



BC's Carbon Conundrum

Why LNG exports doom emissions-reduction targets and compromise Canada's long-term energy security

By J. David Hughes

JULY 2020

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This paper is part of the Corporate Mapping Project (CMP), a research and public engagement initiative investigating the power of the fossil fuel industry. The CMP is jointly led by the University of Victoria, the Canadian Centre for Policy Alternatives and the Parkland Institute. This research was supported by the Social Science and Humanities Research Council of Canada (SSHRC).

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Social Sciences and Humanities
Research Council of Canada

Conseil de recherches en
sciences humaines du Canada

Canada



PUBLISHING TEAM

Marie Aspiazu, Shannon Daub, Emira Mears, Terra Poirier

Layout: Paula Grasdal

Copyedit: Grace Yaginuma

Cover photo: Wojciech Wrzesien / Shutterstock.com

ISBN 978-1-77125-506-6

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Over the past two decades, Hughes has researched, published and lectured widely on global energy and sustainability issues in North America and internationally. In his work for the Canadian Centre for Policy Alternatives, Hughes authored *A Clear View of BC LNG* in 2015, which examined the issues surrounding a proposed massive scale-up of shale gas production in British Columbia for LNG export, *Can Canada increase oil and gas production, build pipelines and meet its climate commitments?* in 2016, which examined the issues surrounding climate change and the Trans Mountain pipeline expansion, and *Canada's Energy Outlook: Current realities and implications for a carbon-constrained future* in 2018. He has also authored multiple reports on unconventional oil and gas development in the United States, consulted for the private sector on unconventional oil and gas, and served as an expert witness on hearings for energy projects in the US and Canada.

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ACKNOWLEDGEMENTS

Special thanks to the Corporate Mapping Project, for providing a platform for this research, Marc Lee from the CCPA, the substantive reviewer of this publication, Grace Yaginuma, who carefully copyedited this paper and made helpful suggestions to improve the figures, Marie Aspiazu from the CCPA, who oversaw the review and publication of the manuscript, and to the three anonymous reviewers who provided comments and suggestions that substantially improved the report.

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Summary

ACCORDING TO THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC), global greenhouse gas emissions must be reduced to net zero between 2040 and 2055 in order to limit global warming to 1.5 Celsius above pre-industrial levels.¹ The British Columbia government has pledged to reduce emissions by 80 per cent from 2007 levels by 2050 through its CleanBC Plan and the federal government has pledged that Canada will be net zero by 2050.

This report assesses the emissions implications of the Canada Energy Regulator's (CER) 2019 oil and gas production forecast for BC, and the implications of ramping up gas production for liquefied natural gas (LNG) export. Emissions data from the most recent Environment and Climate Change Canada (ECCC) submission to the United Nations Framework Convention on Climate Change (UNFCCC) are the basis for the emissions projections.

There are serious questions and considerations surrounding the current enthusiasm for developing a Canadian LNG export industry which are examined in this report. These include the impact of increasing gas production on emissions; the land disturbance and water consumption from the drilling required; the questionable benefits to taxpayers given reduced revenue from gas production royalties and the cost of incentives offered by government; and the fact that full-cycle analysis indicates that LNG exports to Asia will increase global emissions over the critical next few decades. A further consideration is higher long-term gas prices for Canadians if the lowest-cost portion of remaining resources is exported as LNG.

Emissions versus CleanBC and global targets

The emissions created in producing and liquefying LNG have very real implications for BC meeting its climate targets. Even without any LNG exports, and assuming a 15 per cent reduction in upstream emissions through reduced fugitive methane and electrification, emissions from oil and gas production alone would exceed BC's 2050 target by 54 per cent, given the CER forecast — and that is if all other sectors of BC's economy reached zero emissions by 2042. Increasing production for LNG Canada would add a total of 13 megatonnes per year, including the company's estimate of 3.96 megatonnes from the terminal itself. Including LNG Canada, emissions from oil and gas production would exceed BC's 2050 target by 160 per cent, even if emissions from the rest of the economy were reduced to zero by 2035 (Figure E51). If Kitimat LNG and Woodfibre LNG were also built (both of which have 40-year export licenses approved by CER), total LNG emissions

The emissions created in producing and liquefying LNG have very real implications for BC meeting its climate targets.

