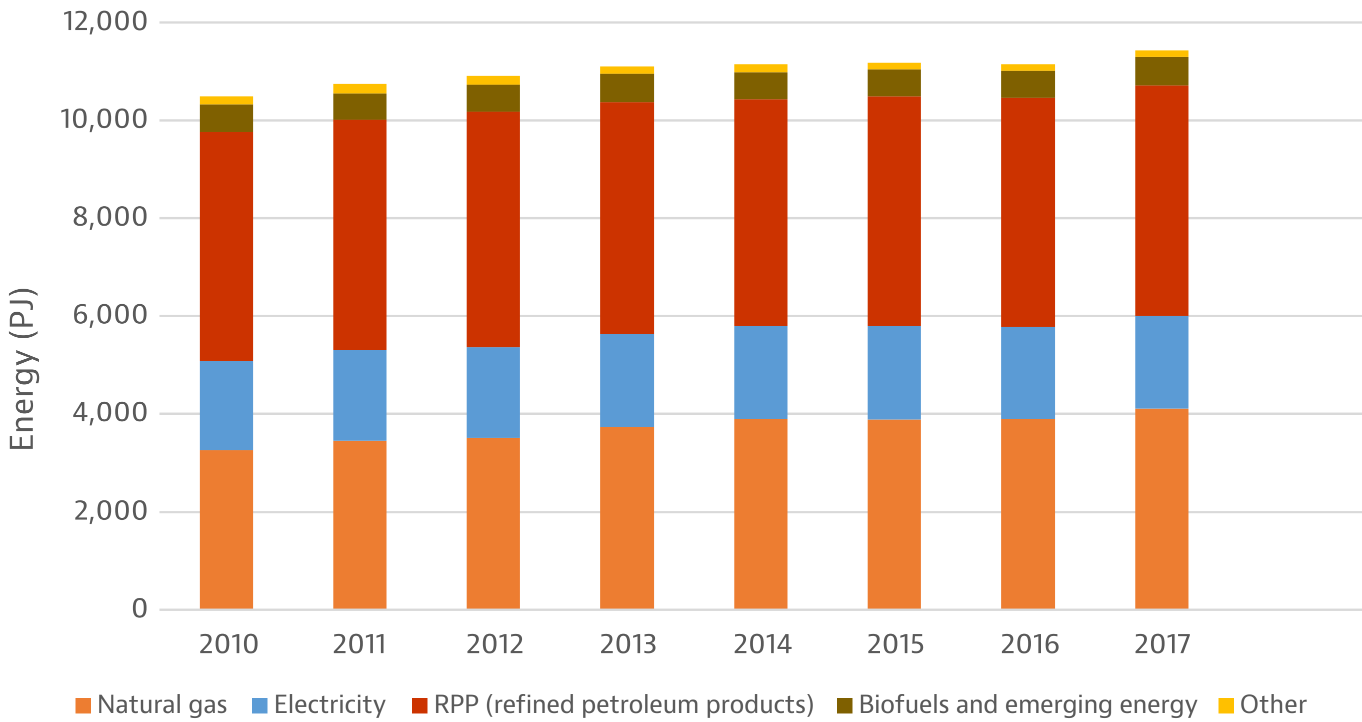
CHAPTER 2: **HOW WE USE NATURAL GAS**

2.1 Regional overview

Canadians rely on a diverse mix of energy sources, both renewable and non-renewable. Canada is the eighth largest consumer of energy and fifth largest producer of energy globally.[8] This places Canada as a significant net exporter of energy which will necessitate more diversification of policy, technologies and infrastructure used to achieves a low-carbon economy. In 2016, natural gas accounted for nearly one-third of Canada's secondary energy use, 4,107 petajoules (PJ) out of a total of 11,433 PJ.[9]

Total secondary energy increased by just over 8% between 2010 and 2017. In that same period natural gas experienced one of the fastest growth rates, approximately 20% (see Figure 1).

Figure 1: Canada's secondary energy use (final demand) by energy source, 2010-2017[10]



8 Natural Resources Canada, *Energy*, October 2017. At https://www.nrcan.gc.ca/earth-sciences/geography/atlas-canada/selected-thematic-maps/16872.
9 Secondary energy use accounts for the energy used by final consumers in the economy. It avoids the transformation losses from primary energy use.
10 Canada Energy Regulator, "End-Use Demand," *Canada's Energy Future 2018: Energy Supply and Demand Projections to 2040*, 2017. At https://apps.cer-rec.gc.ca/ftrppndc/dflt.aspx?GoCTemplateCulture=en-CA.

But where exactly is natural gas used? Figure 2 shows a breakdown of natural gas use by province and territory over time and Figure 3 shows a regional comparison of 2016 levels.

Figure 2: Natural gas energy use by province and territory, 2005 – 2016 [11]

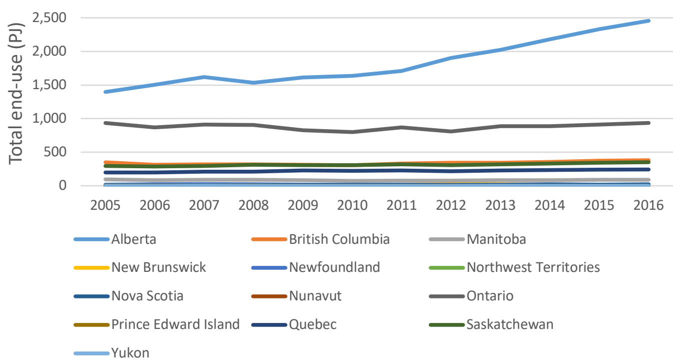
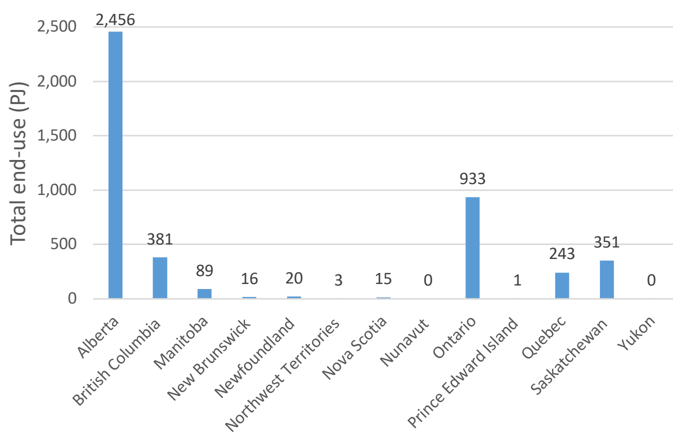


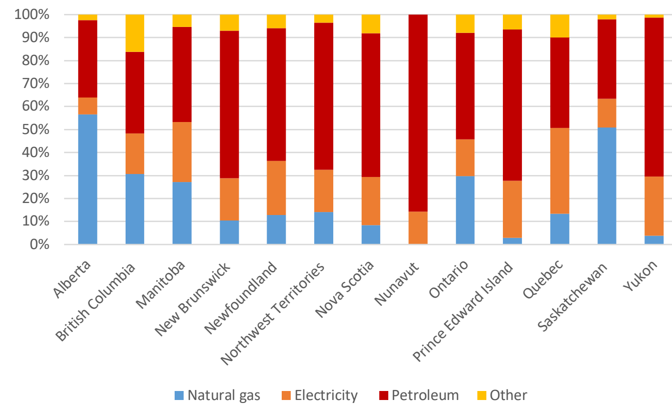
Figure 3: Natural gas energy use by province and territory, 2016 [12]



Figures 2 and 3 highlight the regional variations and the difference in magnitude of natural gas use between the provinces and territories, with Alberta and Ontario using the most in 2016. Alberta and Ontario are the two largest users of natural gas, collectively accounting for around 80% of all consumption.[13] What the graph does not show is which sectors the natural gas is used in and how reliant each region is.

Figure 4 provides a better comparison of natural gas end use by regions across Canada. It can be seen that the importance of natural gas varies in the jurisdictions, from 50% of energy demand supplied through natural gas in Alberta and Saskatchewan, to around a third in Ontario and BC, to lower amounts in other provinces, depending on their connection to the natural gas network. As such a "one size fits all" policy for natural gas will not be possible, and will need to consider regional energy circumstances.

Figure 4: Share of fuel type in energy end use by province and territory, 2016 [14]



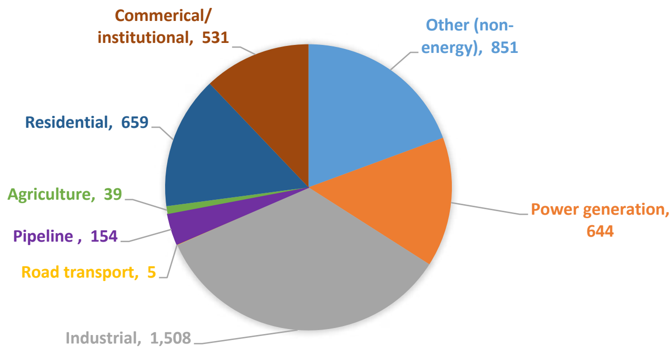
2.2 Natural gas use by sector

It's important to note that natural gas provides a number of different energy services. While it may be linked in many peoples' minds to their monthly gas bill for heating, there are many other services it provides. Figure 5 shows the breakdown of natural gas use by sector across Canada. The industrial sector is the largest user of natural gas, a sector which also includes the use of natural gas in oil and gas exploration and development. Non-energy uses, such as for fertilizer production, is the second largest. Taking commercial and residential together, over a quarter of natural gas is used by people and companies for heating and hot water or for steam.

While Figure 5 shows the natural gas use by sector across all of Canada, it is important to clarify that this breakdown varies for each province and territory.

[11] Canada Energy Regulator, "End-Use Demand," *Canada's Energy Future 2018: Energy Supply and Demand Projections to 2040*, 2017. At https://apps.cer-rec.gc.ca/ftrppndc/dflt.aspx?GoCTemplateCulture=en-CA.
[12] Canada Energy Regulator, "End-Use Demand," *Canada's Energy Future 2018: Energy Supply and Demand Projections to 2040*, 2017. At https://apps.cer-rec.gc.ca/ftrppndc/dflt.aspx?GoCTemplateCulture=en-CA.
[13] Canada Energy Regulator, "End-Use Demand," *Canada's Energy Future 2018: Energy Supply and Demand Projections to 2040*, 2017. At https://apps.cer-rec.gc.ca/ftrppndc/dflt.aspx?GoCTemplateCulture=en-CA.
[14] Canada Energy Regulator, "End-Use Demand," *Canada's Energy Future 2018: Energy Supply and Demand Projections to 2040*, 2017. At https://apps.cer-rec.gc.ca/ftrppndc/dflt.aspx?GoCTemplateCulture=en-CA.

Figure 5: Natural gas demand by sector in PJ, 2017 [15]



2.2.1 How industry uses natural gas

Natural gas is used to create process heat and generate steam for industrial activities as well as for oil production in Saskatchewan and Alberta. For many of these industrial applications, high temperatures are needed and hence controlled combustion, which is difficult to replace with electricity, is required. In addition to its energy use, natural gas can also act as a feedstock for the production of petrochemicals, plastics and fertilizers. Figure 6 provides a breakdown by industrial activity.

While not covered in this report, natural gas has also increasingly played a role in electricity generation, leading to reduced emissions when it has displaced coal. This is expected to continue in Alberta, Saskatchewan, and east of Quebec, especially with the federal coal phase out regulations. In Ontario it is used in "peaking plants" that are needed to meet high-demand days, most commonly during hot summer months.

Figure 7 shows the regional differences between fuel types used in the industrial sector.

Alberta and Saskatchewan use natural gas to fuel over 60% of their industrial sector, with the majority of it used for mining (including developing oil and gas) and petroleum refining. Much of this is for mining (including oil and gas) and petroleum refining, with 78% of industrial natural gas demand in Alberta and 74% in Saskatchewan used in those sectors.[16] In Saskatchewan, for example, industrial demand for natural gas is three times that of its commercial and residential loads combined.[17]

Figure 6: Natural gas demand by industrial sector in PJ, 2017[18]

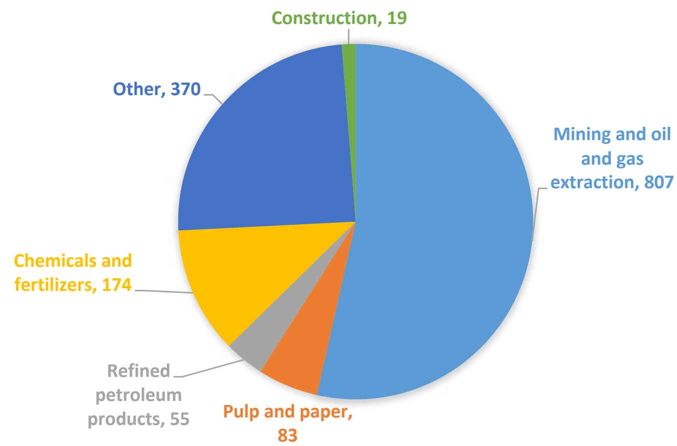
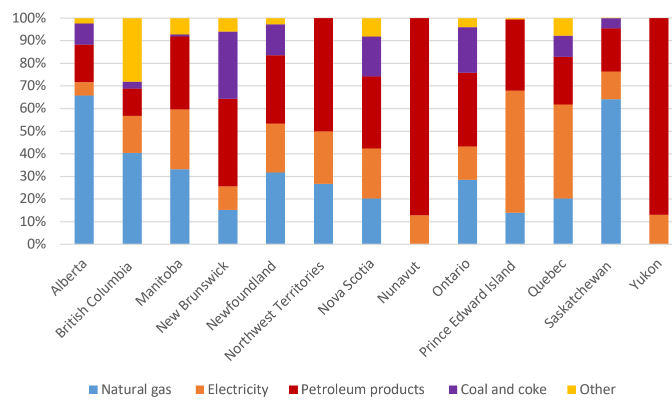


Figure 7: Share of fuel type in industrial use by province and territory, 2016 [19]



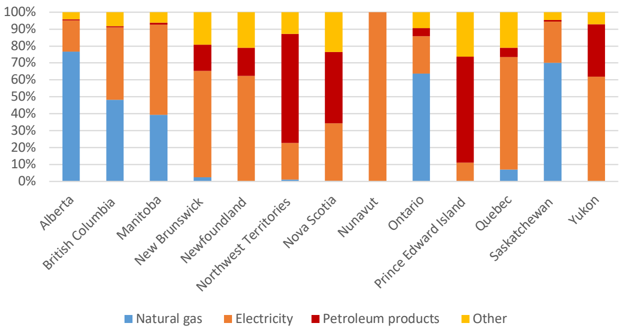
2.2.2 How the commercial and residential sectors use natural gas

In the residential and commercial sectors, natural gas is mainly used for space and water heating, as well as for cooking and other activities. In the commercial and institutional sector, in addition to space and water heating, natural gas is used for steam production in institutional facilities such as hospitals.[20]

On the residential side, natural gas plays a large role as a fuel source for many provinces and territories (Figure 8).

15 Statistics Canada, *Supply and demand of primary and secondary energy in terajoules, annual*, May 2019. At https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=2510002901.
16 Natural Resources Canada, *Comprehensive Energy Use Database,* 2016. At http://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/menus/trends/comprehensive_tables/list.cfm.
17 Information provided by SaskEnergy.
18 Statistics Canada, *Supply and demand of primary and secondary energy in terajoules, annual*, May 2019. At https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=2510002901.
19 Canada Energy Regulator, "End-Use Demand," *Canada's Energy Future 2018: Energy Supply and Demand Projections to 2040*, 2017. At https://apps.cer-rec.gc.ca/ftrppndc/dflt.aspx?GoCTemplateCulture=en-CA.
20 Natural Resources Canada, *Natural Gas: A Primer*, November 2015. At https://www.nrcan.gc.ca/energy/natural-gas/5641#why.

Figure 8: Share of fuel type for residential energy end use by province and territory, 2016 [21]



Around 80% of residential energy use is for space and water heating (see Figure 9). Each province has different mixes of energy that are used for heating, but many provinces rely heavily on natural gas (see Figure 10), and in aggregate over half of the space and water heating in Canada comes from natural gas. For commercial energy end use (Figure 11) natural gas still plays a critical role, again primarily for space and water heating.

Figure 9: Residential appliances energy use (PJ), 2016 [22]

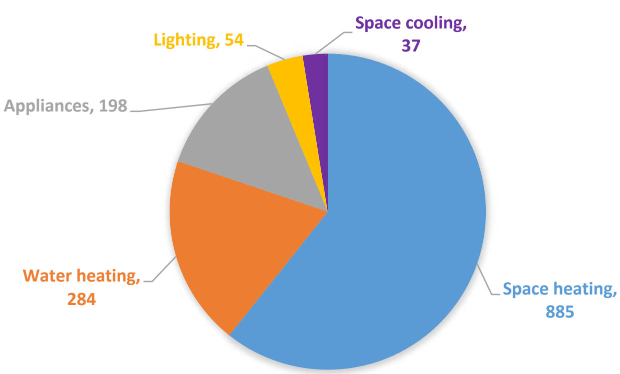


Figure 10: Share of fuel types for heating by province, 2018 [23]

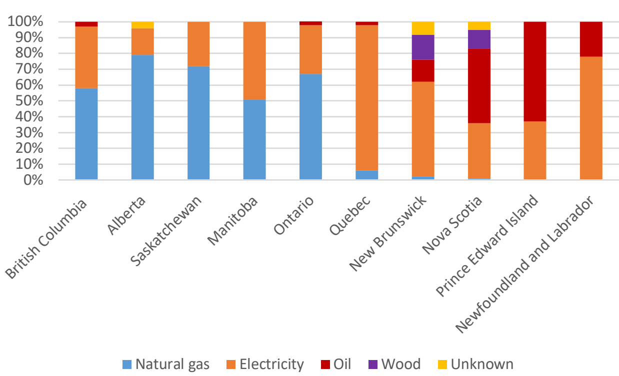
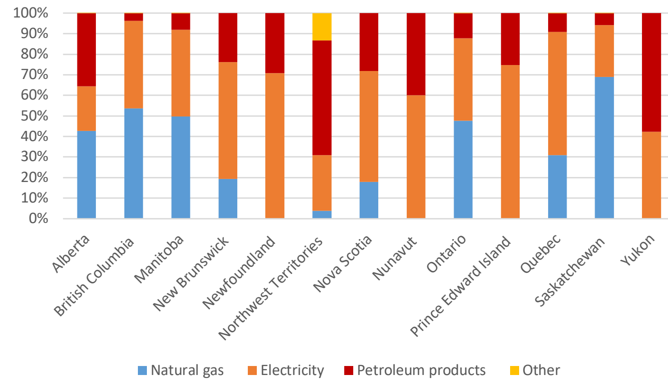


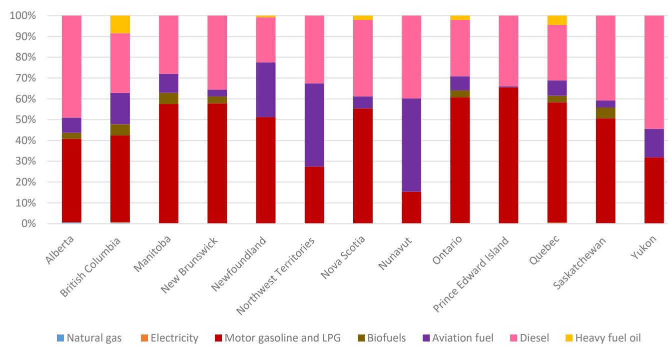
Figure 11: Share of fuel types for commercial energy end use by province and territory, 2016 [24]



2.2.3 How the transportation sector uses natural gas

Natural gas also currently has a role in the transportation sector as an alternative fuel source but this is still quite low compared to the other sectors (Figure 12).

Figure 12: Share of fuel type in transportation energy end use by province and territory, 2016 [25]



[21] Canada Energy Regulator, "End-Use Demand," *Canada's Energy Future 2018: Energy Supply and Demand Projections to 2040*, 2017. At https://apps.cer-rec.gc.ca/ftrppndc/dflt.aspx?GoCTemplateCulture=en-CA.
[22] Natural Resources Canada, *Residential Sector - Energy Use Analysis*, 2018. At http://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/showTable.cfm?type=AN&sector=res&juris=00&rn=11&page=0.
[23] Data was unavailable for the Northwest Territories. Statistics Canada, *Table 25-10-0060-01, Household energy consumption, Canada and provinces*. At https://doi.org/10.25318/2510006001-eng.
[24] Canada Energy Regulator, "End-Use Demand," *Canada's Energy Future 2018: Energy Supply and Demand Projections to 2040*, 2017. At https://apps.cer-rec.gc.ca/ftrppndc/dflt.aspx?GoCTemplateCulture=en-CA.
[25] Canada Energy Regulator, "End-Use Demand," *Canada's Energy Future 2018: Energy Supply and Demand Projections to 2040*, 2017. At https://apps.cer-rec.gc.ca/ftrppndc/dflt.aspx?GoCTemplateCulture=en-CA.

CHAPTER 3: SORTING OUT THE PROS AND CONS

3.1 Advantages of natural gas: Flexibility and costs

There are good reasons why natural gas is such as widely used energy source in Canada: natural gas provides for flexibility in the energy system at a low cost.

3.1.1 Flexibility

Canada has already developed a large system of gas pipelines, compressor stations and storage units across the country. There are over 570,000 kilometres of underground natural gas transmission, distribution and service lines that currently connect to over 7.1 million customer locations across the country. Since 2005, over $25 billion has been invested into the natural gas network.[26] According to calculations by Enbridge Gas, the natural gas transmission and distribution system in Ontario has a book value of $16.3 billion.[27]The natural gas networks have proven to be extremely reliable, partially due to being predominately underground and can still function during electricity power outages.

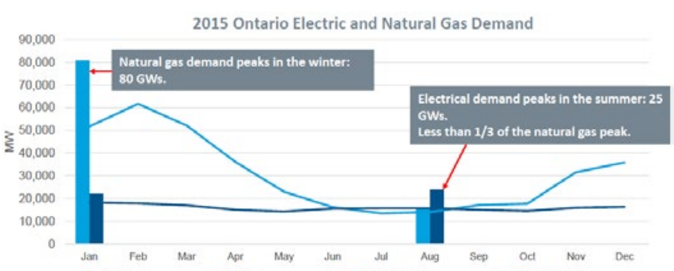
The ability to store natural gas for extended periods of time is a significant advantage for flexibility and reliability. Canada has existing gas storage for 27 billion m^3 of gas, which in energy terms is equivalent to approximately 1,000 PJ – just under a quarter of annual natural gas end-use, or over half of the annual electricity consumption. Through storage alone Canada can meet 63 days' worth of natural gas winter demand. Over half the storage is located in Alberta, a quarter in Ontario, and the remainder throughout the country.[28] Linepack, the volume of natural gas that can be stored in a pipeline, also enhances the storage capability of natural gas and increases flexibility of fuel use.