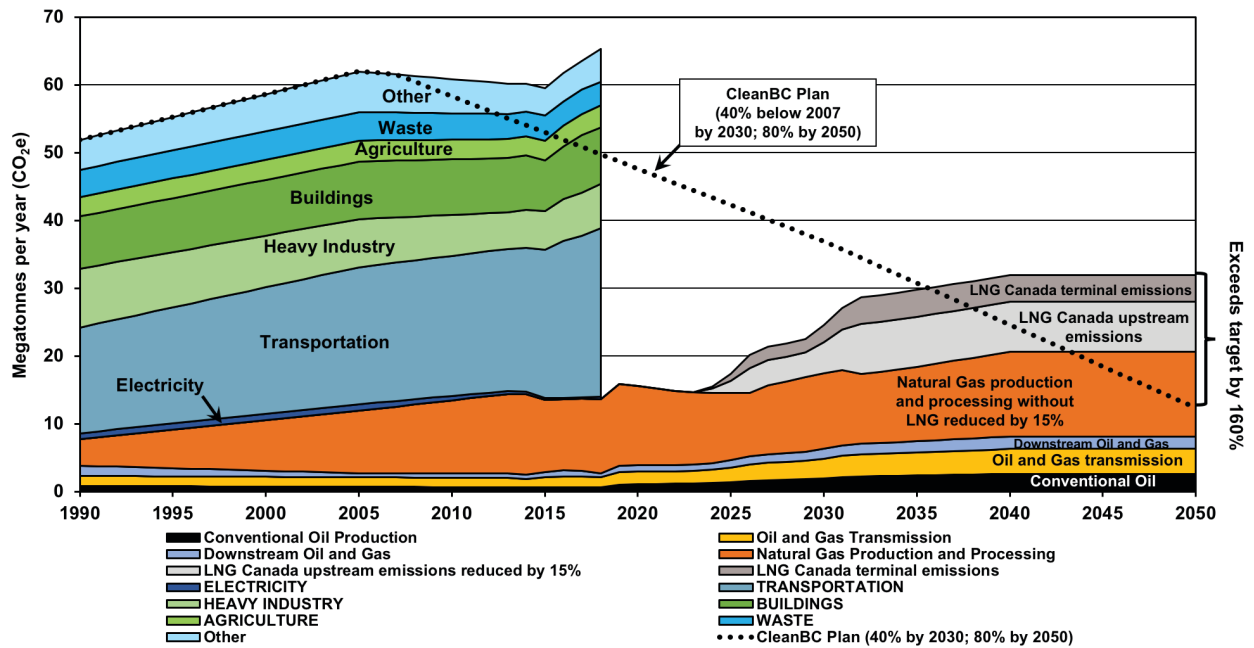
The industry and government narrative that BC LNG will contribute to a reduction in global emissions by displacing coal-fired electricity in China and elsewhere in Asia lacks credibility if a proper accounting of emissions is undertaken.

would amount to 22.6 megatonnes and BC’s 2050 target would be exceeded by 227 per cent, even if all other sectors of BC’s economy reached zero emissions by 2031.

The industry and government narrative that BC LNG will contribute to a reduction in global emissions by displacing coal-fired electricity in China and elsewhere in Asia² lacks credibility if a proper accounting of emissions is undertaken. While it is true that at the point of combustion natural gas emits only 54 per cent of the emissions of coal per unit of heat provided, full-cycle greenhouse gas emissions from LNG include emissions from production and processing of the gas, pipeline transportation, liquefaction, shipping, and regasification. As China replaces older, low-efficiency coal power plants, it has a choice of investing in several technologies, including renewable energy, LNG-fueled combined-cycle natural gas (CCNG), and best-technology coal.

The climate impacts of emissions from BC LNG compared to best-technology coal in China also depend on the timeframe considered and the level of fugitive methane emissions from the production, processing and transportation of the gas or coal. Over 20 years, methane has a global warming impact 86 times greater than carbon dioxide, but this is reduced to 34 times over 100 years. Upstream methane emissions (from the well to the LNG terminal) are estimated at 3.3 per cent of production for the unconventional gas that would supply LNG exports (based on studies of comparable deposits in the US).

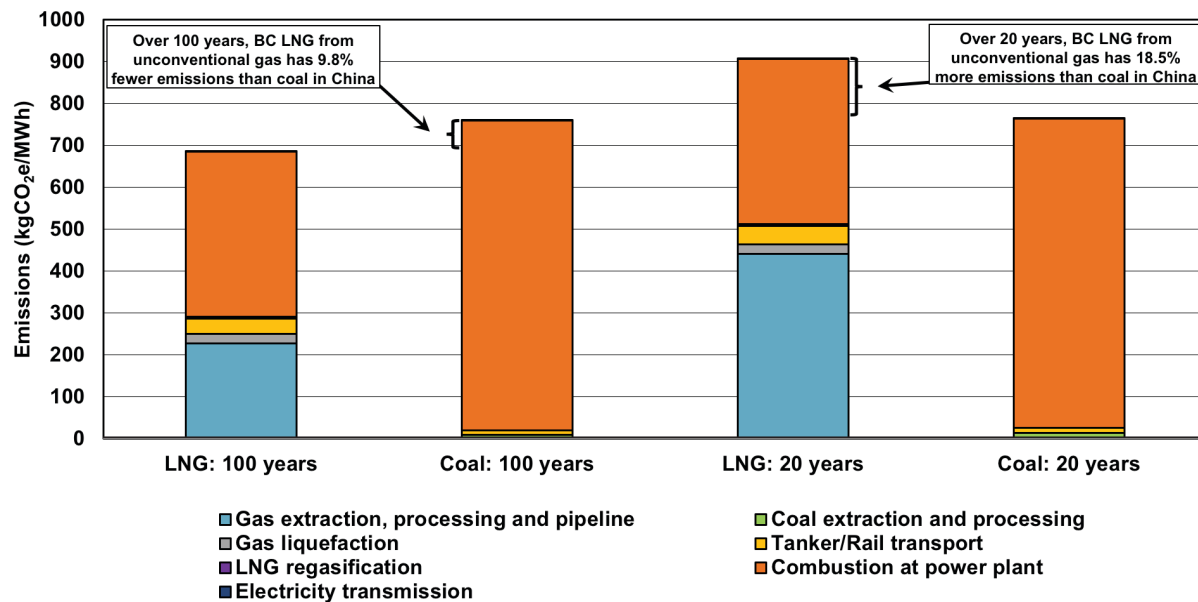
Figure ES1: Projected oil and gas emissions in BC based on CER’s forecasted production, with additional emissions to supply gas to the LNG Canada terminal and emissions from the terminal itself.



Sources: Data from Environment and Climate Change Canada, *National Inventory Report 1990–2018: Greenhouse Gas Sources and Sinks in Canada*; and Canada Energy Regulator’s *Canada’s Energy Future 2019* report (CER’s 2040 production forecast is held flat through 2050).

2 Peter Kenter, “LNG Canada’s Export Terminal Will Enable Coal-Reliant Customer Nations to Reduce GHG Emissions,” *Vancouver Sun*, December 13, 2018, <https://vancouversun.com/sponsored/news-sponsored/lng-canadas-export-terminal-will-enable-coal-reliant-customer-nations-to-reduce-ghg-emissions>.

Figure ES2: Comparison of BC LNG for power generation in China with best-technology coal, assuming fugitive methane emissions of 3.3 per cent.



Sources: Data about emissions from LNG terminals from Environmental Assessment Office, *LNG Canada Export Terminal Project Assessment Report* (Victoria, BC: Environmental Assessment Office, 2015); and data about pipeline and ocean voyage distances (modified) from National Energy Technology Laboratory, *Life Cycle Greenhouse Gas Perspective on Exporting Liquefied Natural Gas from the United States* (Washington, DC: US Department of Energy, 2014).

Figure ES2 illustrates the full-cycle analysis of emissions from BC LNG in China versus best-technology coal. Emissions from LNG are 18.5 per cent greater than best technology coal over 20 years and 9.8 per cent less than coal over 100 years. Meaning that over the critical next few decades LNG exports will make the global climate problem worse. Even if fugitive methane emissions were reduced to 2 per cent (assuming supply came from conventional, not unconventional, gas), LNG exports would make global warming worse over at least the next three decades.

Land and water impacts

According to the CER, the Montney region in northeast BC and northwest Alberta is forecast to provide virtually all of the growth in Canadian gas production through 2040, when it will account for 64 per cent of Canadian production. Most of the gas for LNG exports will come from the BC portion of the Montney.

In order to meet both Canadian needs and LNG Canada exports, the number of wells in the BC Montney would have to more than triple by 2040. Through the end of the three approved 40-year LNG export licenses in 2070, the number of wells would have to increase by nearly 10-fold. The land disturbance impact of doing this would increase the existing oil and gas footprint by nearly four times, to 19.3 per cent of the BC Montney area (Table ES1).

Emissions from LNG are 18.5 per cent greater than best technology coal over 20 years and 9.8 per cent less than coal over 100 years. Meaning that over the critical next few decades LNG exports will make the global climate problem worse.

Table ES1: Cumulative land disturbance under various scenarios of LNG development in the Montney.

	Cumulative area in hectares	Cumulative disturbance as percentage of the BC Montney play
To 2020	129,568	5.07%
To 2040 without the 3 LNG projects	208,683	8.16%
To 2070 without the 3 LNG projects	325,060	12.71%
Plus LNG Canada to 2065	417,502	16.32%
Plus Kitimat LNG to 2070	485,614	18.98%
Plus Woodfibre LNG to 2070	494,773	19.34%

Note: The percentage of the land area disturbed in this table is based on the prospective drilling area which is 25,580 square kilometres.

In 2015 the Blueberry River First Nation, whose lands overlie much of the BC Montney deposit, filed a lawsuit over land disturbance and after a brief settlement returned to court in 2019. The current footprint of well-pads, roads, pipelines and other infrastructure is, however, only 5.1 per cent of the Montney area. A decision on this latest court case is expected in mid-2020, and may severely restrict the capacity of the BC government to double land disturbance on Blueberry River First Nation lands by 2040, let alone the additional land disturbance from drilling that would be required to meet the needs of the three approved 40-year LNG export licenses from 2040-2070.

The existing footprint of the oil and gas industry on agricultural land is also a concern that has been raised by the BC Minister of Agriculture’s Advisory Committee for Revitalizing the Agricultural Land Reserve and the Agricultural Land Commission.