[26] Canada Gas Association, *Canada's 2019 Natural Gas Solutions*, March 2019. At http://www.cga.ca/wp-content/uploads/2019/04/Canadas-Natural-Gas-Solutions-EN-Final.pdf.
[27] Enbridge Gas, *2017 LTEP Submission*, December 16, 2016.
[28] Canada Energy Regulator, *Market Snapshot: Where does Canada store natural gas?,* May 23, 2018. At https://www.cer-rec.gc.ca/nrg/ntgrtd/mrkt/snpsht/2018/05-03whrdscncstrngrlgs-eng.html. Conversion based on CER conversion factors, available at https://apps.cer-rec.gc.ca/Conversion/conversion-tables.aspx?GoCTemplateCulture=en-CA#s1ss2.

Energy needs in Canada are weather dependent due to our cold climate, and the energy demands during the coldest days of the year are immense. It is also "peaky" – in that the energy need can vary dramatically depending on the weather. Gas storage provides flexibility to meet this heating demand very quickly.

As an example of the seasonality in natural gas demand, we can look at Ontario. In 2015 natural gas demand in Ontario peaked in January at around 80 GW, primarily due to the need for heating. In comparison, the summer electricity peak (mostly due to cooling loads) was less than 25 GW (see Figure 13). While not a direct comparison due to various conversion factors, it does highlight the difficulty in replacing the natural gas alone with electricity. Apart from the extra electricity generation required, the electricity transmission and (especially) the distribution system would have to be significantly expanded to meet higher peak demand if there were fuel switching. Timelines are crucial here as well. If the electricity system were expanded to meet the demands supplied by natural gas, it could take years, even decades to build the necessary infrastructure. The costs to do this could be enormous, and if the generation built were natural-gas fired, there would be no benefit to electrification, and it could in fact increase emissions as gas-fired generation is not as efficient as modern natural gas furnaces.

Figure 13: 2015 Ontario electric and natural gas demand [29]



It is not just Canada where this seasonal heating peaks are seen. A paper from the UK Energy Research Council examined the role of natural gas during a severe winter weather storm. The storm on March 1, 2018, accounted for a peak demand on the local natural gas system of 214 GW, compared to an electricity peak of 53 GW during the same period. The flexibility in the natural gas system and reliability in having below ground infrastructure allowed for UK residences to retain energy services during the storm.[30] With increasing severe weather events impacting the electricity delivery systems, this is an important consideration when deciding on the future of how to use the gas system.

3.1.2 Cost

Natural gas is also currently a cost-effective energy source, possibly one of the most cost-effective sources of energy widely available. Given the negative effects of energy poverty on health, and it has been shown that lack of affordable heating leads to an increase in mortality,[31] the current costs of natural gas is a major benefit.

Natural gas is currently around 4-5 times less expensive than electricity. For example, in 2015, in Ontario 270 TWh of energy was supplied through the gas system at a cost of $7.7 billion, or roughly a delivered cost of $30/MWh ($8/GJ), including all network and regulatory fees. In comparison, Ontario's electricity system has a book value over $70 billion, and in 2015 supplied $20.5 billion of energy, at a cost of $142.5/MWh ($40/GJ).[32] And this is not just in Ontario. In Alberta, the average price for delivered electricity (including all network fees) is approximately $100/MWh ($28/GJ). In comparison, the delivered cost of natural gas, again including all network and regulatory fees and including carbon pricing, is around $20/MWh ($6/GJ).[33]

In addition, as mentioned above, the ability to cost-effectively store natural gas for long durations provides for long-term flexibility and keeps costs down. As such, it could be more cost-effective to decarbonize the gas system than build out the electricity supply.

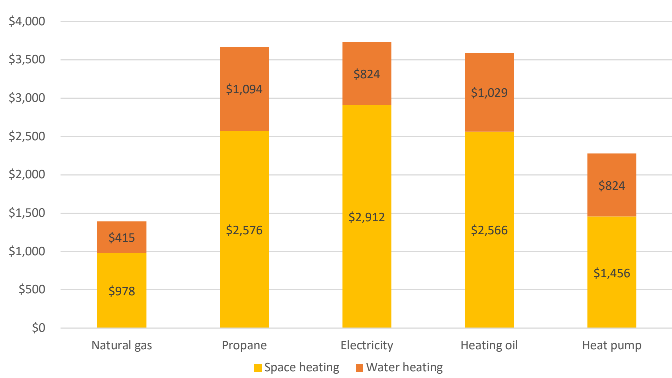
The cost-effectiveness of natural gas can be seen in looking at the average cost in Canada of residential space and water heating for different energy sources, as outlined in Figure 14. The numbers would vary

[29] Enbridge Gas, *2017 LTEP Submission*, December 16, 2016.
[30] Grant Wilson, Ramsay Taylor and Paul Rowley, UK Energy Research Council, *Challenges for the decarbonisation of heat: local gas demand vs electricity supply Winter 2017/2018*, August 2018. At http://www.ukerc.ac.uk/publications/local-gas-demand-vs-electricity-supply.html.
[31] Janjala Chirakijja, Seema Jayachandran, and Pinchuan Ong, *Inexpensive Heating Reduces Winter Mortality*, June 27, 2019. At http://faculty.wcas.northwestern.edu/~sjv340/heating_mortality.pdf.
[32] Enbridge Gas, *2017 LTEP Submission*, December 16, 2016.
[33] Information provided by ATCO.

greatly by jurisdiction, especially those that use legacy hydropower, such as Quebec, to deliver low-priced electricity, but generally speaking on an energy equivalent basis electricity is more expensive than natural gas, at least for residential customers.

Although carbon pricing may change this, the price on carbon would have to rise dramatically to reduce the cost differentials with alternative energy sources. With the current price of natural gas at near $3/GJ, the carbon price would need to rise to at least $60/tonne for a conservative estimate of when natural gas prices would become equitable to electricity prices for space and water heating in provinces like Quebec with a decarbonized electricity grid.[34] Based on the Ontario electricity prices the carbon price would need to range from $300 to $700 per tonne depending on the time of use prices.

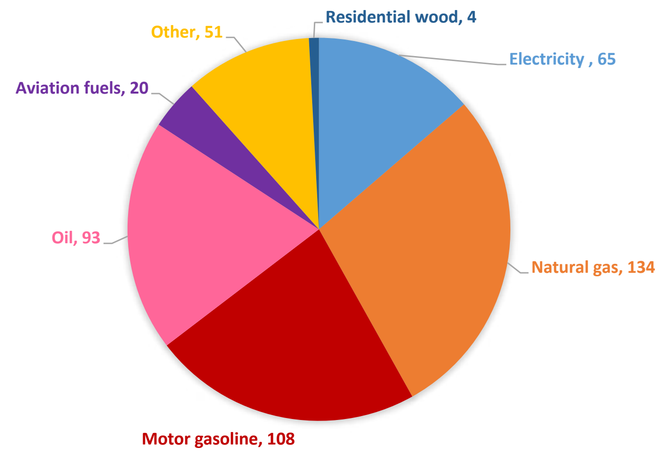
Figure 14: Residential space and water heating costs – Canada 2017 ($ per year) [35]



3.2 Disadvantages of natural gas: Emissions

While natural gas is the cleanest fossil fuel at the point of combustion, it is still a significant source of GHG emissions. In line with natural gas supply, roughly one-third of Canada's secondary energy use (final demand), it is responsible for 28% of the total 475 Mt CO_2e emissions from the end-use of energy (see Figure 15).

Figure 15: GHG emissions by end-use energy source (Mt CO_2e) [36]



3.3 Challenges in replacing natural gas

Given the need to decarbonize our energy systems, and the progress made in reducing emissions from electricity generation, some jurisdictions are also looking into phasing out the use of natural gas entirely, and moving to full electrification. Berkeley, California, became the first city in the US to ban natural gas from new low-rise buildings starting in January 2020, with the ban extending to larger buildings later. Another 50 cities in California are considering similar measures, however they have generally lower heating requirements than in Canada.[37] New Jersey and Maine are considering state-wide policies restricting new natural gas.[38]

Urban areas are already seeing large increases in electricity demand due to urbanization and densification. For example, in Toronto, there is currently work proposed to increase the capacity of the electricity system in many areas of growth.[39] Other urban areas are seeing similar phenomena, and this is before the expected increase in the electrification of transportation is factored in.

Peak demand on energy systems is a large driver of costs and the need for investment. Natural gas and electricity systems are built to accommodate peak

[34] Assuming that the electricity grid is non-emitting and carbon pricing does not affect the cost of electricity. Based on carbon pricing calculations available at Canada Energy Regulator, *Canada's Energy Future 2017: Energy Supply and Demand Projections to 2040 – Chapter 2:Key Assumptions*, 2017. At https://www.cer-rec.gc.ca/nrg/ntgrtd/ftr/2017/chptr2-eng.html?=undefined&wbdisable=true.
[35] Canadian Gas Association, *Gas Stats*, 2017. At http://www.cga.ca/gas-stats/.
[36] Natural Resources Canada, *Canada's Secondary Energy Use (Final Demand) and GHG Emissions by Energy Source*. At http://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/showTable.cfm?type=HB&sector=aaa&juris=ca&rn=1&page=0.
[37] Sarah Ravani, "Berkeley becomes first U.S. city to ban natural gas in new homes," *San Francisco Chronical*, July 21, 2019. At https://www.sfchronicle.com/bayarea/article/Berkeley-becomes-first-U-S-city-to-ban-natural-14102242.php?psid=e4OA4.
[38] Amanda Myers, "As Cities Begin Banning Natural Gas, States Must Embrace Building Electrification Via Smart Policy", *Forbes*, July 22, 2019. At https://www.forbes.com/sites/energyinnovation/2019/07/22/as-cities-begin-banning-natural-gas-states-must-embrace-building-electrification-with-smart-policy/#65fc5aab6ce6.
[39] Toronto Hydro, *Custom Incentive Rate-setting ("Custom IR") Application for 2020-2024 Electricity Distribution Rates and Charges*, August 2018. At https://www.torontohydro.com/documents/20143/63725/CIR2020-Consolidated-Application.pdf/a19245b5-bb5c-15fe-e9ec-599d5644915c?t=1558718500465.

demand for their energy, which, for natural gas, is the coldest day of the year. In much of Canada the electricity system is designed for the hottest day of the year to run air conditioning systems. If electricity is substituted for gas, electricity peak demand will increase to meet the peak winter heating demands currently supplied by natural gas. Meeting this new peak would require large investments in the electricity grid across the country to accommodate the increased demand in the winter months.

There are two examples of studies that tried to quantify the potential costs of electrification that could be of relevance to Canada.

First, an ICF study on the gas system in the north-eastern USA provides a good example of the issues for moving from gas to electricity. In their study, they examined three scenarios for 2050:

- A "cost-efficient decarbonisation" scenario that includes low-carbon gases and provides a 50% reduction in emissions, and would increase energy costs for each household $200 a year
- A "low-carbon fuel priority" scenario that provides an 80% reduction in emissions, includes natural gas and low-carbon gases, and would increase energy costs for each household $1,200 a year
- An "electrification priority" scenario that provides an 80% reduction in emissions, would compel a switch to electricity from natural gas, and would increase energy costs for each household $2,000 a year.

The primary reason for the increase in costs for the electrification scenario is that electrification of space and water heating would increase electricity peak by 55%, and shift the peak from summer to winter.[40]

The Canadian Gas Association (CGA) has completed its own assessment of the potential costs of policy-driven electrification in Canada to 2050.

Table 1 below compares two scenarios from the CGA report that both offer GHG reductions of 47% by 2050. Scenario 2, "Renewables and Existing Gas", assumes policy-driven electrification with a switch to air-source heat pumps, and that all new electricity generation will be renewables, with existing gas-fired generation continuing. Scenario 4, "Integrated Energy Systems," assumes switching to air-source heat pumps with natural gas heating backup. This scenario also did not expect large deployment of low-carbon gases much beyond existing commitments.

As can be seen, the electrification scenario sees a much higher cost of meeting the same GHG reduction, primarily due to the need for increased electrical generating capacity, and almost double the peak demand in the electrification scenarios versus the Integrated Energy Systems scenario.[41]

[40] ICF, *The role of natural gas utilities in a decarbonizing world: Webinar*, 2019. At https://www.icf.com/resources/webinars/2019/gas-utilities-in-a-decarbonizing-world,

[41] ICF, *Implications of Policy-Driven Electrification in Canada: A Canadian Gas Association Study*, October 2019. At http://www.cga.ca/.

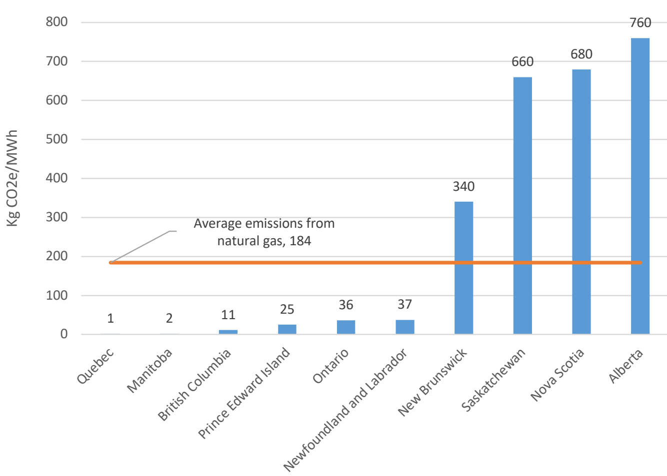
Table 1: Comparison of two scenarios from CGA report on electrification

Scenario	Overview	Total costs to 2050	GHG reduction	Costs of emissions reductions (/tonne CO_2e)	Incremental electricity capacity required
Renewables and Existing Gas (Scenario 2)	Electrification and no new natural gas	$1,330 billion	47%	$291	232 GW
Integrated energy solutions (Scenario 4)	Heat pumps with natural gas backup	$580 billion	47%	$128	108 GW

These two studies are not the only ones with similar findings. In other studies done in the UK, Europe and the USA, the costs for moving to full electrification were substantially higher than for decarbonizing the gas system (see Table 2).

In addition, while great progress has been made on decarbonizing the electricity system, there are still regional differences when it comes to generation intensity, or the amount of GHGs emitted per unit of electricity generated. As shown in Figure 16, New Brunswick, Saskatchewan, Nova Scotia and Alberta all have electricity generation intensities that exceed those of natural gas. This is based on average emissions, and doesn't take into account marginal emissions when demand is high, which in many jurisdictions comes from natural-gas fired electricity generation and would affect these figures.

Figure 16: Electricity generation average emissions intensity with comparison to natural gas intensity [42]



As discussed above, if electrification were to increase to cover other sectors, such as heating, electricity system costs would need to increase significantly to cover the additional costs of building the required new infrastructure to meet the additional electricity demand that is currently supplied through the gas networks. The natural gas system thus provides a valuable economic support service to the electricity system.

Therefore, continuing to use the gas system in the future provides a number of benefits:

- Continued reliability and resiliency
- Using the storage capacity to provide flexibility for meeting changing energy needs, seasonal variations, and to provide for peak energy demand in the winter in a short time frame
- Maximise the use of existing infrastructure, thereby reducing the need for additional costly and potentially socially unacceptable energy infrastructure
- Ability to switch loads between the electricity and gas systems to best manage real-time emissions and reduce high-emitting marginal generation.

We will need to consider how, when and where we use natural gas if Canada is to meet its emissions targets and transition to a low-emissions economy. The natural gas industry, regulators and governments in Canada in the future cannot rest on natural gas's status as a cleaner alternative to other fossil fuels and a low-cost provider of energy. It is clear that the utility sector understands these concerns and is looking into how it can play a larger role in the future low emissions energy system. Yet current government

[42] Information provided by Heritage Gas and Government of Canada, *Canada's official greenhouse gas inventory,* 2019. At https://www.canada.ca/en/environment-climate-change/services/climate-change/greenhouse-gas-emissions/inventory.html.

policy and regulatory proceedings are potentially holding the sector back from reaching its full potential contribution to the low-emission future. As the sector considers its future role, it will have to balance the three factors of costs, GHG impacts and increasing social acceptance issues. Trade-offs are inevitable. How this balancing plays out and the criteria used to judge the alternative solutions will determine the future pathway of the natural gas system and how – or if – it will play a supporting role in Canada's transition to a low-emissions energy system by 2050.

The next section of this report will look into potential future pathways for the natural gas system. First, regardless of any future pathway, immediate reduction in emissions, and increasing affordability, could be achieved through a more efficient use of natural gas. This could also buy time to consider lower emissions alternatives.

Regardless of how efficiently Canada uses natural gas, at some point the gas system will need to be progressively decarbonized to meet GHG targets. Chapter 5 looks at low-carbon gases and how they could reduce the carbon intensity of the gas used in Canada. Chapter 6 examines the barriers to the transition, and chapter 7 highlights next steps.

Table 2: Summary of studies comparing costs of decarbonizing the gas system or electrification

Jurisdiction	Organization	GHG Target	Costs[43]	Commentary and implications for Canadian systems
Northeast USA	ICF	80% below 2005 levels by 2050.	"Cost-Efficient Decarbonisation", 50% reduction at an increase of US$200 (C$266) per household per year; "Low Carbon Fuel Priority" reduces emissions by 80% at an increase of US$1,200 (C$16,00) per household per year; "Electrification Priority" reduces emissions by 80% at an increase of US$2,000 (C$2,660) per household per year	Evaluated three scenarios: "Cost-Efficient Decarbonisation" would continue use of the natural gas system with low-carbon gases; "Low Carbon Fuel Priority" would reduce emissions by 80% and have a higher percentage of low-carbon gases; "Electrification Priority" would reduce emissions by 80% and shift most households to electricity space and water heating. The study found that renewable natural gas has a cost equivalent to a carbon price of $100 a tonne.[44]
Canada	ICF for the Canadian Gas Association	25-52% by 2050	Three electrification scenarios have costs of $990-1,370 billion by 2050. Integrated energy systems scenario with gas backup has a cost of $990 billion by 2050	Evaluated four scenarios, three with policy-driven electrification looking at three different deployment scenarios of non-emitting generation, from all renewable to a market-driven mix. The Integrated Energy Systems scenario uses natural gas a backup, and limited low-carbon gas deployment by 2050 (10% by 2050 in Quebec, 15% in BC, and 10% in rest of Canada). The Integrated Energy Systems scenario has a 47% reduction in GHG from baseline.[45]
Europe	Gas for Climate[46]	Net zero by 2050	€217 billion (C$328 billion) annual savings in 2050 with optimized gas scenario that uses low-carbon gas	The study concluded that 1) full decarbonisation would require substantial amounts of renewable electricity; 2) it is possible to scale up renewable gas; biomethane, power-to-methane, and hydrogen at reduced production costs; 3) battery seasonal storage is unrealistic even at reduced costs and hydrogen is a cost effective option.[47]
UK	Energy Networks Association	UK's 2050 GHG target of emission to equal 20% of 1990 levels.	Savings of £170-196 billion (C$294-339 billion) through using low carbon gases versus an all-electric future	Study concluded that to meet the UK's GHG target, use of the gas network and infrastructure offered a practical and affordable option. Convenience and reliability for heating solutions are important considerations in policy decisions. Recommended more detailed assessment of public acceptance of options and continuation with gas and heating innovation funding.[48]

43 Conversions based on average rate of the first six months of 2019. For US dollar to Canadian dollar, $1.33; for Euro $1.51; for UK Pound $1.73.
44 ICF, *The role of natural gas utilities in a decarbonizing world: Webinar*, 2019. At https://www.icf.com/resources/webinars/2019/gas-utilities-in-a-decarbonizing-world,
45 ICF, *Implications of Policy-Driven Electrification in Canada: A Canadian Gas Association Study*, October 2019. At http://www.cga.ca/.
46 Gas for Climate is an association of European gas network operators and biogas trade associations.
47 Navigant, *Gas for Climate: The optimal role for gas in a net-zero emissions energy system*, March 2019. At https://www.gasforclimate2050.eu/files/files/Navigant_Gas_for_Climate_The_optimal_role_for_gas_in_a_net_zero_emissions_energy_system_March_2019.pdf.
48 KPMG, *2050 Energy Scenarios: The UK Gas Networks Role in a 2050 Whole Energy System*, July 2016. At http://www.energynetworks.org/assets/files/gas/futures/KPMG%20Future%20of%20Gas%20Main%20report%20plus%20appendices%20FINAL.pdf.

Jurisdiction	Organization	GHG Target	Costs[43]	Commentary and implications for Canadian systems
US	American Gas Association	If new gas and propane space and water heating were replaced by electrical by 2023.	Electrification would cost US$1.2 trillion (C$1.6 trillion), versus US$590 billion (C$785 billion) for a market-based electrification that would allow some conventional gas	The study concluded that there would likely be many challenges to complete electrification, such as cost, electricity grid capacity and others. Residential GHG emissions predicted to be <5% of total GHG emissions in 2035. Full electrification would only reduce these emissions by 1.5% of total.[49]
Germany	Gas Value Chain/ EWI	80-95% reduction in GHG by 2050	Electrification would cost an addition €1 trillion (C$1.51 trillion), versus using low-carbon gas	This study focussed on power-to-gas as being the most likely option to achieve the deep decarbonisation targets. The study concluded that using the existing gas infrastructure is key to ensuring continued security of electricity supply. It also saw gas decarbonisation strategies as significantly less costly than solely electrification. However, seasonal demand patterns for gas will change.[50]
Pacific Northwest Pathways to 2050 - US	Oregon and Washington States	80% below 1990 levels across both states	Incremental costs by 2050: Gas Furnace Scenario: US$5 -10 billion (C$7-13 billion); Gas Heat Pump Scenario: US$3-11 billion (C$4-15 billion); Cold Climate Heat Pump Scenario: US$5-11 billion (C$7-15 billion); Electric Heat Pump Scenario: US$10-16 billion (C$13-21 billion)	Four different scenarios were evaluated: 1) "Gas furnace scenario": Gas continues to be used; 2) "Gas heat pumps": gas heat pumps becomes primary technology for space and water heating; 3) "electric heat pump" scenario; 4) "cold climate electric heat pump" scenario. In all scenarios it is assumed that electricity is almost entirely GHG free. In the gas scenarios, 25% of gas is renewable natural gas and hydrogen. Electrification requires additional 17-37 GW, which would be a doubling of the regions current non-emitting capacity. For gas scenarios, 11 GW of capacity required for hydrogen electrolysis.[51]
California	Navigant for SoCal Gas	40% below 1990 levels by 2030 and 80% below 1990 levels by 2050	Cumulative costs to 2030 for RNG options are in the range of US$73-87 billion (C$97-115 billion), electrification options US$92 112 billion (C$122-150 billion)	Study looked at how much GHG reductions could be achieved from building electrification versus use of renewable natural gas. Study found that by 2030, RNG delivered to residential and commercial customers would provide the same GHG reductions as electrification. In general renewable natural gas options have comparable or lower costs than electrification.[52]

[49] ICF, *Implications of Policy-Driven Residential Electrification: A Report for the American Gas Association*, July 2018. At https://www.aga.org/globalassets/research--insights/reports/AGA_Study_On_Residential_Electrification.