Water consumption by hydraulic fracking is also significant. If all three LNG export terminals were built, total water consumption would nearly triple from current levels, reaching 20 billion litres per year after 2030, which for reference is roughly two months of consumption for the city of Vancouver. Contaminated water is produced both by flowback from the initial fracking operation and from formation water produced during gas production. Although some of this contaminated water is treated and reused, most of it is injected into disposal wells. Contaminated water disposal would have to increase seven-fold from current levels by 2065 just with the LNG Canada project. If Kitimat LNG and Woodfibre LNG were also built, the water disposal problem would become even worse.

Lack of benefits for taxpayers

Notwithstanding the climate and other environmental impacts of developing a BC LNG export industry, government insists that LNG exports will provide a revenue and employment boom for its citizens.

In fact, LNG export projects in BC are not economically viable at current Asian prices according to studies by Canadian Energy Research Institute and the Oxford Institute for Energy Studies. The prospect of much higher prices in 2025, when LNG Canada’s first phase comes online, are highly uncertain, given the number of other LNG projects under development around the world, the current global LNG glut, and lower-cost pipeline-based supply from Russia being developed in China.

In fact, LNG export projects in BC are not economically viable at current Asian prices according to studies by Canadian Energy Research Institute and the Oxford Institute for Energy Studies.

Despite the doubling of gas production in BC since 2005, the total royalty revenue has declined by 84 per cent. Although increasing gas production may increase government revenues somewhat, this decline in royalty revenue, along with the other taxpayer funded incentives to spur LNG exports, represents a giveaway of finite, non-renewable resources that Canadians will need at some level in the future.

The argument that BC requires the jobs that LNG expansion will bring is also suspect. According to LNG Canada, the number of permanent jobs that will be created by LNG Canada are half of the 950 estimated by the government.

Natural gas is a finite, non-renewable resource, and Canada is a well-explored petroleum region. Although government estimates of unproven resources have been inflated drastically in recent years, there have been no economic analyses to prove that these purported resources are economically viable. The three 40-year LNG export licenses already approved will alone exceed current proven Canadian gas reserves by 30 per cent. Although more drilling is likely to prove up additional reserves, the lack of credible economic analyses to show that Canada has enough gas to meet its own needs for the foreseeable future before ramping up exports is troubling.

Even assuming enough gas reserves can be proven up to meet projected demand, supplying current approved LNG export licenses will likely result in much higher gas prices for Canadians in the future. Industry always targets the lowest cost resources first in order to maximize profits. Exhausting the lowest cost resources for LNG exports means that more remote, higher cost, resources will have to be used to meet the future needs of Canadians.

The argument that BC requires the jobs that LNG expansion will bring is also suspect. According to LNG Canada, the number of permanent jobs that will be created are half of the 950 estimated by the government.

Need for a viable energy strategy

Government narratives have stated that reducing Canada's emissions and expanding oil and gas production go hand-in-hand. Unfortunately, no amount of wishful thinking can overcome the math on the emissions generated from increased oil and gas production and the proposed LNG exports. Nor can wishful thinking overcome the impacts on the land surface of the increase in well-pads, roads, pipelines and other infrastructure that comes with increased production.

As outlined in my earlier research,³ Canada's practice of ramping up oil and gas production in the hope of financial gain is not a credible plan to meet the long-term energy needs and emissions reduction goals of its citizens.

The projections of BC greenhouse gas emissions in this report are conservative, as they incorporate the older estimates of the 100-year global warming potential of methane used by Canada in its emissions submission to the United Nations. The projections also assume that initiatives to reduce fugitive methane and electrify upstream gas production will reduce emissions further in the future. Even so, they demonstrate that growing oil and gas production is completely incompatible with achieving promised emissions reduction targets. Growth in oil and gas production for export is also incompatible with the long-term energy security of Canadians at affordable prices, and the desire of First Nations to protect the environmental integrity of their lands. Canada needs a viable energy strategy to address these issues and to have any hope of meeting its emission reduction targets.

³ J. David Hughes, *Canada's Energy Outlook: Current Realities and Implications for a Carbon-Constrained Future* (Vancouver, BC: Canadian Centre for Policy Alternatives–BC Office, 2018), <https://www.policyalternatives.ca/energy-outlook>.

Introduction

Gas production in Alberta, the largest-producing province, has declined by 24 per cent since 2000. Only BC has increased production, mainly owing to the advent of fracking, which has allowed access to previously uneconomic resources.