[50] Harald Hecking and Wolfgang Peters, *The underrated long-term relevance of gas in the decarbonizing German energy space*, Gas Value Chain/ EWI, October 2018. At https://www.ewi.uni-koeln.de/cms/wp-content/uploads/2018/10/ewi_ERS_GVC_Gas_in_the_decarbonizing_German_energy_space_Paper.pdf.

[51] Energy and Environmental Economics, *Pacific Northwest Pathways to 2050: Achieving an 80% reduction in economy-wide greenhouse gases by 2050*, November 2018. At https://www.ethree.com/wp-content/uploads/2018/11/E3_Pacific_Northwest_Pathways_to_2050.pdf.

[52] Navigant, *Analysis of the Role of Gas for a Low-Carbon California Future: Prepared for Southern California Gas Company*, July 24, 2018. At https://www.socalgas.com/1443741887279/SoCalGas_Renewable_Gas_Final-Report.pdf.

Case study: Renewable gas targets in Europe

Although every country, and even different parts of each country, face unique energy needs, we can look at what is happening in other jurisdictions to help better understand what issues may arise in Canada. European countries have set ambitious climate targets, and are evaluating the use of natural gas in their jurisdictions as shown in Table 2. It is important to note that most of Europe imports natural gas, and that costs for natural gas can be much higher than in most parts of North America, which will likely indicate different policies when compared to Canada.

The Netherlands's plan to eliminate conventional natural gas

Since the discovery of Groningen - one of Europe's largest natural gas fields - in 1959, the Netherlands has relied on natural gas, and as a result 85% of buildings, and 40-50% of industry rely on natural gas. [53]

However, an increasing number and magnitude of earthquakes over the last several years have been blamed on extraction and in 2018 a 3.4 magnitude earthquake struck, damaging tens of thousands of homes.[54]

In addition, the Dutch government has made various energy-related pledges and entered into a climate agreement to become 'climate-neutral'. Targets include the closure of all coal power plants by 2030, the elimination of natural gas production and the closure of the Groningen field by 2030, and the elimination of natural gas from the energy mix by 2050.

The country's Climate Accord aims to switch all buildings (7.7 million houses and 1 million other buildings) from natural gas by 2050. District heating from low-carbon fuels is expected to account for about 50% of heating load (from about 5% in 2019), with the remaining 50% from heat pumps, half of which will be all-electric and half hybrid, with renewable natural gas or hydrogen as a backup.

This means that by 2050, "the role of gas in the energy system is expected to become a combination of sustainable gases such as green gas and hydrogen, and in specific cases converted into methane. Natural gas will only be used when emissions can be captured." The government plans to increase taxes on natural gas, while simultaneously decreasing taxes on electricity, to encourage the transition.[55]

A 100% renewable gas mix in France by 2050

A study published by ADEME, GRDF and GRTgaz in France looked at the technical and economic feasibility of 100% renewable gas being used in mainland France.[56] The study presents four scenarios, three of which envision a 100% renewable gas mix. The four scenarios are:

- **100% Renewable and Recovered Energies (R&Ren)**: biomass and resource use are similar to ADEME's 2035-2050 scenario, substituting some of the wood and heat co-generation with gas.
- **100% R&REn with high pyrogasification**: the same as 100% R&REn, but renewable gas use is increased through higher production using pyrolysis with wood resources made available by the lesser development of wood-fired cogeneration and wood for heat networks. This scenario corresponds to a higher demand for gas.
- **100% R&REn with limited biomass for gas usages**: the same as 100% R&REn but with biomass resources limited to 80% of their potential. The objective is to assess the impact of resource mobilisation difficulties (e.g. under-estimated environmental impacts or social acceptability, etc.) and/or development difficulties of the less mature sectors.

[53] Karel Beckman and Jilles van den Beukel, *The great Dutch gas transition,* Oxford Energy, 2019. At https://www.oxfordenergy.org/wpcms/wp-content/uploads/2019/07/The-great-Dutch-gas-transition-54.pdf?v=f5c3020d846f

[54] Bart H. Meijer, "Dutch citizens demand end to quake-hit Groningen gas production," *Reuters*, 2019. At https://www.reuters.com/article/us-netherlands-gas-court/dutch-citizens-demand-end-to-quake-hit-groningen-gas-production-idUSKCN1PB0TD

[55] Vanand Meliksetian, "The Netherlands can't afford to keep its natural gas promise," *Oil Price*, 2018. At https://oilprice.com/Energy/Natural-Gas/The-Netherlands-Cant-Afford-To-Keep-Its-Natural-Gas-Promise.html

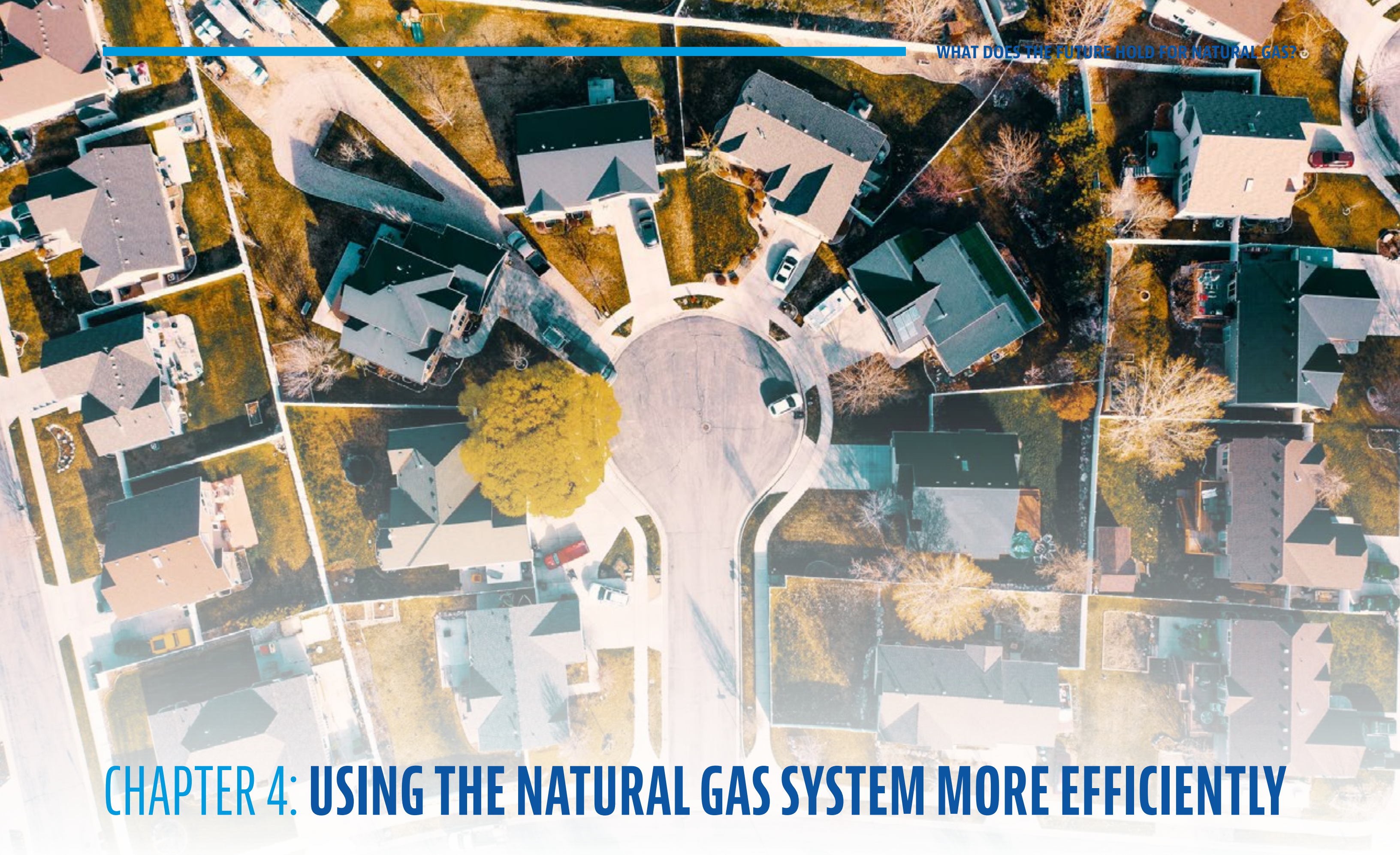
[56] ADEME, *A renewable gas mix in 2050?*, September 2018. At https://www.ademe.fr/sites/default/files/assets/documents/renewable-gas-mix-2050-010521.pdf.

- **75% R&REn**: biomass and resource usages are similar to ADEME's 2035-2050 scenario, natural gas represents 25% of final energy consumption.

According to all four scenarios, the theoretical potential of all injectable renewable gas is 460 TWh which could supply all of France's energy needs by 2050. The three different types of renewable gas production that are analyzed are methanisation (30%), pyrolysis (40%) and power-to-gas (30%). The estimated potentials of these types of production are based on available resources, none of which compete with raw materials and food sources.

The study found that approximately 63 Mt CO_2 a year of direct emissions would be saved with a 100% renewable gas mix and the cost would be between €116/MWh and €153/MWh (which includes the cost of production, storage, use and adaptation of the gas networks) for a gas demand of 276 and 361 TWh in 2050. Enhanced storage and a more decentralized management of the network will be necessary for the mass production of renewable gas.

A key factor highlighted in the study was the need to complement the advancement of the renewable natural gas system with the electricity system and renewable energy production so that they evolve together. It also considers how different solutions will work in different regions in France.



CHAPTER 4: USING THE NATURAL GAS SYSTEM MORE EFFICIENTLY

4.1 Conservation and energy efficiency

4.1.1 Overview

Reducing natural gas use through conservation and energy efficiency programs, including improving building envelope design, is crucial to help reduce energy bills, supply energy more sustainably and for Canada to meet GHG targets. It clearly makes sense that the first course of action should be to reduce demand as much as possible through conservation and energy efficiency.

Between 1990 and 2015, energy efficiency in Canada improved by about 26% and in 2015 alone saved Canadians about $38 billion.[57] In 2017, Canadian gas and electric utilities in total spent approximately $864 million in conservation and demand side measures, a 3% decrease from spending in 2016. The majority of the spending, 83%, was for electricity measures, with only $148 million spent on natural gas. However, spending on gas conservation measures has grown faster than electricity since 2010, with 2017 seeing a 3.5% increase in spending compared to 2016. About a third of that spending is dedicated to the residential sector, with a third for industry, and a third for cost-sector initiatives. This spending reduced natural gas demand in 2017 by approximately 12 PJ, half of which came from the industrial sector,[58] reducing emissions by 0.7 Mt CO_2e.

4.1.2 International comparison

While international comparisons have to account for the differences in the Canadian context and climate, they do reveal some trends. In the UK, transforming heat will partly rely on innovative demand reduction programs. There, overall demand for heat, and therefore natural gas, in homes is falling as a result of increasing energy efficiency.[59] But more must be done if the UK is to meet its commitment to net zero emissions by 2050. National Grid, the gas transmission system operator, says that homes must use at least one-third less energy for heating than they currently

57 Natural Resources Canada, *10 Key Facts on Canada's Energy Sector*, July 2018. At https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/energy/pdf/10_Key_Facts_on_Canada_sEnergy_Sector_e.pdf.
58 Consortium on Energy Efficiency, *2018 State of the Efficiency Program Industry: Budgets, Expenditures and Impacts*, May 2019. At https://library.cee1.org/system/files/library/13981/CEE_2018_AnnualIndustryReport.pdf.
59 UK Government, *Clean Growth - Transforming Heating: Overview of Current Evidence*, December 2018. At https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/766109/decarbonising-heating.pdf.

do, with 85% of houses classified as very thermally efficient (at EPC class C or higher).[60]

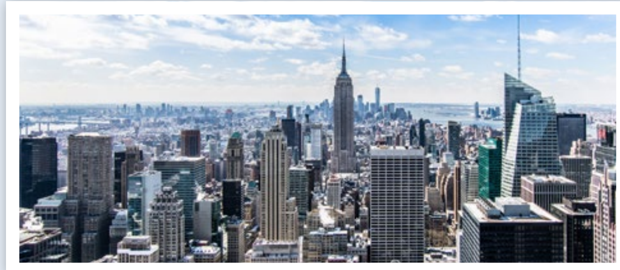
According to the International Energy Agency (IEA), residential buildings in Canada consume 10% more energy per square meter than buildings in similar climates, such as Norway and Sweden, and 15% more than those in the USA, when adjusted for climate. Under the IEA's Energy Efficiency scenario, natural gas use for buildings could decline by 700 PJ. Better building envelope performances, switching to electric heat pumps, and more efficient space and water equipment would account for these savings. To meet the Energy Efficiency scenario, investments in energy efficiency would need to double from current levels, yet the scenario shows that end-user costs would remain stable due to increased efficiency.[61] Government and regulatory policies will need to evolve from today's business-as-usual approach to energy efficiency to be more proactive in advancing both low-emission benefits and maintaining end-user cost stability.

In Canada, energy intensity for residential buildings varies from 0.22 GJ/m^2 for new construction, up to 0.79 GJ/m^2 for those built before 1960. Under the Clean Technology Scenario for buildings prepared by the IEA and the Canada Energy Regulator (CER),[62] deep retrofits of 60% of residential floor space would lead to a reduction in the average energy requirement from 0.36 GJ/m^2. Non-residential buildings energy use is also seen as declining by 40-50% during the same period.

In this scenario, 45% of heating will come from heat pumps, and the share of fossil fuels used for heating in buildings (mostly natural gas) drops to around 30% by 2050. Building-related emissions will be reduced by 80%, to under 25 Mt CO_2e from around 125 Mt CO_2e annually.

According to the IEA, in the long-term the energy efficiency improvements will lead to overall savings. However, in the short-term, economic considerations are not sufficient, especially in Western Canada where natural gas prices are low, and additional policy measures will be required to drive the market.[63]

Case study: New York's Plan to Reduce Emissions and Promote Efficiency



As an example of policy leadership on energy efficiency, we can look to New York. On April 18, 2019, New York City passed the Climate Mobilization Act (CMA), which includes new building requirements and energy efficiency laws to reduce carbon emissions. The laws specifically target buildings over 25,000 square feet since they account for approximately half of the city's total energy use and a significant share of carbon emissions, despite only taking up 2% of the city's real estate.

Under the new legislation, these buildings will be required to reduce their emissions by 40% by 2030 and 80% by 2050 from 2005 levels or incur financial penalties. There are also requirements surrounding the development of clean energy financing tools and research plans to study over 20 natural gas-fired power plants to determine whether they can be replaced with renewable energy and energy storage.[64]

Meanwhile, state-wide climate targets and energy efficiency standards have been progressing with the passing of the Climate Leadership and Community Protection Act (CLCPA) in June of 2019. Targets include: 100% carbon-free electricity by 2040 and 100% economy-wide net-zero carbon emissions by 2050.[65]

New York State also has a Clean Energy Fund (CEF) to provide incentives for a variety of programs including the adoption of air-source and ground-source heat pumps.[66] Depending on the program,

[60] National Grid, *Future Energy Scenarios*, July 2019. At http://fes.nationalgrid.com/media/1409/fes-2019.pdf.
[61] International Energy Agency, *Energy Efficiency Potential in Canada to 2050*, 2018. At https://www.iea.org/publications/freepublications/publication/Insights_Series_2018_Energy_Efficiency_Potential_in_Canada.pdf.
[62] The Canada Energy Regulator was previously the National Energy Board.
[63] IEA, "Heating and cooling strategies in the clean energy transition", 2019. At www.iea.org/publications/reports/nebbuildings/.
[64] Jeff St. John, *New York City set to pass ambitious energy efficiency mandate*, Greentech Media, 2019. At https://www.greentechmedia.com/articles/read/new-york-city-set-to-pass-ambitious-building-energy-efficiency-bill#gs.kmxjy1.
[65] David Roberts, *New York just passed the most ambitious climate target in the country,* Vox, 2019. At https://www.vox.com/energy-and-environment/2019/6/20/18691058/new-york-green-new-deal-climate-change-cuomo.
[66] NYSERDA, *Find a program,* 2019. At https://www.nyserda.ny.gov/All%20Programs.

residents or installers are provided with rebates or incentives to replace less efficient and carbon intensive heating equipment with heat pumps, which helps to increase market penetration while reducing emissions and maintaining affordability for customers. There are also various incentives for commercial buildings to improve energy efficiency including the adoption of high efficiency natural gas heating equipment.[67]

4.1.3 Canadian projects

There is diversity on the methods of delivering energy efficiency across Canada. In some provinces, such as Ontario and BC, the gas utility offers efficiency programs and funds that are provided through the ratebase. The utility is incented to effectively run the program through either earning a return for attaining or exceeding energy efficiency targets, or being allowed to earn a rate of return on energy efficiency programs.

In recent years a number of jurisdictions, such as Alberta, Manitoba, Nova Scotia and Quebec, have outsourced their energy efficiency programs to a third-party organization, either a government organization or a Crown corporation.

Regardless of the program set-up, generally jurisdictions allow for multi-year energy efficiency plans, in which the budget, the target or both are set for multiple years. The energy efficiency funding levels range from 0.2% to 2% of total customer bills and average 1%. Tracking and reporting on the programs is usually done and results audited.[68]

Canadian gas utilities have been very successful in delivering energy conservation programs to their customers. Evidence from Ontario suggests that conservation also makes good economic sense, delivering roughly $3 in benefits for every dollar spent.[69] It now makes even more sense since the implementation of a federal carbon tax, which in Ontario for example has added about $0.044/m^3 to the cost.[70] In BC, this is $0.065/m^3 from their carbon pricing scheme.[71]

The amount of economic potential is still under review. In a study on achievable potential energy efficiency in Ontario by Navigant, the economic potential for natural gas efficiency was a 25% reduction from baseline growth by 2038, which would reduce emissions by 6.8 billion m^3 from what they would be otherwise. Given that gas consumption is projected to rise, that would mean a reduction from 2017 consumption levels of 2.8 billion m^3 (82 PJ), around 12%.[72] This would equate to a reduction in emissions of around 5 Mt CO_2e a year from current levels.[73]

The Ontario Energy Association has higher figures, saying that 119 PJ (3.2 billion m^3) of gas could be saved every year by 2035, equivalent to 14% of 2017's total gas demand, reducing emissions by 6 Mt CO_2e annually. This would reduce Ontario's emissions by 3.7% from 2016 levels.[74]

It would be difficult to see similar savings across Canada given the differences in natural gas use, particularly around industrial uses. But if the Ontario calculations were extrapolated nationally, that could reduce gas emissions by between 300-350 PJ annually, saving between 17-20 Mt CO_2e annually, or 3% of national emissions.

Investments in energy efficiency can also have a corollary effect of avoiding or at least delaying additional infrastructure costs, a case that has been made by Enbridge Gas.[75] The regulatory structure may need to be reformed to better consider such infrastructure deferrals and how utilities could be incentivized to implement this option.

In the US, a number of jurisdictions have developed energy efficiency resource standard (EERS), which are long-term targets that utilities must meet. As an

[67] NYSERDA, *Heating, cooling, and ventilation programs & incentives*, 2019. At https://www.nyserda.ny.gov/ny/PutEnergyToWork/Energy-Program-and-Incentives/Heating-Cooling-Ventilation-Programs-and-Incentives.
[68] See for example Fortis BC reports at https://www.fortisbc.com/about/regulatoryaffairs/elecutility/electricbcucsubmissions/demandsidemanagement.
[69] Environmental Commissioner of Ontario, *Every Joule Counts: Annual Energy Conservation Progress Report 2016/2017*, p. 57. At http://docs.assets.eco.on.ca/reports/energy/2016-2017/Every-Joule-Counts.pdf.
[70] Enbridge Gas, *Federal Carbon Pricing*. At https://www.uniongas.com/campaigns/federal-carbon-charge.
[71] Government of BC, *British Columbia's Carbon Tax*. At https://www2.gov.bc.ca/gov/content/environment/climate-change/planning-and-action/carbon-tax.
[72] Navigant, *2019 Integrated Ontario Electricity and Natural Gas: Achievable Potential Study*, September 2019. At http://www.ieso.ca/en/Sector-Participants/Engagement-Initiatives/Engagements/2019-Conservation-Achievable-Potential-Study.
[73] Conversion from cubic metres to PJ based on Canada Energy Regulator, *Energy Conversion Tables*. At https://apps.cer-rec.gc.ca/Conversion/conversion-tables.aspx?GoCTemplateCulture=en-CA#s1ss2. Emissions associated with natural gas combustion as 57.94 kg CO_2e/GJ. (S&T) Squared Consultants, GHGenius 5.0d, 2018. At https://ghgenius.ca/index.php/downloads. Calculations conducted by BC Ministry of Energy, Mines and Petroleum and cited in Zen and the Art of Clean Energy Solutions, BC Hydrogen Study, 2019. At https://www2.gov.bc.ca/assets/gov/government/ministries-organizations/ministries/zen-bcbn-hydrogen-study-final-v5_noappendices.pdf.
[74] Ontario Energy Association, *Continuing Achievement Climate Strategy Submission*, November 2018. At https://energyontario.ca/wp-content/uploads/2018/11/OEA-Climate-Strategy-Submission.pdf.
[75] Enbridge Gas, *Staff Interrogatory # 11*, November 2018. At https://www.enbridgegas.com/-/media/Extranet-Pages/Projects-tab-links/Bathrust/Leave-to-construct/EGDI_STAFF_IRR_20181126.ashx?la=en&hash=396986C27F95722CC86069CF7D7684AEF187AD72.

example, in Massachusetts and Rhode Island, the EERS requires the utilities to reduce demand by 2.5% annually. The advantage seen for EERS is that the long-term goals allows for clear market signals and encourages large-scale investment.[76]

Case study: Low carbon office building in Edmonton

As reliable and affordable energy continues to be a priority for Canadian businesses and homeowners, companies such as Effect Home Builders in Edmonton are exploring ways to remodel and build sustainable net-zero homes and offices using a range of energy tools and technologies, including solar panels, micro CHP units and window glazing to promote conservation and efficiency.[77]

As of 2019, Effect Home Builders has finished converting a 1940s-era two-storey building (1,867 square feet) into Edmonton's first commercial office space without an electrical grid connection.[78] Instead, the office uses two 1.5 kW micro-CHP units, 4.8 kW solar array and six lithium ion smart batteries (6.6 kWh each) to meet all of the building's energy needs. ATCO provided Effect Homes with the two micro-CHP units and provided guidance on the install. For improved energy efficiency, the builders also undertook extensive exterior wall and roof treatment to improve insulation and air-tightness, and replaced windows and doors. The final result of this project is an office building that relies on natural gas, without electrical grid connection, and has 30% lower costs. When compared to traditional buildings of the type, the builders also estimate that it will have an 80% carbon reduction.[79]

Although the full cost of the remodel has not been disclosed, a $95,000 grant was provided by the Natural Gas Innovation Fund. Ultimately, this conversion highlights that there are various energy options when building sustainable homes and offices that can help reduce emissions and save money.