THE BC AND FEDERAL GOVERNMENTS HAVE EMBRACED EXPORTS of liquefied natural gas (LNG) as a means to create jobs and provide needed government revenue. There have also been claims that LNG will reduce emissions by displacing coal burning for electricity when exported to Asia. Others have raised concerns about the emissions created in producing, transporting, liquefying and shipping gas to Asia, especially considering BC's target of reducing emissions by 80 per cent from 2007 levels by 2050.⁴

Conventional wisdom taken up by the BC government and the Canada Energy Regulator (CER) is that Canada's natural gas resources are, for practical purposes, essentially infinite and hence should be monetized for the benefit of all. CER has produced a forecast of natural gas production and consumption in Canada, which is instructive in determining where the gas to fuel Canada's economy and LNG exports will come from.⁵

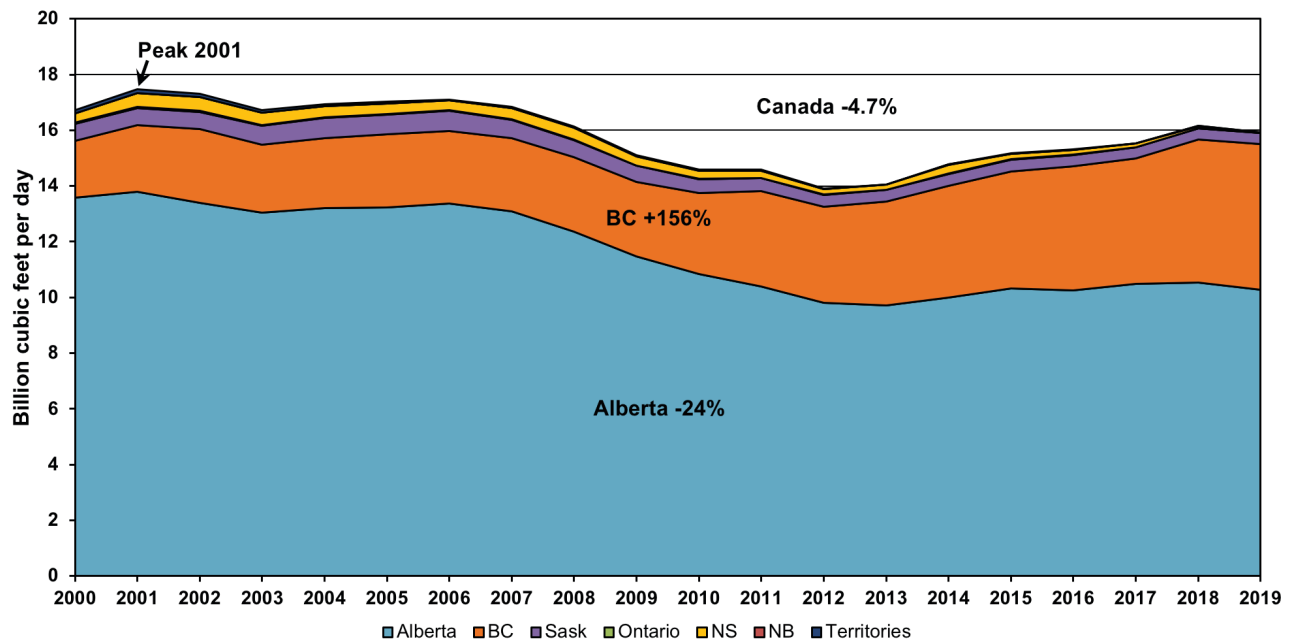
Western Canada, where most Canadian oil and gas is produced, is a mature exploration region, with hundreds of thousands of wells drilled over the past 70-plus years. Natural gas production in Canada peaked in 2001 and is down 4.7 per cent since 2000 (see Figure 1). Gas production in Alberta, the largest-producing province, has declined by 24 per cent since 2000. Only BC has increased production, mainly owing to the advent of fracking (hydraulic fracturing technology that is coupled with horizontal drilling), which has allowed access to previously uneconomic resources.

Although the federal government has approved more than 20 LNG export terminals over the past few years, most of these appear unlikely to be built. In late 2018, however, LNG Canada reached a final investment decision on its terminal in Kitimat, which is now under construction. It also seems likely that Woodfibre LNG in Squamish, which also has a 40-year export license, may reach a final investment decision in the near future, and CER has recently approved a 40-year export licence for Chevron's Kitimat LNG project. Table 1 summarizes the status and amounts of gas that would be exported by these three projects.

4 Government of BC, *CleanBC* (Victoria, BC: Government of BC, 2019), https://blog.gov.bc.ca/app/uploads/sites/436/2019/02/CleanBC_Full_Report_Updated_Mar2019.pdf.

5 *Canada's Energy Future 2019*, Canada Energy Regulator, <https://www.cer-rec.gc.ca/nrg/ntgrtd/fttr/2019/index-eng.html>.

Figure 1: Marketable gas production in Canada with a breakdown by province, 2000–2019, showing percentage change in production over the period.



Source: Data from Canada Energy Regulator (accessed October 22, 2019).

Table 1: The status, annual throughput and 40-year export volume of LNG projects in BC that may proceed.

Project	Average annual throughput (billion cubic feet per day)	40-year export volume (trillion cubic feet)	Status
LNG Canada	3.61	52.73	Under construction
Woodfibre LNG	0.32	4.72	Awaiting final investment decision
Kitimat LNG	2.38	34.68	Awaiting final investment decision
Total	6.31	92.13	

Canada produces far more oil and gas than it consumes, and this production comes at a high cost in terms of emissions and other environmental impacts.