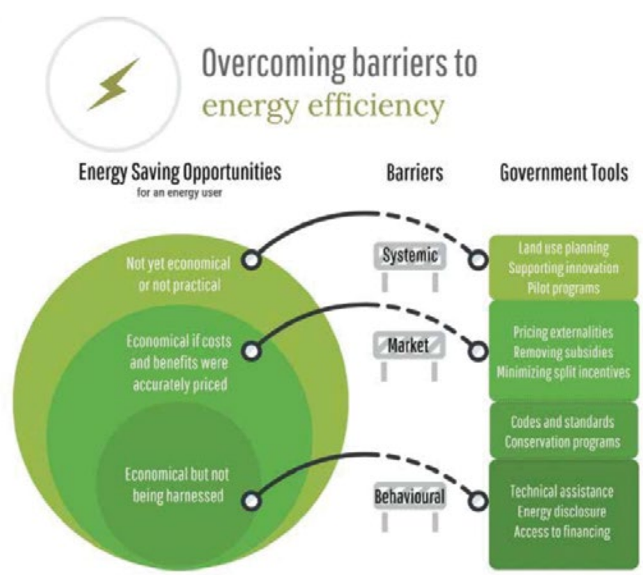
4.1.4 Next steps

Before considering options, the first step should be to try to use natural gas as efficiently as possible.

Reducing barriers to development will be key. The Environmental Commissioner of Ontario has recently pointed out some of the systemic and market barriers to implementing energy conservation programs in Ontario (Figure 17).

It is not clear if delivery is affected by institutional design, such as if the programs are delivered by the utility or through third-party organizations, and the choice will likely be dependent on the energy governance model in each jurisdiction.[80] Where gas utilities deliver energy efficiency programs, it is important that the financial frameworks used by energy regulators appropriately aligns the pursuit of aggressive energy efficiency targets with utility business models and decision making, such as through incentives or rate-basing. In the absence of appropriate financial frameworks, utilities actually have a financial disincentive to invest in energy efficiency, which is an undesirable public policy outcome.

Figure 17: Overcoming barriers to energy efficiency [81]



[76] American Council for an Energy-Efficient Economy, *Energy Efficiency Resource Standard (EERS)*. At https://aceee.org/topics/energy-efficiency-resource-standard-eers.
[77] Effect Home Builders, *The Company*, 2019. At https://effecthomes.ca/the-company/.
[78] Information provided by ATCO
[79] Margeaux Maron, *Edmonton's first off-the-grid business building opens its doors*, Global News, 2019. At https://globalnews.ca/news/5086530/edmonton-off-the-grid-business/.
[80] Brendan Haley, James Gaede, Mark Winfield and Peter Love, "From utility demand side management to low-carbon transitions: Opportunities and challenges for energy efficiency governance in a new era," *Energy Research and Social Science*, Volume 59, January 2020. At https://doi.org/10.1016/j.erss.2019.101312.
[81] Environmental Commissioner of Ontario, *A Healthy, Happy, Prosperous: Ontario 2019 Energy Conservation Progress Report – Summary*. At https://docs.assets.eco.on.ca/reports/energy/2019/why-energy-conservation-summary.pdf.

At the federal level Natural Resources Canada is involved with a number of energy efficiency programs, such as ecoEnergy, and tax incentives are available in addition to the individual provincial and territorial programs delivered locally. There is also a plethora of energy efficiency programs (electricity and gas) in each province and territory, with different names that cover different technologies.[82]

Municipalities often have GHG targets, and the Federation of Canadian Municipalities (FCM) have a number of tools to help municipalities with their GHG management programs and produce annual reports on their progress. While municipalities report that cost savings from reduced natural gas consumption was one of the most common actions taken, there is little detail provided to municipal governments on this option,[83] and it is left to the individual utilities if not the municipality themselves to make the connection. In the absence of sufficient funding from the regulator for utilities to undertake these actions, this may not happen.

Building codes play an important role in energy efficiency. Federally, the energy efficiency regulations that pertain to building codes are under the Model National Energy Code for Houses (1997) and the Model National Energy Code for Buildings (1997). These two publications fall under the National Building Code of Canada (NBC), and though they provide guiding recommendations for the provinces and territories, building codes fall under provincial jurisdiction so provinces and territories are free to adopt various different versions.[84] The federal government has also been active in developing standards for net-zero energy building standards.[85] In the CleanBC plan, the government of BC has a target of improving the efficiency standards in the BC Building Code so that every new building is "net-zero energy ready" by 2032.[86]

A number of provinces and municipalities have explored new ways to make capital available for efficiency projects through local improvement charges or on-bill financing. Another concept is known as Property Assessed Clean Energy (PACE). PACE lowers the risk and cost of the capital by making energy upgrade loans directly linked to the property's municipal tax obligations. Another benefit to the property owner is that when the property is sold, the outstanding balance on the loan and the guarantee of repayment (lien against the property) are seamlessly transferred to the new owner.[87]

Community planning and municipalities can also address energy efficiency. In Ontario, for example, the Guelph Community Energy Initiative (formerly known as Guelph's Community Energy Plan) plans to continue to reduce emissions and reach net-zero by 2050.[88]

Other forms of financing provided by Energy Service Companies (ESCOs) have been available for some time, while business models that take over responsibility for infrastructure and sell energy as a service (EaaS) are emerging.[89] It is important to consider how these programs would intersect with the utility model in Canada.

Case study: Energy efficiency funding by prescription

Beyond reducing emissions and saving money on energy bills, it is important to remember that energy efficiency has other significant co-benefits, including improved health and well-being. Studies have shown that lack of affordable heating leads to an increase in mortality.[90] Around the world, many healthcare patients are being discharged from hospitals and care facilities and ending up back in damp, cold homes, which perpetuates health problems while increasing strain on medical services. In order to combat this within the UK, housing firm Gentoo Group and the Sunderland Clinical Commissioning Group started a project called "Boilers on Prescription" in 2014 where

82 Natural Resources Canada, *Financial incentives by province*. At https://www.nrcan.gc.ca/energy/funding/efficiency/4947.
83 Federation of Canadian Municipalities, *National Measures Report 2018*. At https://fcm.ca/sites/default/files/documents/resources/report/national-measures-report-2018-pcp.pdf.
84 Government of Canada, *Codes, Standards, and Regulations Influencing Energy Demand*, November 2008. At https://www.cer-rec.gc.ca/nrg/ntgrtd/mrkt/archive/2008cdstndrdrgltn/cdstndrdrgltn-eng.html.
85 Natural Resources Canada, *NetZero: future building standards*, 2019. At https://www.nrcan.gc.ca/homes/buying-energy-efficient-new-home/netzero-future-building-standards/20581.
86 See the CleanBC website at https://cleanbc.gov.bc.ca/.
87 Bruce Cameron, Richard Carlson and James Coons, *Canada's Energy Transformation - Evolution or Revolution?, Pollution Probe and QUEST*, March 2019. At https://www.pollutionprobe.org/wp-content/uploads/Canadas-Energy-Transformation-Evolution-or-Revolution.pdf.
88 City of Guelph, *Community Energy Initiative*, October 2018. At https://guelph.ca/plans-and-strategies/community-energy-initiative/.
89 Natural Resources Canada, *Financing Energy Efficiency Retrofits in the Built Environment*, August 2016. At https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/emmc/pdf/Financing%20Report-acc_en.pdf.
90 Janjala Chirakijja, Seema Jayachandran, and Pinchuan Ong, *Inexpensive Heating Reduces Winter Mortality*, June 27, 2019. At http://faculty.wcas.northwestern.edu/~sjv340/heating_mortality.pdf.

doctors are able to prescribe boilers, insulation and double glazing to retrofit homes.[91]

On average, patients with respiratory problems received £5,000 (C$8,400) worth of home improvements per property resulting in energy savings and fewer medical issues. After 18 months of the project, there was a 60% reduction in the number of visits to family doctors and a 25% reduction in admissions to emergency rooms.[92] Overall, the reduction in doctor visits for respiratory problems, heart attacks and strokes helped save the National Health Service £0.42 for every £1 (C$0.70 for every C$1.67) spent on making homes warmer.[93] In addition to the "Boilers on Prescription" project, Gentoo participated in a project with Bangor University and Nottingham City Homes called "Warm Homes for Health". This project found that energy efficient homes led to reductions in anxiety and improvements in health status, overall happiness, overall wellbeing, and satisfaction with finances.

By improving living conditions, it is possible to deal with the root cause of many healthcare problems rather than repeatedly treating symptoms, particularly for elderly patients whose damp, cold homes contribute to their illnesses in the first place.

4.2 District energy and combined heat and power

4.2.1 Introduction

District energy (DE) is the centralized production and supply of thermal energy that is then distributed through a "district" or a region of a city or even a single building through pipes. The thermal energy delivered to the buildings is used for space and water heating, and absorption coolers can use the heat for cooling buildings. Some systems also deliver cold water for cooling. Delivering energy in this way is can in some cases be significantly more efficient than each building generating its own needs from its own individual equipment, depending on the type of equipment used.

DE is based more on infrastructure than a single technology, as there are a number of different heat sources that can be used, from natural gas to renewable sources of heating that can be attached to the end of the pipe. Some DE projects incorporate waste heat produced from other processes, such as heat produced from a data centre, waste water, or an industrial process such as cement making. As multiples sources of heat can be combined into one thermal network, it would thus be possible to start a DE network using natural gas, for example, and then to add other sources, such as waste heat or thermal energy from a renewable source. Solar energy, natural gas, biomass, hydrogen, geothermal, and so on can all play a role in providing the fundamental energy inputs without need to change the whole DE infrastructure. Burning clothing waste is even used for DE in Sweden.[94] This provides flexibility for future decision makers.

In addition, combined heat and power (CHP) is another technology that can be used in DE, in which energy efficient technology generates both the heating load and the electricity as well. CHP is typically located at facilities where there is a need for both electricity and thermal energy.[95]

CHP can provide multiple value streams for organizations that require process heat, as they can either then consume the electricity co-produced onsite or export it to the grid. This can reduce the demand on the grid, and also provide increased resiliency for organizations. For example, a hospital complex could rely on a natural gas-fed CHP plant during an electricity outage for both heat and electricity. Micro-CHP is discussed below in Section 4.4.

4.2.2 International projects

There are plenty of examples where this technology is being used globally.

This concept of generating thermal energy centrally and then distributing it via connected pipelines is most successfully seen in Denmark, which by the end of 2015 had 577 MW of solar thermal energy used in 79 district heating networks, most of which were

[91] Gentoo Group, *Boilers on Prescription scheme reduces GP appointments by 60%,* 2016. At https://www.gentoogroup.com/for-customers/news/2016/march/boilers-on-prescription-scheme-reduces-gp-appointments-by-60/.
[92] Paul Burns and Jonathon Coxon, *Boiler on prescription trial closing report*, 2016. At https://www.gentoogroup.com/media/1061811/boiler-on-prescription-closing-report.pdf.
[93] Alanna Mitchell, *Yes, climate change can be beaten by 2050. Here's how.,* Maclean's, 2019. At https://www.macleans.ca/news/canada/yes-climate-change-can-be-beaten-by-2050-heres-how/.
[94] Jesper Starn, "A Swedish power plant is now burning H&M clothing instead of coal," *Financial Post*, November 2017. At https://business.financialpost.com/news/retail-marketing/a-swedish-power-plant-is-now-burning-hm-clothing-instead-of-coal.
[95] Environmental Protection Agency, *What is CHP?* At https://www.epa.gov/chp/what-chp.

being run by municipalities, with an additional 364 MW being planned. The countries with the largest amount of DE based on percentage served along with the largest capacity are Iceland, China, Italy, Denmark, Poland, Latvia and Norway.[96]

Waste heat has been used to provide heating and cooling in a number of countries in Europe. As an example, waste heat from a crematorium in Aalborg, Denmark; from the underground rail line in London, UK; and from waste water for heating schools in Cologne, Germany.[97]

To illustrate how this technology could play a role, take the Netherlands. The government has a goal to remove all residential buildings from natural gas by 2050, of which 20% will be heated by district heating networks using low-carbon sources (such as renewable natural gas or hydrogen) and the remainder with other technologies.[98]

4.2.3 Canadian projects

In 2019, there were 217 DE facilities, up from 159 in 2016, supplying 2.2% of the heating load in Canada, which has reduced GHG emissions for heating by around 5.5%. Around half of all facilities were located in BC and Ontario. Interest is growing, as half of all systems have been commissioned since 2000, with one-quarter of all systems constructed in the past eight years. Most of the facilities were built for institutions, such as universities and hospitals.[99]

In Canada, examples exist from Markham District Energy[100] to the Okotoks Project, where about 55 houses are connected to a central geothermal/solar system with natural gas as back-up.[101]

In Toronto there is the Enwave system which heats and cools Toronto's downtown buildings using gas-fired DE and a lake cooling system. The lake cooling system reduces electricity demand in the core by 61 MW, equivalent to 5% of electricity demand, and a planned expansion would reduce electricity demand by an additional 30 MW. Enwave has also recently installed a 4 MW CHP plant to its DE system. These projects illustrate how thermal networks could complement the electricity system.[102]

In BC, there are number of projects. In the False Creek area of Vancouver, a district energy system uses a two stage sewage heat pump that recovers waste heat from untreated urban wastewater to provide heating and hot water, reducing GHG emissions more than 60% compared to a traditional solution.[103] The Telus Garden mixed-use development in Vancouver uses waste heat from a Telus data centre next door to provide heating and cooling.[104] The University of BC has installed an innovative biomass gasification project for DE and CHP. The project was expanded to include battery backup and the ability to use RNG supplied through the gas system. The goal is for the project to displace 9,000 t CO_2e.[105] The Vancouver Airport is planning on installing the largest Canadian geothermal DE system to date.[106]

The Federation of Canadian Municipalities has funded numerous feasibility studies involving district energy systems, such as the Hamilton Waterfront Pier 7 & 8 and Saskatoon's District Energy System.[107]

4.2.4 Next steps

Given the growing interest in DE and CHP, growth can be expected. Internationally, implementation of district energy systems is seen as the key to enable cities to achieve 100% renewable energy use.

In one study, the future of DE was thought to be necessarily concentrated on downtown cores and high density urban areas where economies of scale could provide the greatest benefits, particularly in the

[96] Euro Heat and Power, *Top District Heating Countries – Euroheat & Power 2015 Survey Analysis,* July 1, 2016. At https://www.euroheat.org/news/district-energy-in-the-news/top-district-heating-countries-euroheat-power-2015-survey-analysis/.
[97] Nicola Jones, "Waste Heat: Innovators Turn to an Overlooked Renewable Resource," *Yale Environment 360*, May 29, 2018. At https://e360.yale.edu/features/waste-heat-innovators-turn-to-an-overlooked-renewable-resource.
[98] Eline van den Ende, *"A revolution: The Netherlands kisses gas goodbye – but will it help the climate?," Energy Post*, June 7, 2017. At https://energypost.eu/a-revolution-the-netherlands-kisses-gas-goodbye-but-will-it-help-the-climate/.
[99] Canadian Energy and Emissions Data Centre, *District Energy in Canada*, March 2019. At https://www.sfu.ca/content/dam/sfu/ceedc/publications/facilities/CEEDC%20-%20District%20Energy%20Report%202019.pdf.
[100] See the Markham District Energy website at http://www.markhamdistrictenergy.com/district-energy-101/.
[101] Drake's Landing, *Welcome to Drake Landing Solar Community.* At https://www.dlsc.ca/.
[102] City of Toronto, *Attachment 1: Downtown Energy Strategy*, April 2018. At https://www.toronto.ca/legdocs/mmis/2018/pg/bgrd/backgroundfile-114280.pdf.
[103] City of Vancouver, *Southeast False Creek Neighbourhood Energy Utility*, 2019. At https://vancouver.ca/home-property-development/southeast-false-creek-neighbourhood-energy-utility.aspx.
[104] "Telus Garden towers in Vancouver to use recycled heat," *Daily Hive*, December 19, 2017. At https://dailyhive.com/vancouver/telus-garden-towers-in-vancouver-to-use-recycled-heat/.
[105] Clean Energy Fund: *Advanced Biomass Gasification For Combined Heat And Power Demonstration*, 2015. At http://energy.sites.olt.ubc.ca/files/2015/11/UBC-EN-Outreach-Report.pdf.
[106] International District Energy Association, *Versaprofiles Awarded Largest Canadian Geothermal Energy Project Contract*, March 28, 2019. At https://www.districtenergy.org/blogs/district-energy/2019/03/28/versaprofiles-awarded-largest-canadian-geothermal.
[107] Federation of Canadian Municipalities, *Funded Initiatives*. At https://data.fcm.ca/home/programs/green-municipal-fund/funded-initiatives.htm?lang=en&srch=natural%20gas%&back=true.

institutional sector.[108] In Toronto alone, 27 new locations have been identified as being suitable for DE systems.[109]

DE systems to a certain extent are dependent on local development patterns, and DE in less densely developed areas and regions may be harder to justify. Saying that, it is not just large cities that could use DE, as many medium-sized cities, such as Hamilton, London and Cornwall, have DE systems, and there are examples of individual buildings developing thermal networks, many using waste heat. There are also examples of First Nations using district energy systems (such as Kluane First Nation) and this is an obvious target sector given the energy generation problems many such communities have across the North.[110]

In complex buildings, switching to DE generally takes place as part of major building renewals. Across Canada, between 2017 and 2030, approximately 40% to 80% of major equipment in buildings may naturally undergo major renewals. This may present an opportunity to implement DE systems in older buildings that currently have less efficient energy systems.[111] Provinces with high-carbon intensity grids – such as Alberta, Saskatchewan, Nova Scotia and New Brunswick – could potentially achieve the greatest emissions reductions from the installation of DE. However, these provinces also have among the lowest population densities in Canada, which could make some DE systems that require a dense urban area difficult to develop.

In July 2017, Toronto City Council committed to expanding DE sites across the city through the unanimous adoption of the TransformTO climate plan. A number of developments have happened since then, including the city's decision to work with Enwave on the development of low-carbon thermal energy networks throughout the city.[112]

4.3 Fuel switching

4.3.1 Introduction

Fuel switching is a term for the replacement of high-carbon intensity fossil fuels with lower GHG alternatives. While substituting natural gas with low-carbon gases (see Chapter 5) is a form of fuel switching, this section is about switching from more emissions-intensive fuel, generally diesel or fuel oil, to natural gas. Compressed natural gas (CNG) and liquefied natural gas (LNG) have the potential for immediate emissions reduction in hard to decarbonize sectors, such as heavy-duty transportation, marine transportation and off-grid communities.

4.3.2 Ground transportation

Moving freight is critical to our economy. In Ontario, for example, the freight sector is the fastest growing source of emissions, increasing by 117% since 1990.[113]

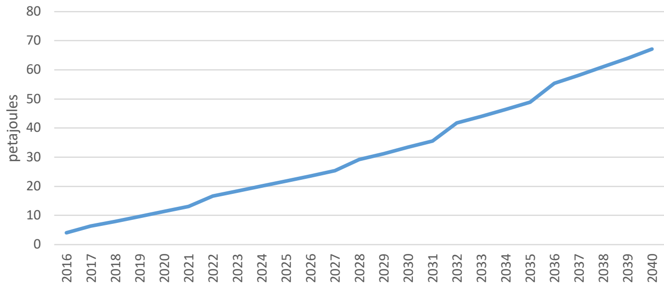
Unlike light-duty transportation, which can be converted to electric vehicles relatively easily, alternatives for heavy-duty vehicles are not as commercially available. By switching from diesel to natural gas, an immediate 25% reduction in emissions can be achieved on a well-to-wheel basis, in addition to improvement in local air quality and reducing noise.[114]

As of 2015 only about 0.1% of fuel used for transportation is natural gas. On the assumption that 25% of Canada's transport fleet converts to natural gas, this would realize a GHG reduction of about 5.5 Mt CO_2e by 2030. The majority of this reduction could come from Ontario, with lesser amounts from Alberta, Quebec and British Columbia.[115]

While the role of natural gas in transportation is currently quite low, it is projected to grow by 2040 (Figure 18).

[108] Natural Resources Canada, *An Action Plan for Growing District Energy Systems Across Canada*, June 2011. At https://static1.squarespace.com/static/546bbd2ae4b077803c592197/t/58c83aad37c581e14113a68d/1489517239056/CUIPublication.GrowingDistrictEnergy.pdf.
[109] Philip Lee-Shanok, "How a century-old idea is heating and cooling new communities in Toronto," *CBC News*, November 24, 2018. At https://www.cbc.ca/news/canada/toronto/toronto-condo-boom-fuels-new-district-energy-projects-1.4918943.
[110] Natural Resources Canada, *Toward a Positive Energy Future in Northern and Remote Communities: Summary Paper*, July 2018. At https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/emmc/pdf/2018/en/3c-energy-transition-in-northern-and-remote-Communities-workshop-repor-eng.pdf.
[111] Canada Green Buildings Council, *A Roadmap for Retrofits in Canada: Charting a Path Forward for Large Buildings*, 2017. At https://www.cagbc.org/cagbcdocs/advocacy/CaGBC_Roadmap_for_Retrofits_in_Canada_2017_EN_web.pdf.
[112] The Atmospheric Fund, *TransformTO Steps: Lake Ontario points to the future of district energy*, April 5, 2018. At https://taf.ca/low-carbon-solutions-lake-ontario-future-district-energy/.
[113] Environmental Commissioner of Ontario, *Ontario's Climate Act: From Plan to Progress - Annual Greenhouse Gas Progress Report*, 2017. At http://docs.assets.eco.on.ca/reports/climate-change/2017/From-Plan-to-Progress.pdf.
[114] Government of Canada, *Canada's Mid-Century Long-Term Low-Greenhouse Gas Development Strategy*, 2016. At https://unfccc.int/files/focus/long-term_strategies/application/pdf/canadas_mid-century_long-term_strategy.pdf.
[115] Canadian Gas Association, *The Natural Gas Opportunity: Reducing emissions, providing affordable energy, driving innovation, and growing the economy, Presentation to the Senate Committee on Energy, the Environment and Natural Resources*, April 2017. At https://sencanada.ca/content/sen/committee/421/ENEV/Briefs/CGA_Presentation_e.pdf.

Figure 18: Projected natural gas growth in transportation [116]



In 2018, with assistance from the federal and provincial governments, Union Energy Solutions, a subsidiary of Enbridge Gas and Clean Energy Fuels, launched three new public-access CNG stations along Ontario's 401 corridor. The stations in London, Windsor and Napanee allow heavy-duty truck fleets travelling these routes to have more reliable access to a natural gas supply.[117]

Internationally, the LNG Blue Corridors project in Europe has seen an increase in LNG refuelling stations from 30 to 155 between 2014 and 2018, supporting that jurisdiction's commitment to LNG as a fuel source for transportation in the future. Plans are in place to increase this number to 2,000 refuelling stations.[118]

Switching to natural gas for heavy duty vehicles also has the potential for further reductions if the sourced fuel is later converted to renewable natural gas (see Section 5.1 below). UPS in the US, for example, has committed to purchasing renewable natural gas for its natural gas-fueled vehicles.[119]

4.3.3 Marine transportation

Transport Canada has collaborated with industry on marine LNG roadmaps. Marine technologies for the use of LNG are all proven and commercially available. Development of engine and onboard fuel storage is ongoing.

Growth on the west coast has been larger than elsewhere in Canada. BC Ferries has been converting its vessels from diesel to LNG.[120] FortisBC has been looking to expand LNG on marine vessels,[121] and the BC government is supporting the development of an LNG terminal at the Port of Vancouver. Switching from bunker fuel to LNG would have immediate GHG savings, and it is estimated that emissions from marine shipping could decrease by 26% through the use of LNG produced through clean electricity in the province.[122]

According to a study by the Canadian Natural Gas Vehicle Alliance, under a "medium" LNG adoption scenario, there would be 150 LNG vessels operating on Canada's West Coast by 2025. These vessels would consume approximately 570,000 tonnes of LNG annually, representing 8.5% of BC's total natural gas demand during 2012.[123]

The Great Lakes and East Coast have limited LNG and CNG production and distribution capacity (as of 2017) and as marine natural gas demand increases, new infrastructure investments will be needed.

Realistic adoption rate scenarios indicate that there could be significant demand for LNG for marine uses on the Great Lakes and East Coast within the next

[116] Canada Energy Regulator, "End-Use Demand," *Canada's Energy Future 2018: Energy Supply and Demand Projections to 2040*, 2017. At https://apps.cer-rec.gc.ca/ftrppndc/dflt.aspx?GoCTemplateCulture=en-CA.
[117] "Union Energy Solutions Announces Contractual Agreement with Clean Energy Fuels for the Construction of CNG Fuelling Stations along Ontario's Highway 401", April 19, 2018. At https://www.newswire.ca/news-releases/union-energy-solutions-announces-contractual-agreement-with-clean-energy-fuels-for-the-construction-of-cng-fuelling-stations-along-ontarios-highway-401-680269373.html.
[118] Natural Gas Vehicles Association, *Natural gas infrastructure and outlook towards 2030*, November 9, 2018. At https://www.ngva.eu/medias/natural-gas-infrastructure-and-outlook-towards-2030/.
[119] UPS, *"UPS Makes Largest Purchase of Renewable Natural Gas Ever In The U.S.", Global Newswire*, May 22, 2019. At https://www.globenewswire.com/news-release/2019/05/22/1840772/0/en/UPS-Makes-Largest-Purchase-Of-Renewable-Natural-Gas-Ever-In-The-U-S.html.
[120] Carla Wilson, "B.C. Ferries vessel running on LNG after fuel conversion," *Times Colonist,* June 2018. At https://www.timescolonist.com/news/local/b-c-ferries-vessel-running-on-lng-after-fuel-conversion-1.23326142.
[121] See FortisBC website at https://www.fortisbc.com/est/marine.
[122] BC Government, *Province supports proposal for LNG ship-refuelling facility*, October 23, 2019. At https://news.gov.bc.ca/releases/2019PREM0116-002035.
[123] Canadian Natural Gas Vehicle Alliance, *Liquefied Natural Gas: A Marine Fuel for Canada's West Coast*, April 2014. At http://cngva.org/wp-content/uploads/2017/12/04-2014-Liquefied-Natural-Gas-A-Marine-Fuel-for-Canadas-West-Coast-EN.pdf.

decade. Under a "medium" adoption scenario, there would be 148 LNG vessels operating on the Great Lakes and East Coast by 2025, requiring 783,000 metric tonnes of LNG annually.[124]

4.3.4 Off-grid communities

Remote northern Canadian communities that currently rely on diesel can also benefit from the use of CNG and LNG. By 2030, ICF, a consultancy, estimates 4 Mt CO_2e could be saved by delivering LNG and CNG to northern communities and industries that are currently using diesel and oil.[125]

There are 200,000 people living in 300 remote communities in Canada's north who are disconnected from central energy supplies, and rely on delivery, sometimes by flying it in, of expensive and environmentally hazardous diesel for electricity. When a diesel barge failed to arrive as scheduled at Paulatuk, Northwest Territories, the government spent $1.75 million to fly in 600,000 litres of diesel.[126]

The federal government has announced a $20 million initiative to help reduce diesel reliance in remote Indigenous communities called 'Generating New Opportunities: Indigenous Off-diesel Initiative'.[127] Different solutions will apply to different communities, involving a variety of energy sources including increased renewables, batteries and natural gas.

A long-term vision for energy for the north needs to be developed and an increased use of trucking in and storing LNG may be part of the solution. Some projects include:

- A $40 million project that was funded by the federal and Ontario governments, Goldcorp, the Municipality of Red Lake and Union Gas, now Enbridge Gas, to bring natural gas to Red Lake, Ontario
- The federal government and Énergir co-funded projects to bring natural gas from Vallée Jonction to Thetford Mines and Asbestos in Quebec.

4.3.5 Next steps

The opportunities for growth in this future sector as described above include:

- in marine, converting from bunker heavy fuel oil to LNG
- in trains, converting from diesel to LNG
- in converting heavy duty long haul trucks from diesel to CNG/LNG
- in remote communities converting from diesel to LNG
- at remote industrial sites converting from diesel to LNG.

Other fuel switching initiatives include turbine designs that can run on a mixture of natural gas and hydrogen. Companies such as Siemens, GE, Mitsubishi Hitachi Power Systems (MHPS) and Ansaldo Thomassen are actively working on fuel gas mixtures of natural gas and hydrogen that can lower and ultimately eliminate carbon emissions from turbomachinery. They are also developing machines that will function on 100% hydrogen.[128] Equipment manufacturers are therefore looking for new ways to meet anticipated new regulations.

While switching to conventional natural gas from more emissions-intensive fuels does not provide a long-term answer to meeting climate change targets, there can nonetheless be significant GHG and air quality benefits in specific sectors and timeframes. Furthermore, many of these sectors could in the future cost-effectively transition from conventional natural gas to renewable natural gas in the future.

4.4 Consumer-side technologies

4.4.1 Introduction

New and innovative consumer-side technologies are also changing the way some consumers use natural gas, and could be used to reduce the carbon intensity of energy services.

[124] Canadian Natural Gas Vehicle Alliance, *Liquefied Natural Gas: A Marine Fuel for Canada's Great Lakes and East Coast*, May 2017. At http://cngva.org/wp-content/uploads/2017/12/LNG-Great-Lakes-and-East-Coast-Report-June-2017-ENGLISH.pdf.
[125] Canadian Gas Association, *The Natural Gas Opportunity: Reducing emissions, providing affordable energy, driving innovation, and growing the economy, Presentation to the Senate Committee on Energy, the Environment and Natural Resources*, April 13, 2017. At https://sencanada.ca/content/sen/committee/421/ENEV/Briefs/CGA_Presentation_e.pdf.
[126] Jimmy Thomson, "How can Canada's North get off diesel?," *The Narwhal*, February 2019. At https://thenarwhal.ca/how-canadas-north-get-off-diesel/.
[127] Government of Canada, *Canada Launches Off-Diesel Initiative for Remote Indigenous Communities*, February 2019. At https://www.canada.ca/en/natural-resources-canada/news/2019/02/canada-launches-off-diesel-initiative-for-remote-indigenous-communities.html.
[128] Drew Robb, "Fuel Switching," *International Turbomachinery*, September 2018. At https://www.turbomachinerymag.com/fuel-switching/.

The natural gas industry recognized the importance of innovation with the establishment of the Natural Gas Innovation Fund (NGIF), created by CGA to support the funding of cleantech innovation in the natural gas value chain. This is a collaborative effort with all natural gas utilities to find new natural gas solutions (see *case study* below).

The consumer-side innovations discussed here include:

- hybrid heating (air-source heat pumps plus gas)
- natural gas heat pumps (gas-absorption and other new technologies)
- micro-CHP
- micro carbon capture and storage.

Case study: Natural Gas Innovation Fund

The Natural Gas Innovation Fund (NGIF) was created by the Canadian Gas Association (CGA) and supports the advancement of natural gas cleantech innovation. The goal of the fund is to field-test innovation and advance cleantech projects that have potential for market uptake and commercial viability.[129] All of the projects focus on natural gas, either in terms of production, transmission or distribution. The funding comes from pooled capital across the natural gas industry, including distribution and production investors.[130]

Currently, NGIF is supporting the development of a variety of innovative technologies and systems from promising businesses such as CharTech Solutions, Enersion, G4 Insights Inc., Hydrogenics, iGen Technologies and Next Grid.[131] Examples of technological advancements include the development of an absorption based cooling technology that uses heat instead of electricity and a zero-waste targeted gas cleaning solution to filter hydrogen sulfide out of renewable natural gas. Funding is also supporting the construction of demonstration plants to convert electricity into hydrogen and to produce renewable natural gas from biomass.

There have also been innovations at the systems level, including the development of a multi-residential/small commercial combined heat and power system (CHP) that uses turbine and combustion technologies, as well as the development of a Hybrid Smart Furnace, which uses natural gas to generate heat and electricity for residential use.

NGIF also supports a range of projects through other research and technology organizations such as Canmet Energy, the Gas Technology Institute (GTI) and the Natural Gas Technologies Centre (NGTC).

4.4.2 Hybrid heating

Hybrid heating uses two fuels – electricity and natural gas – to deliver heating and cooling. Hybrid heating combines an electric-driven air-source heat pump (ASHP) with an efficient natural gas combustion boiler, and the system switches between the two fuels depending on the outdoor temperature, resulting in the lowest running cost.

ASHPs draw ambient heat from the outside air, and remove interior heat for cooling. In addition to regular ASHP, there are specific cold climate ASHP that are designed to work more effectively at lower air temperatures. All ASHPs are extremely efficient, but become less efficient as temperatures decrease as it is more difficult to extract heat from cooler air. For example, at +5°C, the coefficient of performance (COP) of an ASHP is roughly 3.5, meaning that 3.5 units of heat are delivered for every unit of electricity consumed, whereas at -8°C, the COP drops to 2.3 as there is less heat in the air (for comparison, a modern natural gas boiler has a COP of 0.93). Even cold climate ASHPs become ineffective at around -5°C to -10°C. In systems that rely entirely on electricity, at that temperature the energy-intensive electric-resistive heating would kick in.[132]

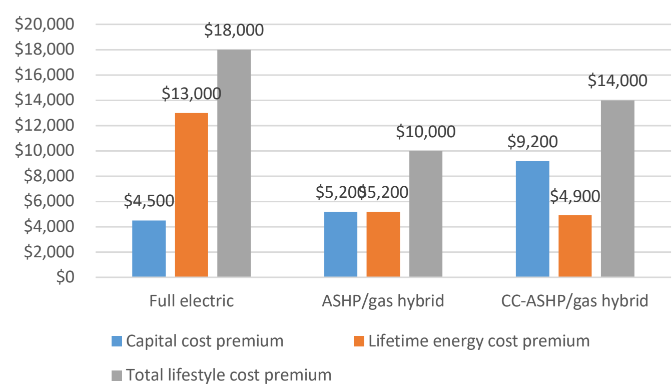
While the temperature constraints are not a concern for all areas of the country, 20% of the country's total heat demand is for when temperatures are below -10°C when the ASHPS become less efficient.[133] If

[129] Natural Gas Innovation Fund, *About,* 2017. At http://www.ngif.ca/about/
[130] M. Bredin, *Natural Gas Innovation Fund (NGIF): Funding for Cleantech,* Mentor Works, 2019. At https://www.mentorworks.ca/blog/government-funding/natural-gas-innovation-fund-overview/
[131] Natural Gas innovation Fund, *Portfolio,* 2017. At http://www.ngif.ca/portfolio/
[132] MaRS Advanced Energy Centre, *Future of Home Heating*, April 2018. At https://www.marsdd.com/wp-content/uploads/2019/03/Future-of-Home-Heating.pdf.
[133] ICF, *Implications of Policy-Driven Electrification in Canada: A Canadian Gas Association Study*, October 2019. At http://www.cga.ca/.

Canada were to rely on electricity and ASHP for its heating needs, it would require significant electricity investments to provide for the electric-resistive backup heating. The hybrid system is an alternative that pairs an ASHP with an efficient natural gas boiler for backup when there is congestion on the electricity grid, as form of demand response, or the outside air temperature results in ASHP efficiency levels that place electricity grid emissions higher than direct use of natural gas. The hybrid system thereby reduces the GHG emissions from a natural gas boiler being used alone, assuming the grid has been progressively decarbonized, while still using the resiliency and flexibility offered by the gas system.

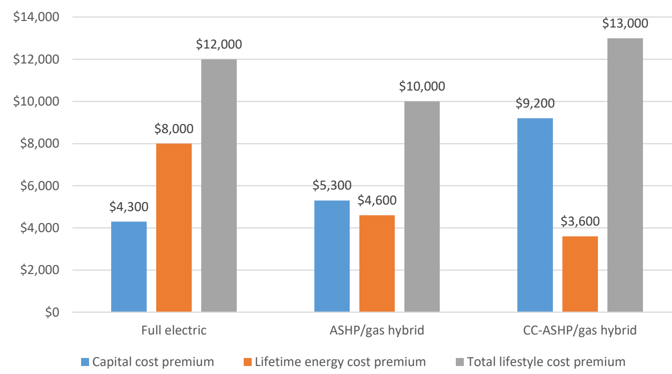
MaRS Advanced Energy Centre in Toronto examined the costs of using a full electric heating system, an air-sourced heat pump with a gas hybrid, and a cold-climate air-sourced heat pump with a gas hybrid. Results are seen in Figures 19 and 20.

Figure 19: Existing homes - Incremental cost increase compared to natural gas baseline per home [134]



The study showed that the lifetime costs of an ASHP-gas hybrid to be the most economical. For new homes, the full electric saw a 1.9 t CO_2e annual decline, the ASHP-gas hybrid a 1.7 t CO_2e annual decline and the cold climate ASHP-gas hybrid a 2.0 t CO_2e annual decline.

Figure 20: New homes - Incremental cost increase compared to natural gas baseline per home [135]



In addition, the hybrid solution reduced the need for massively increased investments in the electricity system as peak heating will still be provided through gas, ensuring flexibility in the energy system.[136] If the gas system were to be increasingly decarbonized, the GHG savings from a hybrid solution would be even higher.

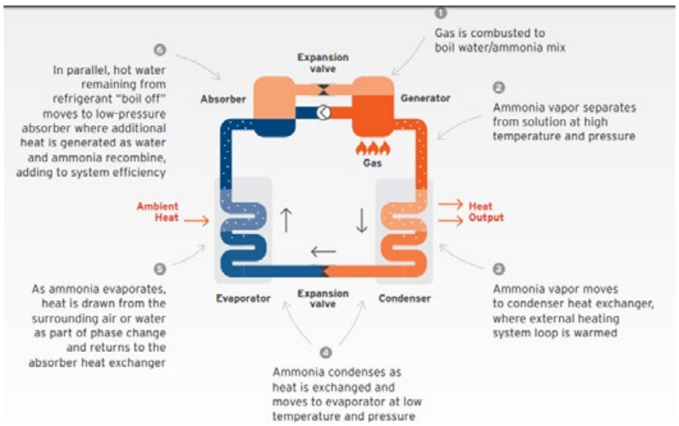
It should also be noted, and was mentioned above, in Alberta, Saskatchewan, New Brunswick and Nova Scotia electricity generation has a higher emissions intensity than natural gas, and thus switching to electrical sources of heat would actually increase emissions compared to running a high efficient natural gas boiler. While there are plans to increasingly reduce the carbon intensity of electrical generation, the time frames and costs in installing new equipment and current conditions would need to be considered. Hybrid systems that can switch between input energy supplies may be the most flexible and cost-effective approach to manage the uncertainties related to new energy infrastructure time frames and future costs.

[134] MaRS Advanced Energy Centre, *Future of Home Heating*, April 2018. At https://www.marsdd.com/wp-content/uploads/2019/03/Future-of-Home-Heating.pdf.
[135] MaRS Advanced Energy Centre, *Future of Home Heating*, April 2018. At https://www.marsdd.com/wp-content/uploads/2019/03/Future-of-Home-Heating.pdf.
[136] MaRS Advanced Energy Centre, *Future of Home Heating*, April 2018. At https://www.marsdd.com/wp-content/uploads/2019/03/Future-of-Home-Heating.pdf.

4.4.3 Natural gas heat pumps

Apart from ASHPs, natural gas can be used a fuel for heat pumps. The most common technology is the gas absorption heat pumps (GAHP), which are driven by combustion instead of electricity and are generally used in commercial and institutional properties, but increasingly in residences as well. The heat conducting fluid is a mixture of water and ammonia — neither of which contribute to GHG emissions. A schematic of how this technology works is given in Figure 21.

Figure 21: Ammonia-based gas-absorption heat pump process [137]



These systems are much more efficient than a regular gas boiler. For example, with an ambient air temperature of 7°C and a water load temperature of 35°C, a heat pump efficiency of around 143% can be achieved.[138] To date in Canada this technology has been used in commercial buildings for space and water heating. The Gas Technology Institute lists the following benefits for this technology:

- Efficiency: With projected 140% annual fuel utilization efficiency (AFUE), GAHP combined system may yield thermal savings of up to 45%
- Reliability: GAHPs do not require backup heating and can continue operation without interruption during defrost
- Emissions/Combustion Safety: GAHPs can decreased NOx emissions, which are associated with smog, and GHG emissions are decreased by up to half
- Climate: GAHPs use natural refrigerant/absorbent pairs with 0.0 GWP/ODP (ozone depletion potential).[139]

While GAHPs are more expensive than traditional gas boilers, their operational costs are much lower. As such, The Atmospheric Fund (TAF), a Toronto-based funding organization, expects market penetration to increase in regions that have low natural gas prices, high electricity rates and high heating demands (e.g. Ontario and the Northeastern United States).[140]

TAF, in partnership with Enbridge Gas, has run a pilot in a 1972-era multi-unit residential building in Toronto retrofitted with two GAHPs that provide 58% of the hot water for both water and heating (the building uses a hydronic heating system), along with new modern high-efficiency boilers supplying the remainder and other energy efficiency upgrades. The average COP between March 2018 and February 2019 was 1.12. While the performance was lower in cold weather, its efficiency exceeded that of a condensing natural gas boiler in temperatures above -13°C. When compared to energy use pre-retrofit, in the first year of operations the GAHP system saved over 10,000 m^3 of natural gas and lowered emissions by 19 t CO_2e.[141]

Apart from GAHPs, industry research groups, like the Gas Technology Institute, are supporting the development of next-generation natural gas heat pumps that could even be more efficient.

4.4.4 Micro-CHP

Micro combined heat and power (micro-CHP) is a technology (generally less than 50 kW electrical output) which generates heat and electricity simultaneously, from the same energy source, in individual homes or buildings.

The main output of a micro-CHP system is heat, with some electricity generation, at a typical ratio of about 6:1 for domestic appliances.[142] The efficiency is above 90%. A typical domestic system will generate around 1 kW of electricity once warmed up: the amount of electricity generated over a year depends on how long the system is able to run, and some systems are able to adjust output based on electricity grid demands.

137 The Atmospheric Fund, *Gas Absorption Heat Pumps: Technology Assessment and Field Test Findings*, 2018. At http://taf.ca/wp-content/uploads/2018/10/TAF_GAHP-White-Paper_2018.pdf.
138 CIBSE Journal, *Module 21: Gas-absorption heat pumps*, October 2010. At https://www.cibsejournal.com/cpd/modules/2010-10/.
139 Gas Technology Institute, *Overview of Gas-Fired Absorption Heat Pumps: Combination Space/Water Heating*, April 2017. At https://www.etcc-ca.com/sites/default/files/nextgenhvac_final.pdf
140 The Atmospheric Fund, *Gas Absorption Heat Pumps: Technology Assessment and Field Test Findings*, 2018. At http://taf.ca/wp-content/uploads/2018/10/TAF_GAHP-White-Paper_2018.pdf.
141 The Atmospheric Fund, *Retrofitting Arleta Manor: A TowerWise Case Study*, September 2019. At https://taf.ca/wp-content/uploads/2019/09/Retrofitting-Arleta-Manor-September-2019.pdf.
142 Energy Saving Trust, *Micro CHP*. At https://www.energysavingtrust.org.uk/renewable-energy/electricity/micro-chp.

Although natural gas is used as a fuel, the technology can be considered low-carbon technology because it is more efficient than just burning natural gas for heat and getting electricity from the grid. Definitions of whether CHP is low carbon vary upon the jurisdiction, but CHP with increasing amounts of RNG or hydrogen in the gas system would be low carbon.

There are three main micro-CHP technologies (the difference is the way in which they generate electricity):

- Fuel cell CHP (these are still being field tested in Europe)
- Internal combustion engine CHP (this is the most proven technology)
- Combustion turbines
- Stirling engine CHP.

Japan is the main user of this technology, with some 230,000 units sold by 2015, and with 85% of the global market.[143] The benefits of a micro-CHP system are:

- Electricity generation as a by-product of heat. When the micro-CHP is generating heat, the unit will also generate electricity to be used in the home (or exported to the grid)
- Carbon savings. Generating electricity on-site saves carbon dioxide compared with using grid electricity and a standard heating boiler
- Installation is relatively easy
- Servicing costs and maintenance are estimated to be similar to a standard boiler (in the UK).

The main hurdle for adoption of micro-CHP in North America is price, according to Aisin World Corp, a manufacturer in Japan. Units sell for $12,000 to $13,000 each, which is a large premium compared to traditional gas boilers. Union Gas, now part of Enbridge Gas, had micro-CHP systems at commercial locations where the availability of heat and electricity was a benefit. But a barrier was regulations around re-selling excess power to the grid.[144]

In Ontario, Alectra Utilities, Enbridge Gas, the City of Markham and Ryerson University have started a Power.House Hybrid pilot that integrates solar PV, battery storage, electric vehicle charging, as well as a hybrid heating system based on air source heat pumps, micro-CHP, high efficiency boiler and smart air handlers. Installation in 10 homes will start in 2020, and the pilot will run until 2022.[145]

Residential and commercial potential in Canada will depend on climate, new vs. retrofit housing stock, location, electricity costs, and building type characteristics that will determine the energy needs, as well as public acceptance of this new technology. If the gas system were to be increasingly decarbonized, the GHG savings from a micro-CHP solution would be even higher.

Case Study: The Japanese micro-CHP success story

Japan is an undisputed leader in cogeneration (combined heat and power) with the success of its nationwide, government-backed micro-CHP program. These units can replace or supplement grid electricity and most require natural gas as a fuel source. A micro-CHP unit can have one of several prime movers – an internal combustion engine (ICE), a Stirling engine (SE), a proton exchange membrane fuel cell (PEMFC) or a solid oxide fuel cell (SOFC). PEMFCs are considered well suited to residential use but have a comparatively low operating temperature of approximately 80°C, necessitating frequent start-and-stop operation to generate enough heat for residential water and space heating demands. The technology is highly efficient; almost all the energy losses from electricity generation are recoverable as usable heat. Panasonic, a market leader in Japan, claims a 97% overall energy efficiency, or 87.6% based on hydrogen's higher heating value.