Canada is a major producer and exporter of oil and gas, ranking fifth and fourth, respectively, in global production in 2018.⁶ Although the energy sector's contribution to Canadian GDP has remained relatively constant over the past two decades at about 9 per cent, revenue to government per unit of oil and gas produced has declined by 77 per cent since 2008.⁷ Canada produces far more oil and gas than it consumes, and this production comes at a high cost in terms of emissions and other environmental impacts.

Notwithstanding the fact that both the BC and federal governments have declared that new pipelines and export terminals are in the "national interest," both levels of government have committed to drastic reductions in emissions. Canada has declared it will have "net zero" emissions by 2050, and BC has pledged to reduce emissions by 80 per cent by that date.

Emissions are just one aspect of evaluating a "national interest" case for LNG export terminals and pipelines. Canadians also require long-term security of energy supply at reasonable prices and protection of land and water resources. This report addresses the following key questions that need to be answered before making a national-interest case for LNG exports:

- Where will the gas come from?
- Does Canada have sufficient long-term gas supplies at reasonable prices?
- How many wells would be needed, and what would their environmental footprint be?
- What are the implications for emissions, and how do they relate to pledged targets?
- Are government assertions on reducing global emissions by turning to LNG credible?
- Are LNG exports economically viable?
- What about jobs and revenue for health care and schools?

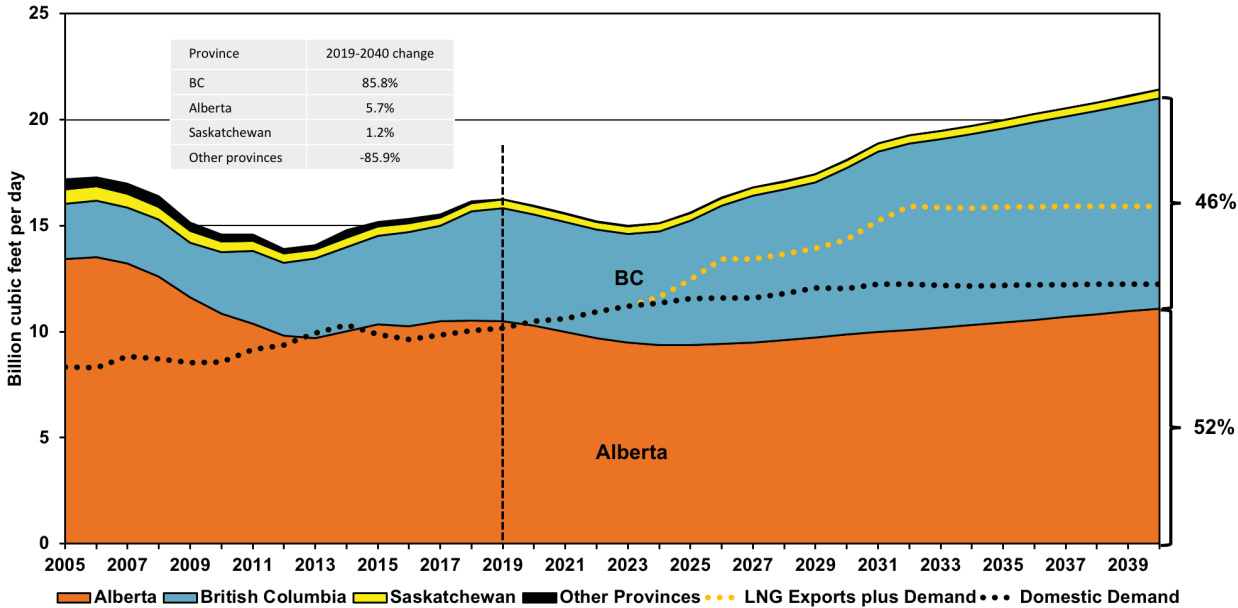
⁶ BP, *BP Statistical Review of World Energy*: 2019, 68th ed. (London, UK: BP, 2019).

⁷ My calculations are based on Statistics Canada, Financial and Taxation Statistics for Enterprises, by Industry Type (table 33-10-0006-01); Canadian Association of Petroleum Producers' Statistical Handbook (accessed February 2020), <https://www.capp.ca/publications-and-statistics/statistics/statistical-handbook>; Canada Energy Regulator (accessed October 2020), <https://www.cer-rec.gc.ca/nrg/sttstc/ntrlgs/stt/mrktblntrlgsprdcn-eng.html>; and Bank of Canada's inflation adjustment calculator.

Where will the gas come from?

FIGURE 2 ILLUSTRATES CER'S FORECAST OF CANADIAN NATURAL GAS PRODUCTION through 2040. Production is forecasted to be dominated by the three Western provinces, two of which would provide 98 per cent of 2040 Canadian production. Of these, BC is projected to grow by 87 per cent over the 2019–2040 period, whereas Alberta and Saskatchewan are projected to remain flat and the remainder of Canada to decline by 86 per cent. Canadian domestic demand is expected to grow gradually over the period, as shown in Figure 2.