Work on development and deployment of micro-CHPs in the country has been ongoing since 1993, with an intensive research and development period that culminated in a large-scale stationary fuel cell demonstration project (involving 17 energy utility companies and five fuel cell suppliers) being carried out between 2005 and 2009. During this period, 3,000 micro-

143 CogenEurope, *The benefits of micro-CHP*, 2015. At http://www.cogeneurope.eu/medialibrary/2015/05/19/d6648069/miro-CHP%20study_merged.pdf.
144 Dina O'Meara, "Micro CHP – Creating Opportunities of a Different Scale," *Energy Magazine*, 2015. At http://www.energymag.ca/markets/micro-chp-creating-opportunities-of-a-different-scale/.
145 Alectra Utilities, *Backgrounder – Power.House Hybrid*, June 21, 2019. At http://alectrautilities.com/wp-content/uploads/Backgrounder-Power.House-Hybrid.pdf.

CHP units were installed across Japan. Among the main findings of the project were insights into consumer needs and the national energy demand as well as data on the efficiency, performance levels and associated costs of the micro-CHP units. An average Japanese household could, it was concluded, prevent 1.2 t CO_2e emissions each year with the adoption of a fuel-efficient micro-CHP unit. Moreover, the units offer added resilience in the event of natural disasters, and reduce household electricity bills – an especially significant benefit given the increasing cost of electricity with the loss of nuclear power following the 2011 Fukushima disaster.

In 2009, after the conclusion of the demonstration project, Japanese utilities companies and fuel cell developers launched a joint initiative to sell PEMFC/SOFC fuel cell micro-CHP units to the residential sector. The ENE-FARM program had a starting production target of 150,000 units for the 2009-2010 fiscal year. While Japan's latest targets – 1.4 million units by 2020 and 5.3 million by 2030 – are considered ambitious, the number of installations has nevertheless increased steadily each year, with 305,000 units in place as of early 2019. The capital cost of a micro-CHP unit has also progressively decreased – a model released in 2015 was about 1/5th the cost of a unit sold in 2005 and about half the cost of the first 2009 commercial model. The Japanese government has supported the program with high initial subsidies, gradually reducing these with the aim of withdrawing them altogether as the industry matures and costs become low enough to render them unnecessary. The industry reached a major milestone in 2019 when the price of PEMFCs dropped low enough to be ineligible for subsidy (though SOFCs still qualify).

4.4.5 Micro carbon capture and storage

Most current work on carbon capture and storage (CCS) has been targeted at large central electricity generation stations. Saskatchewan's Boundary Dam Coal Power Plant, developed in 2014, is one of the first large-scale trials of the technology.

But CCS does not have to be installed at large electricity plants – it could be placed in individual commercial and industrial locations, with the carbon capture used for industrial processes. The technology is still in its early stages, but a Canadian company CleanO2 has developed a CARBiNX system that is being trialled by FortisBC (see *case study* below).

Case study: CleanO2 and its consumer-side carbon capture

Calgary-based CleanO2 Carbon Capture Technologies (CleanO2) has developed the world's first aggregated commercial carbon capture device called CARBiNX.[146] The device is about the size of a residential air conditioner and works by capturing excess heat and emissions from commercial sized-boilers and furnaces. Depending on the size of the boiler, emissions can be reduced by approximately 10-20%.

When emissions are drawn into the CARBiNX reaction chamber, a chemical reaction occurs converting captured carbon into sodium carbonate, also known as soda ash.[147] Sodium carbonate can be used for a variety of products including pharmaceuticals, soap and glass, making it a massive global industry. The device also promotes energy efficiency and cost savings by using the heat generated from the chemical reaction to heat water for the building's water heating system. Therefore, many businesses, including hotels, can benefit from the device in terms of energy savings and emissions reductions while using the sodium carbonate to make their own laundry detergent and soap.

146 CleanO2, *About CleanO2*, 2019. At http://cleano2.ca/.
147 Denis Lanthier, *A look at the world's first carbon capture technology by CleanO2*, Energy Magazine, 2018. At http://www.energymag.ca/markets/a-look-at-the-worlds-first-carbon-capture-technology-by-cleano2/.

Due to its innovative work, CleanO2 has already won several awards and is supported by FortisBC, NGIF and ATCO among several other businesses and industry representatives. In 2017, CleanO2 began a pilot project with FortisBC to deploy its units across Vancouver's lower mainland and ATCO has a unit running at its site. Since then, interest in the CARBiNX device has only grown.[148] With its growing success in Canada, CleanO2 is looking to expand into the international market and foreign delegates from Germany and Norway have already expressed interest and visited Canadian facilities.

[148] FortisBC, *First-ever micro carbon capture unit installed in B.C. as part of FortisBC's pilot program*, 2018. At https://www.fortisbc.com/news-events/media-centre-details/2018/03/15/20180315-First-ever-micro-carbon-capture-unit-installed-in-BC-as-part-of-FortisBCs-pilot-program.

CHAPTER 5: LOW CARBON GASES

5.1 Renewable natural gas

5.1.1 Introduction

Renewable natural gas (RNG) is gas formed from renewable resources that is chemically identical to conventional natural gas in terms of methane content. RNG can be captured from wet agriculture waste, as well as from landfill and waste water treatment plants. Wood waste and other solid waste can also be converted to gas.

RNG can be burned directly on-site or injected into the existing natural gas pipeline network to be used in the same way as conventional natural gas is used.

The BC government introduced a target for 15% of gas consumption to come from renewable gas by 2030.[149] Quebec has recently set a target of 1% of gas distributed to come from RNG by 2020, and 5% by 2025.[150] Ontario and others have voluntary programs or dedicated RNG suppliers.

5.1.2 The technologies

There are two main technologies that can be used to create RNG: anaerobic digestion and gasification.

5.1.2.1 Anaerobic digestion (AD)

Anaerobic digestion (AD) is a process that works on organic material, such as organic waste, sewage waste and farm residues. It harnesses the natural process of decomposition by securing the waste in an oxygen free environment and then capturing the methane emitted from the decomposition process. A side benefit of AD is that it captures the fugitive methane that is either emitted at landfills or flared at sewage treatment plants, further reducing the climate impact. Additionally, selling the waste or the RNG can be a revenue source for farmers and municipalities. Capturing and using the methane from these sources provides additional benefits as unburned methane has a higher global warming potential than the CO_2 post combustion.

[149] BC Government, *CleanBC*, March 2019. At https://blog.gov.bc.ca/app/uploads/sites/436/2019/02/CleanBC_Full_Report_Updated_Mar2019.pdf.

[150] *Regulation respecting the quantity of renewable natural gas to be delivered by a distributor, CQLR c R-6.01, r.4.3*, Canlii, July 1, 2019. At https://www.canlii.org/en/qc/laws/regu/cqlr-c-r-6.01-r4.3/latest/cqlr-c-r-6.01-r4.3.html.

The gas collected from AD is called biogas, and it has a much lower methane content than conventional natural gas. Biogas can either be combusted onsite for electricity or heat, or upgraded to renewable natural gas (RNG) with around 90% methane content for delivery through the pipelines. One limitation of AD is that there are limits to the availability of waste types that can be diverted to producing RNG to meet needs.

5.1.2.2 Gasification

Another way to convert biomass into RNG is through gasification. Gasification is a process that converts solid biomass to a syngas by combustion at a high temperature in an oxygen-free environment. The syngas can then be converted into RNG and mixed with pipeline gas.[151] If the RNG is made from wood wastes, then it can be carbon neutral as additional trees are planted to replace those previously cut down.

Gasification is an old technology, an earlier version of which was used to create "city gas" from coal, which was distributed in some urban areas prior to the development of the natural gas system.

Gasification has many benefits over AD. Almost any type of organic material can be used, such as wood waste. As the process is more controlled, it can also lead to higher yields. Using AD, only around 20% of the material is converted – through gasification, anywhere from 60-80% can be converted. One downside of gasification is the additional costs.

5.1.2.3 Cost comparison

Given the technological development of many of the technologies, a true cost comparison is difficult, but a recent comparison of costs in Canada can be seen in Table 3.

Table 3: Cost comparison of renewable natural gas [152]

Source		$/GJ	$/MWh
Conventional natural gas	Current average	3	11
	Carbon price $50/t	5.50	20
	Carbon price $90/t	7.50	27
Gas from landfill, agricultural waste and wastewater		6-17	22-61
Gasification of biomass		23-29	83-104

[151] Canadian Biogas Association and Canadian Gas Association, *Renewable Natural Gas Technology Roadmap for Canada*, December 2014. At https://biogasassociation.ca/images/uploads/documents/2017/rng/The_Renewable_Natural_Gas_Technology_Roadmap.pdf.

[152] Canadian Gas Association, *Federal Policy Proposal: The Canadian Renewable Gas Initiative*, August 2018. At http://www.cga.ca/wp-content/uploads/2018/08/Renewable-Gas-Proposal_Final_August-28.pdf. Costs with carbon pricing based on calculations available at Canada Energy Regulator, *Canada's Energy Future 2017: Energy Supply and Demand Projections to 2040 – Chapter 2: Key Assumptions*, 2017. At https://www.cer-rec.gc.ca/nrg/ntgrtd/ftr/2017/chptr2-eng.html?=undefined&wbdisable=true. Additional RNG figures from Enbridge Gas, *Alberta woody biomass syngas to Renewable Natural Gas/Combined Heat and Power (RNG/CHP) for Oil Sands, Report to NRCan*, March 23, 2016. At http://www.sysene.com/images/Articles/SyeEne_NRCan_Alberta_Biomass_RNG_Summary_Presentation.pdf.

Currently, there is a $14/GJ gap between the costs of conventional natural gas and that of RNG. This does not include provincial subsidies. FortisBC is able to offer RNG producers up to $30/GJ and Énergir in Quebec can offer around $20/GJ, with the difference between the two prices recoverable through rates. The federal carbon tax, at $20 a tonne rising to $50 by 2030, will offset some of the current price differentials, as will the Clean Fuel Standard (CFS), at $50/tonne rising to $150 in 2030, as these will not apply to RNG. Assuming the cost of RNG production declines to $13/GJ by 2030, from $17/GJ today, as projected, the Canadian Gas Association says that a project developer would not have a positive cash flow until 2028 to 2030 without additional policies.[153] The study found that renewable natural gas has a cost equivalent to a carbon price of $100 a tonne.[154]

5.1.3 International projects

EU studies have concluded that by 2050 increased use of RNG is practical and possible to help the EU reach their 2050 GHG goals.

The number of RNG plants in Europe has greatly increased, growing to 17,662 installations in 2016 from 6,227 in 2009. Most of that growth has come from the increase in plants running on agricultural waste, followed by sewage and landfill gas. RNG use has increased as well, to 62 PJ in 2016 from 2.7 PJ in 2011. Germany, Sweden and France saw the greatest increases.[155]

SoCal, a California energy company, has said that using RNG for residential and commercial buildings would provide the same GHG benefit as electrification, although SoCal's territory has a much lower heating demand than Canada.[156] Energy Networks Australia, an industry body, sees RNG as a key component of meeting their carbon reduction targets.[157]

5.1.4 Canadian projects

As of 2017, there were 61 agriculture and food waste digesters in operation, 86 wastewater treatment facilities and 53 landfill gas projects underway.[158]

There are 11 plants upgrading biogas to RNG in Canada:[159]

- Surrey, BC (AD)
- Abbotsford, BC (AD)
- Delta, BC (AD)
- Salmon Arm, BC (landfill)
- Richmond, BC (waste water)
- Kelowna, BC (landfill)
- Hamilton, ON (waste water)
- St-Hyacinthe, QC (waste water & AD)
- Terrebonne, QC (landfill)
- Riviere-du-Loup, QC (landfill)
- Beauhamois-Salaberry and Roussilon, QC (AD).

The Atmospheric Fund, a Toronto-based funding agency, has recently invested in a demonstration project to produce RNG from food waste in Ontario.[160]

Case study: Renewable natural gas in Canada

Across the country there are a number of examples where innovative renewable natural gas production is happening. Saint-Hyacinthe, Quebec, is demonstrating how a wastewater treatment plant can act as biogas energy centre hub. Organic and sewage wastes are combined and converted in an anaerobic digester to high quality biosolids and pipeline quality RNG. This RNG is then used to heat and cool the local municipal buildings and run municipal vehicles. The excess RNG is then sold to the regional utility Énergir, and injected into the local pipeline. This biomethanation project is a first in Quebec and the winner of the 2016 FCM Sustainable Communities Award for Waste.[161]

[153] Canadian Gas Association, *Federal Policy Proposal: The Canadian Renewable Gas Initiative*, August 2018. At http://www.cga.ca/wp-content/uploads/2018/08/Renewable-Gas-Proposal_Final_August-28.pdf.
[154] ICF, *The role of natural gas utilities in a decarbonizing world: Webinar*, 2019. At https://www.icf.com/resources/webinars/2019/gas-utilities-in-a-decarbonizing-world,
[155] European Biogas Association, *EBA Statistical Report 2017*. At http://european-biogas.eu/2017/12/14/eba-statistical-report-2017-published-soon/.
[156] Navigant, *Analysis of the Role of Gas for a Low-Carbon California Future*, July 24, 2018. At https://www.socalgas.com/1443741887279/SoCalGas_Renewable_Gas_Final-Report.pdf.
[157] Energy Networks Association, *Gas Vision 2050*, March 2017. At https://www.energynetworks.com.au/sites/default/files/gasvision2050_march2017_0.pdf.
[158] Canadian Biogas Association, *Biogas Projects in Canada*. At https://biogasassociation.ca/about_biogas/projects_canada.
[159] Information provided by Canadian Biogas Association.
[160] The Atmospheric Fund, *TAF Investment in Renewable Gas will Reduce Carbon Emissions, Advance Good Climate Policy*, September 6, 2019. At https://taf.ca/taf-investment-renewable-gas/.
[161] FCM, *Case study: How Saint-Hyacinthe turns organic waste into biogas and revenue,* 2016. At: https://fcm.ca/en/resources/gmf/case-study-how-saint-hyacinthe-turns-organic-waste-biogas-revenue

Another RNG innovation project underway is the Surrey BioFuel Facility in BC. FortisBC is partnering with the City of Surrey to produce RNG at the Surrey Biofuel Facility. A closed loop organics processing operation collects and processes curbside organic waste from Surrey residents and businesses. Along with compost, the facility will also produce biogas, which will then be captured and upgraded to RNG and used to power Surrey's waste collection trucks as well as the city's growing fleet of natural gas powered vehicles. It will produce around 100,000 GJ, or enough energy to heat approximately 1,100 homes annually. It will also provide heat for the district energy system which will heat and cool Surrey's city centre.[162]

5.1.5 Next steps

In addition to the provincial requirements in BC and Quebec, the Canadian Gas Association is proposing a standard of meeting 5% of Canada's natural gas demand through RNG by 2030, which would equate to 187 PJ.[163] Such an action would reduce GHG emissions by 11 Mt CO_2e annually,[164] equivalent to 1.5% of national emissions.[165]

In 2011, Alberta Innovates prepared a study for Enbridge on RNG in Ontario. According to the study, AD has the potential to produce 51 PJ[166] (1,372 million m^3) of RNG annually in the short term, which could represent 6% of the Ontario's residential, commercial and industrial gas demand. RNG could reduce emissions by 3 Mt CO_2e, or 2% of Ontario's emissions. Biomass gasification could supply an additional 114 PJ (3,063 million m^3) of RNG in the longer term, which would be equivalent to 12% of Ontario's gas demand, or 7 Mt CO_2e, 4.4% of provincial emissions.[167]

A report for Énergir, a Quebec gas distributor, estimated that 12% of Quebec's gas demand, equivalent to 25.8 PJ, could be technically and economically met with RNG from current biogas technologies, assuming a purchase price of $15/GJ, which would be cost-effective with electricity. This would account for 1.5 Mt CO_2e, around 2% of provincial emissions. By 2030 this could increase to around two-thirds, to 144 PJ, 82% of which would come from gasification.[168] By 2030, this would amount to 8 Mt CO_2e, or 10% of provincial emissions.

5.2 Hydrogen

5.2.1 Introduction

Using hydrogen as an energy carrier has recently received significant attention. At the Clean Energy Ministerial in May 2019, Canada, the United States, Japan, the Netherlands and the European Commission announced the creation of a partnership looking into further developing hydrogen as a low-carbon energy sources.[169]

Although hydrogen is less energy-dense than fossil fuels, when compressed it has a significantly higher energy density than batteries. Hydrogen can also be stored in large volumes, at quantities that can last for months rather than hours or days.[170] Hydrogen can also be combined with carbon via methanation to create synthetic natural gas. Hydrogen can be combusted directly or used in a fuel cell to generate heat and electricity.

Despite its abundance, hydrogen is hard to capture and control, and producing large quantities can be economically challenging. In addition, research is needed on the ability of the current gas infrastructure to accommodate large amounts of pure hydrogen (over 20%) in the network as the molecule of hydrogen is smaller than that of methane.

Despite these concerns, hydrogen is seen as a potential low-cost option in heat decarbonisation.[171]

[162] City of Surrey, *Surrey Biofuel Facility*. At https://www.surrey.ca/city-services/13015.aspx.
[163] Canadian Gas Association, *Federal Policy Proposal: The Canadian Renewable Gas Initiative*, August 2018. At http://www.cga.ca/wp-content/uploads/2018/08/Renewable-Gas-Proposal_Final_August-28.pdf.
[164] Emissions associated with natural gas combustion as 57.94 kg CO_2e/GJ. (S&T) Squared Consultants, GHGenius 5.0d, 2018. At https://ghgenius.ca/index.php/downloads. Calculations conducted by BC Ministry of Energy, Mines and Petroleum and cited in Zen and the Art of Clean Energy Solutions, *BC Hydrogen Study*, 2019. At https://www2.gov.bc.ca/assets/gov/government/ministries-organizations/ministries/zen-bcbn-hydrogen-study-final-v5_noappendices.pdf.
[165] Emissions figures from Environment and Climate Change Canada, *Greenhouse Gas Emissions*. At https://www.canada.ca/en/environment-climate-change/services/environmental-indicators/greenhouse-gas-emissions.html.
[166] Conversion from cubic metres to PJ based on rates from Canada Energy Regulator, *Conversions*. At https://apps.cer-rec.gc.ca/Conversion/conversion-tables.aspx?GoCTemplateCulture=en-CA#s1ss2.
[167] Enbridge Gas Distribution, *Renewable Natural Gas Application* September 2011. At http://www.rds.oeb.ca/HPECMWebDrawer/Record/299468/File/document. Emissions associated with natural gas combustion as 57.94 kg CO_2e/GJ.
[168] Deloitte and WSP, *Renewable natural gas production in Québec: A key driver in the energy transition -- Assessment of technical and economic potential in Québec (2018–2030)*, October 2018. At https://www.energir.com/~/media/Files/Corporatif/Publications/181120_Potentiel%20GNR_Rapport%20synth%C3%A8se_ANG.pdf?la=en.
[169] Clean Energy Ministerial, *"Countries launch a new international effort on hydrogen to help achieve global clean energy ambitions"*, May 29. At https://www.cleanenergyministerial.org/news-clean-energy-ministerial/countries-launch-new-international-effort-hydrogen-help-achieve.
[170] Committee on Climate Change, *Hydrogen in a Low Carbon Economy*, November 2018. At https://www.theccc.org.uk/wp-content/uploads/2018/11/Hydrogen-in-a-low-carbon-economy.pdf.
[171] See Element Energy and E4 Tech, *Cost analysis of future heat infrastructure options: Report for National Infrastructure Commission*, March 2018. At https://www.nic.org.uk/wp-content/uploads/Element-Energy-and-E4techCost-analysis-of-future-heat-infrastructure-Final.pdf.

In the UK, a report concludes that hydrogen in combination with electrification and energy efficiency programs will be key to meeting their GHG targets.[172] The BC government released a hydrogen study in 2019, focusing on how hydrogen can be used to supplement electrification and renewable natural gas to meet climate targets. The study found that hydrogen could help meet 31% of the province's 2050 carbon reduction target, reducing emissions by 15.6 Mt CO_2e annually through injecting hydrogen into the gas grid and hydrogen vehicles.[173]

5.2.2 Technologies

There are two methods of producing hydrogen. The most common and commercially viable method for obtaining hydrogen is steam methane reformation (SMR), which is used to separate the carbon and hydrogen from natural gas. SMR produces CO_2 as a by-product. If the CO_2 is captured and stored (through carbon capture and storage, CCS), the hydrogen produced is called "blue hydrogen".[174]

Another technique is electrolysis, which involves running an electric current through water, producing hydrogen and oxygen. When the electricity for this electrolysis comes from clean sources such as nuclear, hydro, wind or solar, the resulting hydrogen is called "green hydrogen", a corollary to green electricity. Although expensive, some think that this approach could be economically viable by 2035.[175] There is also the potential for hydrogen production to be paired with surplus renewable energy generation that would otherwise be curtailed, and the electrolyser can be used as a demand response resources for the electricity grid, being able to help the grid adapt to fluctuations in renewable electricity.

It takes on average 9 litres of water to produce 1 kg of hydrogen. There are a number of different methods of using electrolysis, each with different requirements for electricity and some needing high temperatures and steam.[176]

Costs of producing hydrogen vary greatly depending on the technology used, with SMR being much more cost effective than electrolysis. The capital costs of electrolysers is higher, and therefore load factors are crucial for the economics, as would the costs of the electricity. If paired with low-cost renewable electricity, costs could be lower. See Table 4 for a comparison of costs.

Table 4: Costs of hydrogen production (in Canadian dollars)

Technology		IEA[177]			BC[178]		
		$/kg	$/GJ	$/MWh	$/kg	$/GJ	$/MWh
Steam methane reformation	No CCS	1.33	10.64	38	1.32	10	36
	With CCS	2	16.63	60	2.28	17	61
Electrolysis from renewables		3-8	28-67	100-241	5.13	42	151

[172] Committee on Climate Change, *Hydrogen in a Low Carbon Economy*, November 2018. At https://www.theccc.org.uk/wp-content/uploads/2018/11/Hydrogen-in-a-low-carbon-economy.pdf.
[173] Zen and the Art of Clean Energy Solutions, *BC Hydrogen Study*, 2019. At https://www2.gov.bc.ca/assets/gov/government/ministries-organizations/ministries/zen-bcbn-hydrogen-study-final-v5_noappendices.pdf.
[174] Royal Society, *Options for producing low-carbon hydrogen at scale*, January 2018. At https://royalsociety.org/~/media/policy/projects/hydrogen-production/energy-briefing-green-hydrogen.pdf.
[175] Craig Richard, "Green hydrogen economically viable by 2035," *Wind Power Monthly*, March 12, 2019. At https://www.windpowermonthly.com/article/1578773/green-hydrogen-economically-viable-2035-researchers-claim.
[176] International Energy Agency, *The Future of Hydrogen: Seizing Today's Opportunity*, June 2019. At https://webstore.iea.org/download/direct/2803?fileName=The_Future_of_Hydrogen.pdf.
[177] International Energy Agency, *The Future of Hydrogen: Seizing Today's Opportunity*, June 2019, pp. 53-54. At https://webstore.iea.org/download/direct/2803?fileName=The_Future_of_Hydrogen.pdf. Conversions based on average rate of the first six months of 2019. For US dollar to Canadian dollar, $1.33
[178] Zen and the Art of Clean Energy Solutions, *BC Hydrogen Study*, 2019. At https://www2.gov.bc.ca/assets/gov/government/ministries-organizations/ministries/zen-bcbn-hydrogen-study-final-v5_noappendices.pdf.

Costs are expected to decline dramatically for electrolysis with increasing deployment of electrolysers and renewable energy. According to Bloomberg New Energy Finance, the costs to use renewables to extract hydrogen through electrolysis could be as low as C$32/MWh[179] (C$9/GJ) in 2030, and C$20/MWh[180] ($6/GJ) by 2050. This could mean that by 2050 hydrogen would be competitive to conventional natural gas with carbon pricing. [181]

5.2.3 Uses of hydrogen

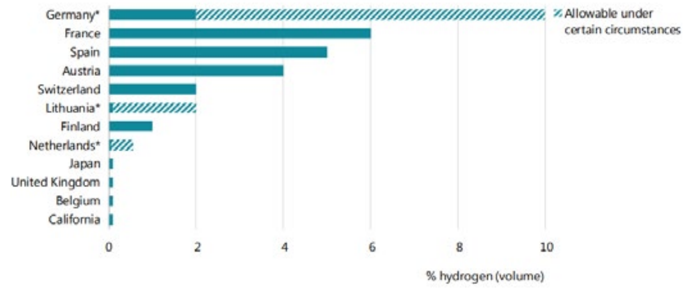
Hydrogen could be supplied directly to consumers through the current gas system, either blended with natural gas or as a substitute.

5.2.3.1 Hydrogen blending

Blending hydrogen with conventional natural gas has numerous benefits since the current infrastructure can be maintained. However, the energy density of hydrogen is about one-third that of natural gas, and a 3% hydrogen blend, for example, would reduce the energy content of the gas by around 2%. Despite this energy loss, it would lead to immediate reductions in GHG emissions.

According to research from the US National Renewable Energy Labs, blending up to 20% of hydrogen into the current natural gas system would be feasible.[182] While hydrogen can lead to the embrittlement of some forms of pipe, there are no concerns in the new forms of pipe commonly used in distribution systems, such as polyethylene (PE), polyvinylchloride (PVC) or elastomeric materials.[183] Figure 22 shows the allowed blending rate by jurisdiction, and additional research will be required to investigate how hydrogen interacts with the current natural gas system and equipment.

Figure 22: Allowed hydrogen blending in the gas system by jurisdiction [184]



Note: The allowed blending in some jurisdiction is constrained depending on what is attached to the pipeline. For example, in Germany if a CNG refuelling station is on the network, hydrogen blending is limited to 2%.

A further option would be to replace 100% of the gas through the existing system with hydrogen.

The costs of converting the gas system for hydrogen would depend on the concentration of hydrogen, although current polyethylene distribution pipelines and salt caverns can work with pure hydrogen without any need for upgrades. In Europe, modern gas heating and cooking appliances in Europe are certified for up to 23% hydrogen, although long-term observations would be needed. Research on the tolerance of commercial and industrial customers, and those using gas engines, would be needed.[185]

5.2.3.2 Synthetic methane

Another option is methanation (the second step in power-to-gas) to create synthetic natural gas from the hydrogen. Hydrogen can be combined with CO_2 to create methane (with oxygen as the by-product), which would be chemically the same as conventional natural gas. For the whole process, from renewable energy to storage in the gas grid, an efficiency of approximately 64% can be reached.[186]

179 US$24/MWh
180 US$15/MWh
181 Will Mathis and James Thornhill, "Hydrogen's Plunging Price Boosts Role of Gas as Climate Solution," *Bloomberg New Energy Finance*, August 21, 2019. At https://www.bloomberg.com/news/articles/2019-08-21/cost-of-hydrogen-from-renewables-to-plummet-next-decade-bnef.
182 M. W. Melaina, O. Antonia, and M. Penev, *Blending Hydrogen into Natural Gas Pipeline Networks: A Review of Key Issues*, March 2013. At https://www.energy.gov/sites/prod/files/2014/03/f11/blending_h2_nat_gas_pipeline.pdf.
183 Zen and the Art of Clean Energy Solutions, *BC Hydrogen Study*, 2019. At https://www2.gov.bc.ca/assets/gov/government/ministries-organizations/ministries/zen-bcbn-hydrogen-study-final-v5_noappendices.pdf.
184 International Energy Agency, *The Future of Hydrogen: Seizing Today's Opportunity*, June 2019, p. 72-73. At https://webstore.iea.org/download/direct/2803?fileName=The_Future_of_Hydrogen.pdf.
185 Klaus Altfeld and Dave Pinchbeck, "Admissible hydrogen concentrations in natural gas systems," *Gas for Energy*, Issue 03/2013. At http://www.gerg.eu/public/uploads/files/publications/GERGpapers/SD_gfe_03_13_Report_Altfeld-Pinchbeck.pdf.
186 Tanja Schaaf, Jochen Grünig, Markus Roman Schuster, Tobias Rothenfluh and Andreas Orth, *Methanation of CO2 - storage of renewable energy in a gas distribution system, Energy, Sustainability and Society*, 2014. At https://energsustainsoc.biomedcentral.com/articles/10.1186/s13705-014-0029-1.

In order to be low-carbon, the CO_2 would have to be produced from a non-emitting source (such as combustion from biomass). For example, in Germany, a pilot plant with an electrolyser has been producing 300 m^3 per hour of synthetic methane since 2013, with CO_2 being provided from a biogas-fired power plant.[187] However, even where CO2 is captured from conventional fossil operations this recycling of CO2 could have a meaningful reduction in emission intensity levels assuming the hydrogen for methanation is from renewable or low-carbon sources.

While creating synthetic natural gas adds approximately 50% to the costs of producing hydrogen by itself, the ability to use the current gas infrastructure may make it more feasible than using direct hydrogen.[188]

5.2.4 International projects

Internationally, different countries are devoting significant financial, technical and economic resources towards solving the problem of how to use hydrogen. Research on the use of hydrogen in transportation is ongoing and there are currently 37 demonstration projects examining hydrogen blending in the gas grid.

The Ameland project in the Netherlands found that blending hydrogen up to 30% did not pose any difficulties for household devices, including boilers, gas stoves and other cooking appliances. Injection has also been tested at both the transmission and distribution level. [189] The GRHYD project in northern France, launched in 2014, is piloting blending hydrogen starting with 100 homes and the health centre, and increasing to 200 homes, in the Capelle la Grande district of the Dunkerque Urban Community. Starting with a 6% hydrogen blend, the pilot will test up to a 20% blend in 2020.[190] In Turkey in 2011, the island of Bozcaada installed hydrogen produced from renewable energy to help meet the island's energy demands.[191] Germany has in place a commercially operating electrolyser producing hydrogen from wind energy.[192]

HyDeploy, a UK initiative, will run a 12-month trial of blending 20% hydrogen with natural gas starting in early 2020. Around 130 homes and buildings will receive the gas blend.[193] In addition, Northern Gas Networks, a gas distribution company in Leeds, is proposing to convert a section of Leeds to 100% hydrogen. The hydrogen will be sourced from SMR.[194]

Australia too has developed a hydrogen roadmap, and as part of this, recently announced a coal-to-hydrogen pilot project in which the hydrogen will be exported to Japan.[195] The US are also investigating hydrogen. NREL with SoCal Gas have launched their first power-to-gas project in which excess electricity is used in an electrolyser which is then combined with CO_2 to generate methane. The resulting gas will be injected into the pipeline.[196]

5.2.5 Canadian projects

Canada is recognised as a leader in the hydrogen and fuel cell research sector, with the largest cluster of companies located in BC. Quebec, Ontario and Alberta also have clusters, so the technology is widespread across the country. According to an annual survey conducted by the Canadian Hydrogen and Fuel Cell Association, 60% of the organizations working on hydrogen in Canada have been involved in this sector for more than 10 years. All projects in Canada are considered demonstration projects and the majority of these by far are located in British Columbia (21%), followed by Ontario (4%) and Quebec (1%).[197]

Enbridge Gas in Ontario has installed an electrolyser in Markham, Ontario, in partnership with Hydrogenics (see *case study* below). Currently the project receives its revenue from providing grid balancing services to the electricity grid. Enbridge has proposed a Low-Carbon Energy Project, which would blend the hydrogen from the facility into the natural gas grid

187 International Energy Agency, *The Future of Hydrogen: Seizing Today's Opportunity*, June 2019, p. 57-63. At https://webstore.iea.org/download/direct/2803?fileName=The_Future_of_Hydrogen.pdf.
188 Agora Verkehrswende, Agora Energiewende and Frontier Economics, *The Future Cost of Electricity-Based Synthetic Fuels*, September 2018. At https://www.agora-energiewende.de/fileadmin2/Projekte/2017/SynKost_2050/Agora_SynKost_Study_EN_WEB.pdf.
189 International Energy Agency, *The Future of Hydrogen: Seizing Today's Opportunity*, June 2019, p. 73. At https://webstore.iea.org/download/direct/2803?fileName=The_Future_of_Hydrogen.pdf.
190 Engie, *The GRHYD demonstration project*. At https://www.engie.com/en/businesses/gas/hydrogen/power-to-gas/the-grhyd-demonstration-project/.
191 United Nations Industrial Development Organization, *First hydrogen energy production on a Turkish Island has started on Bozcaada*, 2011. At https://www.unido.org/news/first-hydrogen-energy-production-turkish-island-has-started-bozcaada.
192 "Hydrogen becoming technology of the future," *Hamburg News*, February 2019. At https://www.hamburg-news.hamburg/en/renewable-energy/hydrogen-becoming-technology-future/.
193 HyDeply, *Positive progress to reduce UK C02 emissions*, 2019. At https://hydeploy.co.uk/.
194 Northern Gas Networks, *H21 Leeds City Gate*, July 2016. At https://www.northerngasnetworks.co.uk/wp-content/uploads/2017/04/H21-Report-Interactive-PDF-July-2016.compressed.pdf.
195 Joanna Sampson, "Australian coal-to-hydrogen pilot gets green light," *Gas World*, February 2019. At https://www.gasworld.com/australian-coal-to-hydrogen-pilot-gets-green-light/2016639.article.
196 NREL, *NREL and Southern California Gas Launch First U.S. Power-to-Gas Project*. At https://www.nrel.gov/esif/partnerships-southern-california-gas.html/
197 Canadian Hydrogen and Fuel Cell Association, *Sector Profile 2018*, 2018. At http://www.chfca.ca/media/CHFC%20Sector%20Profile%202018%20-%20Final%20Report.pdf.

(up to 2%).[198] BC, Alberta and Quebec have also looked into hydrogen vehicles.

Case study: Hydrogenics and Enbridge Gas's first multi-megawatt electrolyser

In order to advance hydrogen technology and energy storage in Canada, Hydrogenics (since purchased by Cummins) and Enbridge Gas formed a joint venture to build North America's first multi-megawatt hydrogen facility in Markham, ON. Since operations began in 2018, the Markham Energy Storage Facility has provided regulation services under contract to the Independent Electricity System Operator (IESO) of Ontario making the grid more reliable and flexible.

The 2.5 MW facility (built on a 5 MW scalable platform) works by balancing the second-by-second variations in grid supply and load. Similar to adding or reducing power generation on the grid, the hydrogen electrolyser load is increased (less generation on the grid) or reduced (adding generation to the grid) and the simultaneous by-product is clean hydrogen generation, receiving revenue from providing ancillary services such as frequency control to the electricity grid.[199] The electrolyser technology has one of the highest power densities and smallest footprints around. Once it is produced, hydrogen can be stored for later use, converted back into electricity when needed, or blended into the natural gas distribution system to reduce the carbon content of the gas.[200]

Following on from the start of the project, Enbridge is now proposing to blend the hydrogen into the natural gas grid (up to 2%).[201]

5.2.6 Next steps

There are a number of options for hydrogen in the gas system, from blending, to power-to-gas, to 100% hydrogen conversion.

One major advantage of hydrogen is that it can make use of existing gas infrastructure. Another advantage is that it could provide synergies with the transitions happening in other energy areas, including transportation, but also in electricity with electrolysers helping to balance the electricity grid and store, in effect, excess renewable electricity that might be curtailed today.

But a move to hydrogen, apart from low-volume blending, would entail costs. The UK's Committee on Climate Change (CCC) estimates that switching to 100% hydrogen would cost up to £50-100 billion (C$84-167 billion), which would work out to £2,000-4,000 (C$3,300-6,600) per household, excluding network costs, which are expected to be low due to the network already being suitable for hydrogen use.[202] Such conversion costs are not unprecedented. The UK, US, Austria and Germany faced such costs when in the 1960s and 70s they switched from town gas (with 50% hydrogen) to natural gas. The UK alone spent US$120 billion (C$160 billion) over 10 years to convert 40 million appliances to natural gas.[203] Due to the need to convert end-use appliances, power-to-gas and the creation of synthetic methane could reduce the costs of the transition by allowing existing end-use infrastructure to continue.

198 Enbridge Gas, *Hydrogen Storage*, 2019. At https://www.enbridgegas.com/Natural-Gas-and-the-Environment/Enbridge-A-Green-Future/Hydrogen-Storage.
199 Hydrogenics, *North America's first multi megawatt power-to-gas facility begins operations,* 2018. At https://www.hydrogenics.com/2018/07/16/north-americas-first-multi-megawatt-power-to-gas-facility-begins-operations/
200 Enbridge Gas, *Hydrogen Storage*, 2019. At https://www.enbridgegas.com/Natural-Gas-and-the-Environment/Enbridge-A-Green-Future/Hydrogen-Storage.
201 Enbridge Gas, *Hydrogen Storage*, 2019. At https://www.enbridgegas.com/Natural-Gas-and-the-Environment/Enbridge-A-Green-Future/Hydrogen-Storage.
202 Committee on Climate Change, *Hydrogen in a Low Carbon Economy*, November 2018. At https://www.theccc.org.uk/wp-content/uploads/2018/11/Hydrogen-in-a-low-carbon-economy.pdf.
203 International Energy Agency, *The Future of Hydrogen: Seizing Today's Opportunity*, June 2019, p. 73. At https://webstore.iea.org/download/direct/2803?fileName=The_Future_of_Hydrogen.pdf.

CHAPTER 6: WHAT'S HOLDING US BACK?

The natural gas sector is in a time of transition. While it has – and continues to – safely, reliably and affordably provide energy to Canadians, the sector will need to prepare to be part of a larger low-emissions energy system.

Of course the natural gas sector is not standing still. The CGA has noted that there are many forward looking collaborative projects in the innovation field but more needs to be done. As an example, FortisBC, a BC gas distributor, has introduced a "30BY30 Target," which aims to reduce customers' GHG emissions by 30% by the year 2030.[204]

Given the global drive to low-emissions energy systems and the interest from utilities, a transition is achievable. While the drive is there, there are still major barriers to development, namely:

- policy and regulatory uncertainty
- financing
- costs
- regional differences
- public acceptance.

6.1 Policy and regulatory uncertainty

Gas infrastructure is a long-lived asset, with an expected operational lifetime in excess of 40-50 years. As a result gas utilities and their regulators tend to be conservative about investments.

Policy drives regulations, and in many jurisdictions there are no clear long-term visions on the future of energy. In other cases, changes in government leads to major changes in energy policies. This lack of a policy consistency and certainty hampers innovation and investment.[205]

According to the World Economic Forum, the countries that are the most successful in the energy transition have three things in common: 1) A stable regulatory framework, 2) an innovative business environment and 3) a strong political commitment to the energy transition. In the Forum's Energy Transition Index, a measurement of a country's readiness for the energy transition, Canada was ranked 35th in the world in 2019, below most European countries and the USA.[206]

Research in the Netherlands has also noted that the countries that have been the most successful at the

[204] FortisBC, *Sustainability*. At https://www.fortisbc.com/about-us/sustainability.
[205] See Bruce Cameron, Richard Carlson, and James Coons, *Canada's Energy Transformation: Evolution or Revolution?*, Pollution Probe and QUEST, April 2019. At https://www.pollutionprobe.org/wp-content/uploads/QUEST_Pollution-Probe-Policy-Innovation-Report.pdf.
[206] World Economic Forum, *Fostering Effective Energy Transition*, 2019 edition, March 2019. At http://www3.weforum.org/docs/WEF_Fostering_Effective_Energy_Transition_2019.pdf.

energy transition, and in bringing industry and the public along, have set long-term visions based on a consensus from society and parties from all parts of the political spectrum.[207]

Another barrier is the nature of regulatory regimes in Canada. Generally, regulators only assess proposed projects on a strict short-term economic basis, controlling costs for the consumer, without necessarily taking into consideration long-term costs, emissions and innovation. Research has shown that Canada's energy regulators, policymakers and utility leaders are almost unanimous in their view that our legislative regulatory frameworks are not flexible enough and don't easily adapt to change.[208] As an example, Ofgem, the UK energy regulator, has set three priorities for its work: 1) enabling competition and innovation, 2) decarbonizing at the lowest cost and 3) protecting consumers. Ofgem says that by focusing on these priorities it will be able to protect customers while ensuring that the UK can meet the government's target of being net-zero on emission by 2050.[209]

With the changes coming to the country's energy systems, Canada must examine how our energy policies and regulatory models need to be adapted to allow for innovation and a holistic examination of the best methods for affordably and sustainably providing energy services. Integrated energy planning will be key, and the regulatory and planning process needs to move beyond the current two disparate silos of electricity and natural gas to create holistic energy planning and have the ability to evaluate the best energy source to meet their energy needs and public policy goals within the restrictions of reducing our GHG emissions. Regulatory and government policy could seek to optimize renewable and low-carbon energy costs by evaluating costs in equivalent energy units. Such an example would be to normalize all energy supplies to $/MWh or $/GJ to assist in stakeholder education and transparency and to evaluate the best energy source for meeting needs.

6.2 Financing

The lack of consistent energy policies and regulatory uncertainty, which has been evident to date, also inhibits investment. In BC, for example, the CleanBC policy and other regulatory frameworks have led to a development of the RNG market. Quebec has also recently introduced regulations to set the minimum quantity of RNG delivered by natural gas distributors at 5% by 2025. As a result, natural gas utilities in Quebec and BC are interested in signing long-term contracts to procure RNG. These are two good examples of where government intervention has resulted in the energy systems changing to meet the future needs.

Outside of these provinces, policy uncertainty or lack of subsidies could limit investment. The federal government's Clean Fuel Standard (CFS) may alleviate some of the uncertainty. While the gaseous stream of the CFS is still under development, and not expected to be introduced until 2023, under the CFS, gas utilities will be obliged to reduce the carbon intensity of the fuel or to purchase credits on the market to meet their obligation.

While the CFS will provide some benefits to financing projects, there continues to be uncertainty around the credit market and whether it can provide the long-term price signal required for project financing. As such, more policy certainty or mandates will be required if projects are to be financed.

Consultations on the gaseous stream of the CFS will start in 2020. As part of that consultation it will have to be decided if fuel switching and advanced energy efficiency measures (for example, switching from a natural gas furnace to a natural gas heat pump) will be able to earn CFS credits.

6.3 Costs

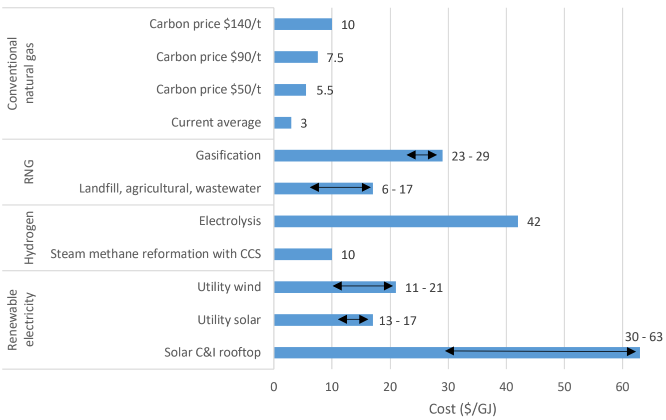
Regardless of the technology, the costs of low-carbon alternatives to conventional natural gas are much higher (see Figure 23). As discussed in section 5.2, costs for hydrogen production are expected to decrease rapidly through learning and deployment. However even with the added costs of the CFS and

[207] See European Climate Foundation (ECF), PBL Netherlands Environmental Assessment Agency (PBL), and Clingendael International Energy Programme (CIEP), *Germany, Denmark and the United Kingdom: lessons to be learnt for the Netherlands? Report on a seminar for the SER negotiations on the Netherlands' National Energy Agreement*, 2013. At https://www.pbl.nl/sites/default/files/cms/publicaties/PBL-2013-germany-denmark-and-the-united-kingdom-lessons-to-be-learnt-for-the-netherlands-1150.pdf.
[208] Bruce Cameron, Richard Carlson, and James Coons, *Canada's Energy Transformation: Evolution or Revolution?*, Pollution Probe and QUEST, April 2019. At https://www.pollutionprobe.org/wp-content/uploads/QUEST_Pollution-Probe-Policy-Innovation-Report.pdf.
[209] Ofgem, *Our Strategic Narrative*, 2019-2023, July 2019. At https://www.ofgem.gov.uk/system/files/docs/2019/07/our-strategic-narrative-2019-23.pdf.

carbon pricing, the price differential is likely to remain significant for the near- and medium-term.

It is also important to compare the costs of low-carbon gases with other renewable alternatives, and not only to conventional natural gas. As shown below, low-carbon gases are cost-competitive to other forms of clean energy, such as solar and wind.

Figure 23: Cost comparison of low-carbon natural gas and renewable electricity (in Canadian dollars per GJ) [210]



6.4 Regional differences

All provinces and territories want to reduce their GHG emissions, but each jurisdiction has significant differences in their internal energy resources and demand. Saskatchewan's and Alberta's natural gas load is primarily in the industrial side. In comparison, in Ontario the natural gas demand is more mixed, with industrial loads and residential and commercial loads almost equivalent.

In provinces with high emissions intensity for electricity generation, increased electrification could actually increase emissions. It would thus make more sense in the short term to consider electrification in provinces with a high share of low emitting electricity generation.

The availability of energy sources also varies. In western Canada the availability of low-cost natural gas will likely mean a different pathway than in Quebec, for example, where its large hydropower resources may make hydrogen production more economically feasible. In the Maritimes, natural gas is more expensive, and the infrastructure is not as developed as in other provinces. As a result, much of the residential and commercial heating load is from propane and oil, which has higher GHG emissions than natural gas. In addition, the region's continued use of coal in electricity generation means that switching to natural gas from other heating sources, even electricity, could bring immediate GHG reductions.[211]

It is not just differences in energy that could affect policies. Weather conditions vary across the country and that could limit potential solutions, such as the role of ASHPs in areas that have cold winters. Dense urban areas with high use of natural gas for residential customers will also require different solutions than rural areas.