Figure 2: Natural gas production in Canada with Canada Energy Regulator forecast from 2019 to 2040, including domestic demand and LNG exports.

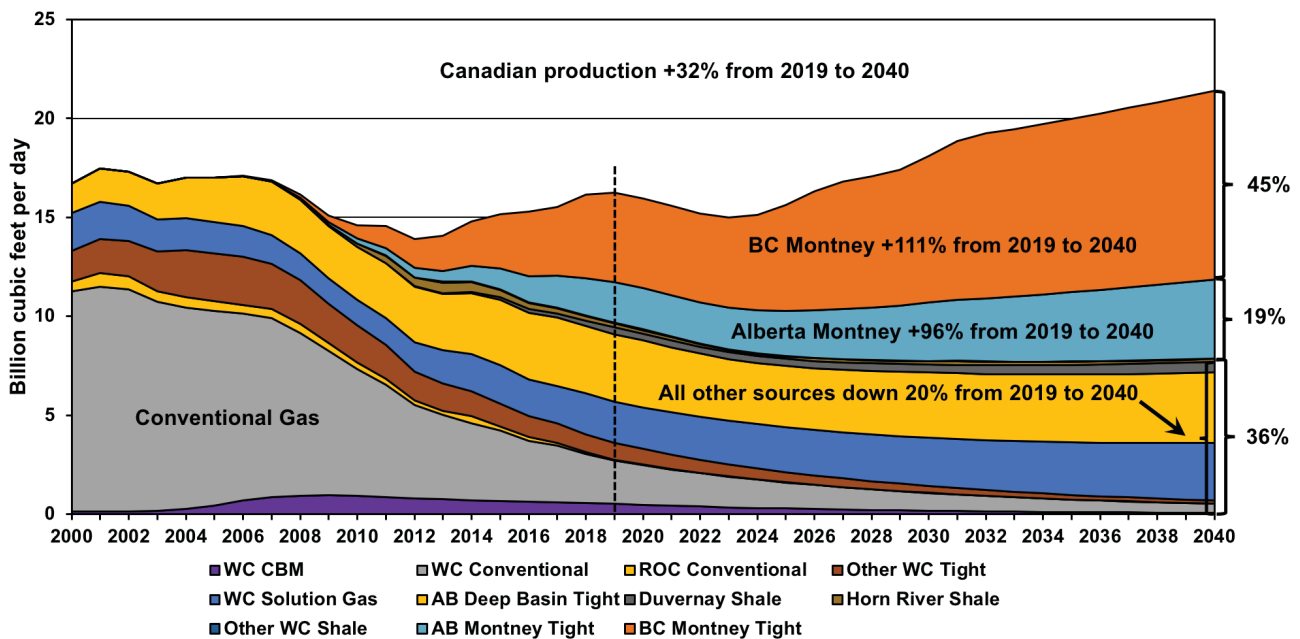


Source: Canada Energy Regulator, *Canada's Energy Future 2019*, December, 2019.

The growth in BC gas production is almost entirely a result of the introduction of fracking in the mid-2000s, which allowed the extraction of previously inaccessible tight and shale gas by injecting large volumes of water and proppant (mainly sand with other additives) to fracture rocks with low permeability and allow gas to be produced. Since 2014, 98 per cent of the wells drilled in BC have been horizontal fracked wells.⁸

Figure 3 illustrates CER’s forecast of Canadian gas production by formation and type. Conventional gas, which has provided most of Canada’s production since the 1950s, is forecasted to shrink to almost nothing by 2040. Although minor amounts of shale gas are forecasted to be produced from the Duvernay Formation in Alberta and the Horn River play in BC, a single formation — the Montney, which occurs in northeast BC and northwest Alberta — is forecasted to provide virtually all of the growth in Canadian gas production through 2040. According to CER, the Montney will provide 64 percent of Canadian production in 2040.

Figure 3: Canadian gas production by formation and gas type with Canada Energy Regulator forecast from 2019 to 2040.



Source: Canada Energy Regulator, *Canada’s Energy Future 2019*, December, 2019.

Note: WC = Western Canada; ROC = rest of Canada.