All of this means that a national policy on the future of the natural gas system is difficult given the disparity of the jurisdictions, and any federal-level policy must take into account these local differences.

6.5 Public acceptance

Changing the gas system and the heating system will differ from changes that have been made in electricity. While there has been opposition to costs in some parts of the country, for the majority of Canadians not engaged in the process, the switch to more low-carbon forms of electricity in Canada has been relatively invisible from an end-user perspective – when turning on the lights they turn on like before regardless of the source of electricity. Generally people do not like to change their lifestyles, so the more "invisible" the change the better.

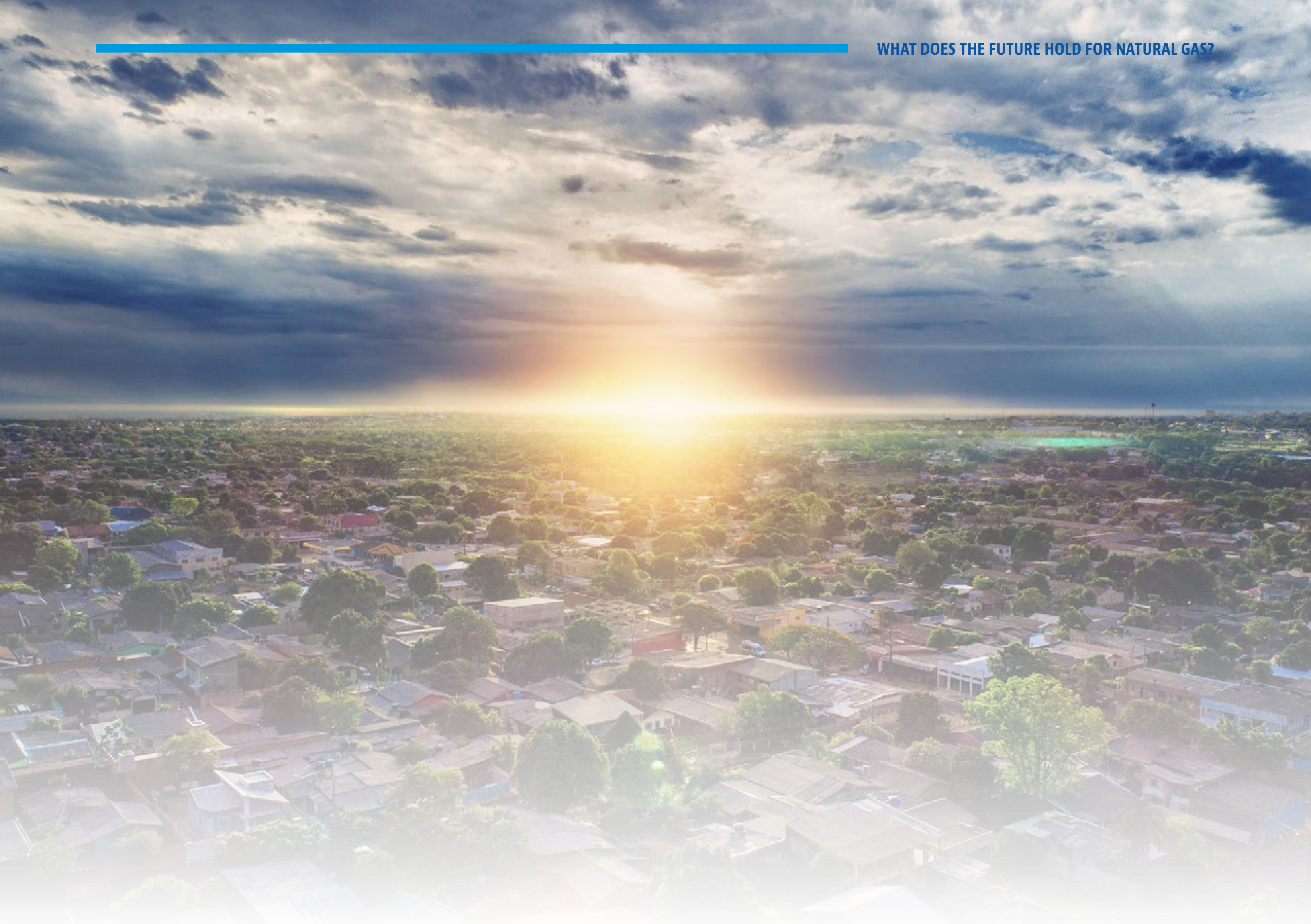
But Canada is a cold country, and heating is crucial for the health and well-being of our population. As such, when changing how homes are heated, consumers will need to be brought along, educated and informed so they can feel comfortable with and have some degree of agency in the changes, rather than being tied to the status quo. Most Canadians do not appreciate the amount of energy used for heating, and the difference in units commonly used in bills (kWh for electricity, and m^3 or PJ for gas) do not allow for straightforward comparisons or understanding. Increasing acceptance

[210] See sections above for discussion on costs and impact of carbon pricing, and for costs of RNG and hydrogen. Renewable electricity costs from the unsubsidized costs from Lazard, *Lazard's Levelized Cost of Energy Analysis*, version 12, November 2018. At https://www.lazard.com/media/450784/lazards-levelized-cost-of-energy-version-120-vfinal.pdf. US dollar to Canadian dollar conversion based on the average rate of the first six months of 2019 of $1.33.

[211] Information provided by Heritage Gas.

will require a lot of face-to-face engagement to make sure consumers are comfortable with the technology and prepared to make the change.

In addition, developers, contractors and equipment installers will need to be educated on how to install and maintain new equipment and to implement energy efficiency practices.



CHAPTER 7: NEXT STEPS AND CONCLUSION

7.1 Paths forward

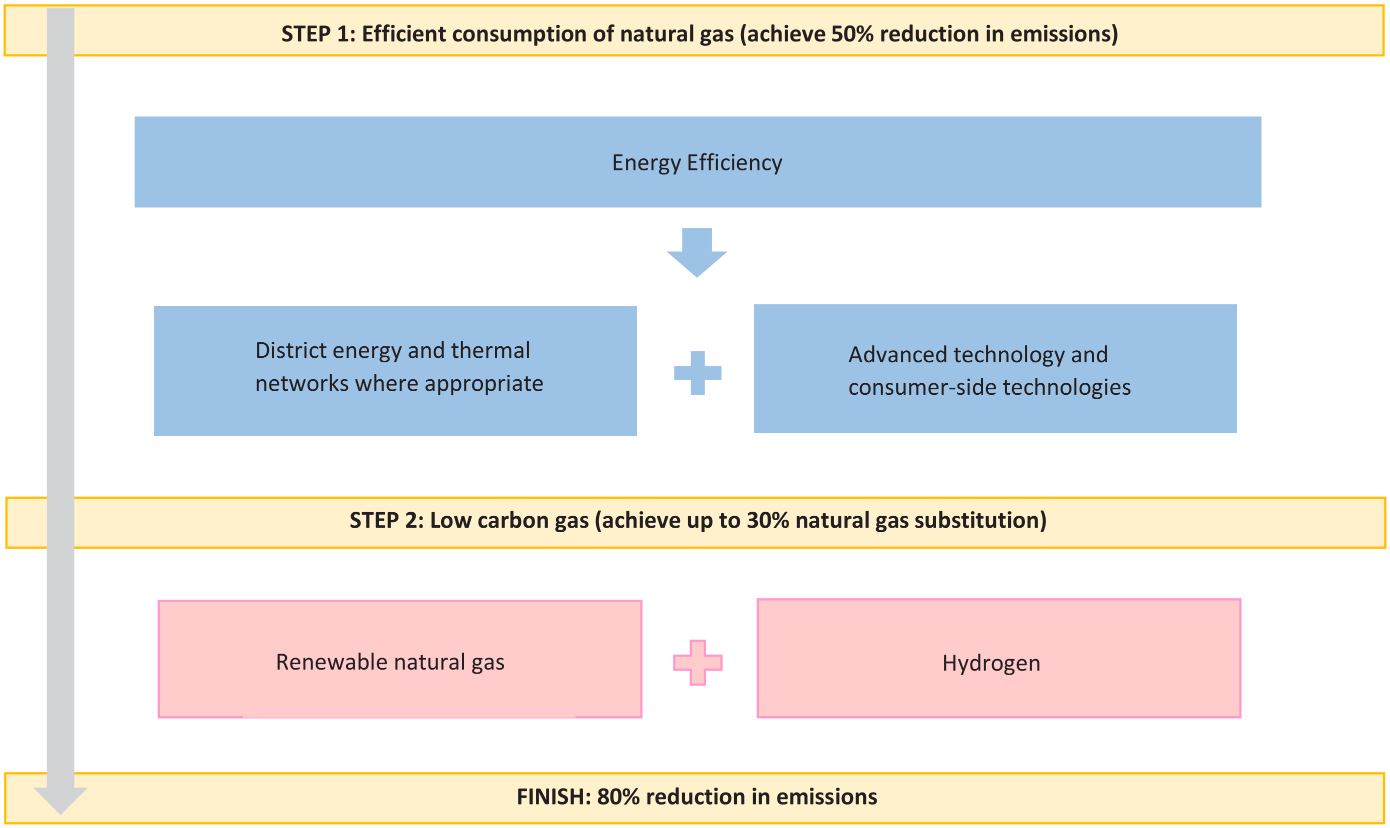
A suite of coordinated actions will be required to effectively address the future of natural gas in Canada including those barriers that will be faced in areas such as decarbonizing the gas system. As numerous studies have demonstrated, using the gas system to provide energy services in the future can be the most cost-effective and practical way to reduce emissions throughout the entire energy system.

The paths forward is illustrated below. The first step should naturally be to ensure customers are using natural gas as efficiently as possible, followed by examining technologies that could provide needed local energy services with a lower emissions intensity. In some areas, particularly dense urban areas, thermal networks, using waste heat, CHP or other forms of thermal energy, can also more efficiently and cleanly provide energy.

As indicated in the ICF report for the CGA, we are able to reduce our emissions by nearly 50% by 2050 primarily though promoting conservation and demand side measures as well as introducing more efficient end-use technologies, such as hybrid heating. While this would be a great start, it will not get us to the 2050 target of an 80% reduction. To achieve greater reductions, it is likely that we will have to consider a larger role of low-carbon gases, such as RNG or hydrogen. Local circumstances – RNG in those areas with a large agricultural sector, or hydrogen in a hydropower province, for example – will likely dictate the low-carbon gas chosen. For a potential pathway see Figure 24.

It should be noted that while Step One should be initial activities, that does not preclude also looking into Step Two and to start introducing low-carbon gases at the same time.

Figure 24: A potential pathway for using the gas system to reduce emissions



7.2 Matrix of action

Decarbonizing the gas system will require action by a number of stakeholders. Based on research and feedback from stakeholders, Pollution Probe devised a matrix of action to highlight the areas, actions and players that need to be considered as we look at next steps (see Appendix 1).

The purpose of the matrix is not to recommend specific actions that every jurisdiction should adopt in Canada but rather to present six potential areas of activity. It is anticipated that specific jurisdictions and stakeholders will determine which actions are most appropriate to support or pursue based on their own priorities.

Based on research and feedback from stakeholders, six areas of action were identified.

7.2.1 Policy and regulatory reform

Policy and regulatory uncertainty is hindering progress. Policy makers need to develop a consensus and a vision on the future of energy, a vision that demonstrates long-term commitment while also allowing for flexibility in achieving it.

The gas system needs to be evaluated in these future plans. Any analysis of a potential energy future needs to at least consider the role of the gas system and low-carbon gases. Even if an alternate choice is made, all potential options need to be considered.

Any plan needs to account for regional differences in Canada, namely the carbon intensity of the electricity grid, and potential feedstocks for low-carbon gas. Using natural gas to produce hydrogen (with CCS) may be more feasible in jurisdictions with large natural gas reserves and suitable storage areas, while other jurisdictions with large renewable electrical capacity might be better suited to electrolysis.

Energy regulators take direction in some form or another from governments. The regulatory process needs to be broadened to allow for a holistic assessment when evaluating projects to look beyond pure economics and also include social and environmental factors. For example, for energy efficiency programs, if the regulatory assessment of any proposal was also based on reducing GHG emissions in addition to straight economics, it might allow for other projects to be included. This would allow for a discussion of what is the right energy source for meeting energy needs with the lowest emissions and costs.[212]

7.2.2 Conservation and efficiency

When looking to reduce emissions from an energy system the first step should be to reduce the amount of energy needed. It is much easier to transition to new forms of energy when the system is optimally efficient.

As part of this, innovation on the customer side that increases efficiency needs to be encouraged, such as transitioning to hybrid heating, gas absorption heat pumps, CHP and district energy. Highly efficient thermal networks using wastewater, industrial and low-grade commercial heating waste heat, supplemented potentially with other fuels or even CHP, should be developed where appropriate. Where their uses would increase efficiency and reduce emissions, such technologies should be encouraged, either through the CFS or other programs.

As a further benefit, increased conservation and efficiency could reduce the need for new gas infrastructure, thereby keeping future costs down for customers.

While the manner in which energy efficiency is conducted will vary on the jurisdiction, new methods such as energy efficiency resource standard (EERS) and PACE financing can be looked at. An additional idea is the development of energy service companies (ESCOs) that supply "energy services" such as heating to customers. ESCOs could be third-party companies or current utilities that can be allowed to operate as ESCOs as well. As they are selling energy services rather than a fuel, ESCOs can help in deciding on what is the right energy for the customer based on local conditions. An ESCO model could allow for more innovative programs and allow for on-bill financing of energy efficiency programs.

7.2.3 Move to low-carbon gas

Conservation and efficiency, while important and a good start, will not be sufficient to meet Canada's long-term climate targets. In the long-term, low-carbon gases, either RNG or hydrogen or some mixture, will need to displace conventional natural gas in part or in whole. In the near term, promoting the increasing use of RNG from waste sources is a feasible option to reduce emissions, and gasification could be an option. Hydrogen has enormous potential, and early steps of blending hydrogen in the gas system should be encouraged. As an immediate step, all new gas pipeline projects should be made "hydrogen ready," which will not be a large burden as most new equipment is already as such.

The choice of low-carbon gas will depend on regional and jurisdictional factors. Regions with large agricultural waste streams could promote additional RNG, while other jurisdictions could look into hydrogen production from natural gas or electrolysis, depending on energy source availability. Additional research will be needed to consider hydrogen's role, including full hydrogen conversion or the development of synthetic methane.

The conversion of higher-carbon fuels to lower carbon fuels also needs to be considered. While potentially not a long-term strategy, the conversion of coal-fired power plants, heavy-duty vehicles and marine transportation to natural gas, for example, can have immediate GHG and other air pollution benefits.

7.2.4 Education and marketing

Energy is complicated, and many Canadians are not interested in energy beyond what they receive and how much it costs.

In the end it will be up to utilities, regulators and governments to increase their public engagement with energy consumers and to demonstrate that they are actively working toward a low-carbon energy system vision, such as FortisBC's 2030 emissions reduction commitment. For gas utilities to be part of the energy future they need to continue to demonstrate that they can be. While some effort has been made on this, public buy-in is crucial, and regulatory and policy processes can play a role here by ensuring any analysis considers the role of gas.

But other actions can also be taken to increase public awareness. It is hard for most people to understand how much energy they use for heating in comparison to the energy they use for electricity. By changing

[212] Andrew Campbell, "Redirecting Energy Efficiency Policies for the Climate," *Energy Institute Blog, UC Berkeley*, August 5, 2019, https://energyathaas.wordpress.com/2019/08/05/redirecting-energy-efficiency-policies-for-the-climate/.

the way energy is billed and communicated into consistent units (eg. kWh or GJ), it would be easy for people to understand their own energy use. This could also allow for a better discussion on conservation and energy efficiency retrofits so that the greatest energy and climate impact can be achieved.

Since many changes will be needed in lots of individual buildings, realtors, suppliers and trades will also need to be trained so they can explain the new systems, and what the benefits and trade-offs are.

7.2.5 Finance

One of the largest barriers to development is financing. While costs for new technology need to decline, for the most part the technology to meet our goals is already available. A major problem is securing the financing for research and development, and for new projects.

One of the major barriers to the financing of new projects is the lack of long-term commitment by many governments - federally, provincially and municipally. Government commitment and support for utilities offering long term contracts for RNG would increase the number of projects getting off the ground.

While mandates for low-carbon gases, incentives and subsidies can be part of the package to encourage project development and reduce risks, there are other options that can be pursued. Long-term commitment even without subsidies can help, although the growth may be slow in the beginning without seed funding. Another option would be to include efficiency and innovation in the CFS so they can benefit from the compliance market.

7.2.6 Integrated energy planning

Planning will need to be done on a regional basis and based on the needs of the region. What will work in rural areas may not work in urban areas that are already facing electricity capacity constraints. What works in jurisdictions with large legacy hydropower will likely be different in regions without.

Holistic all-energy planning that integrates electricity and thermal energy needs and considers all potential alternatives is needed to adequately assess cost-benefits of different solutions. Such planning needs to consider other factors, including impact on peak demand of the different options, and resiliency to extreme weather. The ability to use efficiency or new technologies, such as hybrid heating, to reduce the need for new infrastructure investments has to be included in this planning, and should be incentivised. The timelines of construction of new infrastructure also need to be considered, especially if new electricity generation or transmission are needed.

There will be numerous questions to ask, such as the potential for district energy or CHP; the capacity of the electricity grid in that area; the availability of RNG or hydrogen source materials. To answer these questions people will need to understand the whole system in order to identify trade-offs and choices that can be made. While utilities and federal and provincial governments all have a role to play, much of this will have to be decided at the local or regional level, developed through community energy plans, and with support from the people who live in that area.

7.3 Conclusion

The natural gas sector's big advantage is the pipeline and integrated storage infrastructure, which can be used to move "gaseous molecules" of renewable energy. That infrastructure, and the flexibility of the long-duration storage, needs to be leveraged so that the transition to a low-carbon future minimizes cost pressures that would otherwise occur.

Energy demand in Canada is very seasonal, and our heating season is longer than most other countries. Full electrification, even using high-efficiency cold climate heat pumps, could lead to large seasonal imbalances in power demand, especially in some urban areas that are already facing electricity capacity constraints. We need to develop a policy framework that focuses on goals and outcomes that allow for innovation and multiple technological pathways for achieving those goals and outcomes, allows for customer choice and preserves the benefit of a competitive marketplace.

Other jurisdictions are also considering the future of their gas systems. Importantly, in the studies on the role for gas systems in the future energy system in Canada and internationally, all saw savings compared to an electricity-only future.

If the gas system were ignored in future planning in favour of alternatives, it could increase energy costs for consumers, which could lead to public hostility towards any emissions-reduction plan. The timelines for meeting Canada's 2030 and 2050 targets are important, and if the electricity system were to be expanded to replace the natural gas system, it could take decades to build the necessary infrastructure. Trying to supply additional electrical capacity into dense urban areas, many of which are already near capacity, will be an additional difficulty.

But it is important to note that this does not mean that the gas system will play a role. It will be up to the gas sector, energy regulators and government policy makers to demonstrate continuing commitment for the gas system to not only provide reliable, cost-effective energy services but also play a role in reducing emissions, and help Canada transition to a lower-emissions energy system.

It is necessary to move beyond a pipes-versus-wires debate to see how all sectors can play a collaborative part in the energy systems transition.[213] The advancement of a low-carbon energy future would clearly benefit from holistic energy planning that embraces both increased electrification and the development of renewable gas supplies. We will likely need both – clean electricity and clean gas.

213 Dave Elliott, *Rethinking power: pipes versus wires*, March 6, 2019. At https://physicsworld.com/a/rethinking-power-pipes-versus-wires/.

Appendix 1: Matrix of Action

Areas of action	Policy and regulatory	Conservation and efficiency	Low carbon gas alternatives	Education and Marketing	Finance	Integrated planning
Categories of action	Develop a consensus vision of our energy future including binding targets for decarbonisation	Advocate for stronger codes and standards for buildings and appliances (eg. net zero buildings)	Develop renewable content requirements that incents the development of RNG.	Highlight benefits of the gas system and demonstrate how it can promote low carbon development.	Provide regulatory support for innovation by allowing more experimentation with shared risk (such as in a regulatory sandbox)	Promote regional integrated resource planning involving all utilities and stakeholders to develop holistic solutions
	Create regional outcome-oriented and objective-based policy and regulatory strategies to meet a future vision that allows all technologies to compete	Change cost effective test for conservation funding to include carbon reduction	Facilitate the development of hydrogen pilots, starting with blending and investigating further (replacing or synthetic methane)	Discuss all energy in the same units to allow for comparison on amount of energy used, costs and costs of alternatives (such as between low carbon gases and other renewables)	Allow innovation and new technologies to benefit from regulatory credits (such as the CFS) where they can demonstrate emissions reductions	When modelling and planning the future energy system, the gas system has to be included in the analysis. Much of this modelling will have to be done on a regional or local basis
	Expand the regulatory framework to consider more than economic consideration (such as environment, GHG reduction, innovation, etc.)	Enable utility on-bill financing of energy retrofits	Research tolerance of the gas system and gas appliances to hydrogen	Rebrand conservation to actions that reduce emissions in addition to costs	Establish long-term contracts for low carbon gas supply to ensure financing of new projects	Work with communities and municipalities to develop community energy plans, and incorporate them into utility planning
	Develop a clear, long-term roadmap for the transition of gas infrastructure to be used for lower carbon options	Investigate new business models that could help deploy additional energy efficiency and conservation measures (such as ESCOs)	Build out network of natural gas refueling stations for heavy-duty vehicles and marine transportation	Develop home energy programs with consistent labelling and certification	Increase funding for R&D to overcome the smaller market size challenge	Update land use planning to encourage lower reliance on natural gas in new developments

Areas of action	Policy and regulatory	Conservation and efficiency	Low carbon gas alternatives	Education and Marketing	Finance	Integrated planning
Categories of action	Work with the federal government to include innovation that increases efficient use of the gas system and decreases net emissions, such as CHP, heat pumps, and vehicles in policy targets such as the CFS	Creation of an energy efficiency body (commodity neutral) and delivery organization, either within utilities or operating as a standalone entity	Liaise with other countries that are developing similar low-carbon gas programs	Targeted training to realtors, trades, and suppliers	Take advantage of low-cost financing, such as with Green Banks	Adopt a technology-neutral planning system to meet policy goals and targets
	Develop new utility business models that incents utilities to incorporate conservation and coordinate gas and electric planning			Undertake educational programs targeting various stakeholder groups based on unique informational needs	Develop energy service companies model, either as a third party or though utilities	
Legend	**Utilities**	**Communities/ municipalities**	**Government (federal/provincial)**	**NGOs**	**Academics**	**Regulators**

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