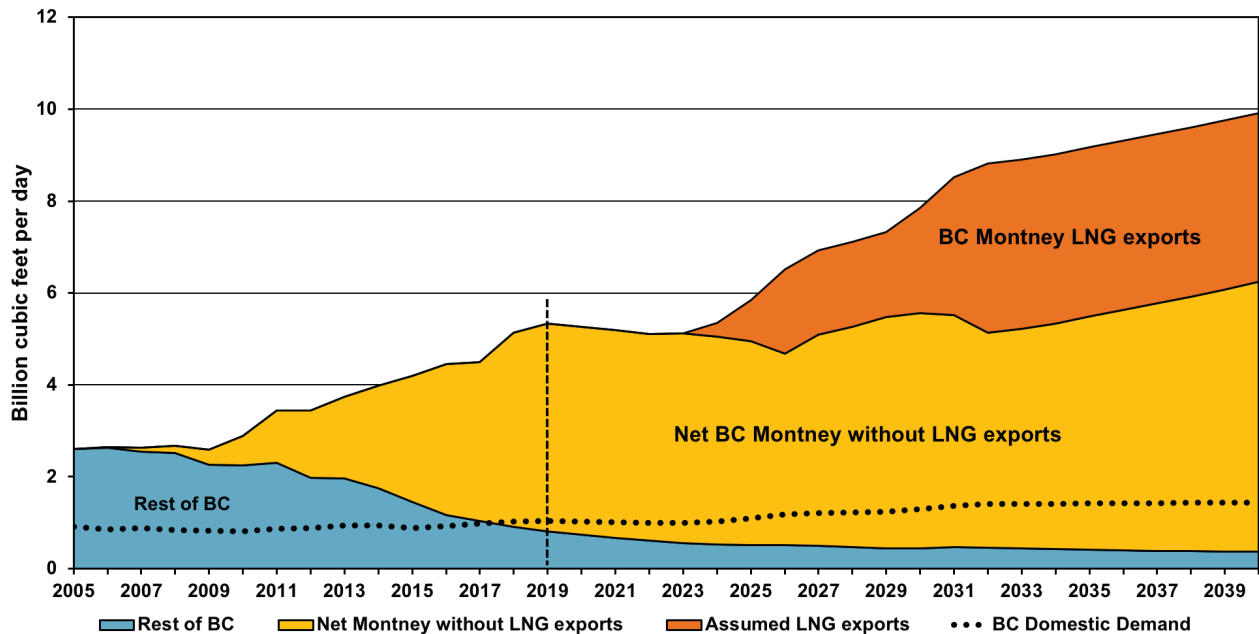
The fact that Canadian gas production, which was once obtained from diverse fields and reservoirs in BC, Alberta and Saskatchewan, has become dependent for growth on one formation in a small portion of Alberta and BC should be a red flag when planning increased exports. Although some gas remains to be developed outside of the Montney, it is mainly in more remote, higher-cost deposits in the Western Canadian Sedimentary Basin, the Arctic and offshore. According to CER, without the Montney, Canadian gas production would be down 20 per cent from 2019 levels by 2040, whereas with the Montney would increase by 32 per cent.

8 Enverus (formerly Drillinginfo) data (accessed February 2020).

Gas production for export by the LNG Canada project would come almost entirely from the BC Montney, given that it is the major source of production growth and that two of LNG Canada’s owners, Petronas (25 per cent) and Shell (40 per cent), are the second- and fourth-largest BC Montney producers, respectively. Although Shell has other assets in Alberta, Petronas is mainly focused on the BC Montney, and none of the other owners are gas producers.

The forecasted growth of BC Montney production from nothing in 2007 to 96 per cent of the province’s production (which would be 44 per cent of Canada’s production) in 2040 is illustrated in Figure 4, along with the proportion that would be exported as LNG. The volume of gas to be exported as LNG in the CER forecast is sufficient only to meet the requirements of the LNG Canada project (additional LNG projects would require production not included in the CER forecast). LNG Canada would be implemented in two phases—the first in 2025 with 14 million tonnes per year of export capacity and the second in 2030, bringing the total to 28 million tonnes per year, or 3.6 billion cubic feet per day. As domestic consumption in BC is a small fraction of the total forecasted production, the balance not exported as LNG would presumably be exported to Alberta and the northwest US.

Figure 4: BC gas production by formation, with Canada Energy Regulator forecast from 2019 to 2040 showing proportion that would be dedicated to LNG exports.



Source: Canada Energy Regulator, *Canada’s Energy Future 2019*, December, 2019.

Note: Also shown is BC domestic gas consumption.

Does Canada have sufficient long-term gas supplies at reasonable prices?

Issues such as emissions, environmental footprint and the longer-term price Canadians may have to pay for gas are not considered.

IN ORDER TO APPROVE THE EXPORT LICENCES FOR LNG CANADA, Woodfibre LNG and Kitimat LNG, CER had to meet the requirements of section 118 of the National Energy Board Act which specifies that:

On an application for a license to export oil or gas, the Board shall satisfy itself that the quantity of oil or gas to be exported does not exceed the surplus remaining after due allowance has been made for the reasonably foreseeable requirements for use in Canada, having regard to the trends in the discovery of oil or gas in Canada.⁹

Undefined in this regulation is how much gas is needed for the “reasonably foreseeable requirements for use in Canada” and what scientific data the board should use to make this calculation. Issues such as emissions, environmental footprint and the longer-term price Canadians may have to pay for gas are not considered.

The Canadian Association of Petroleum Producers (CAPP) defines established gas reserves as:

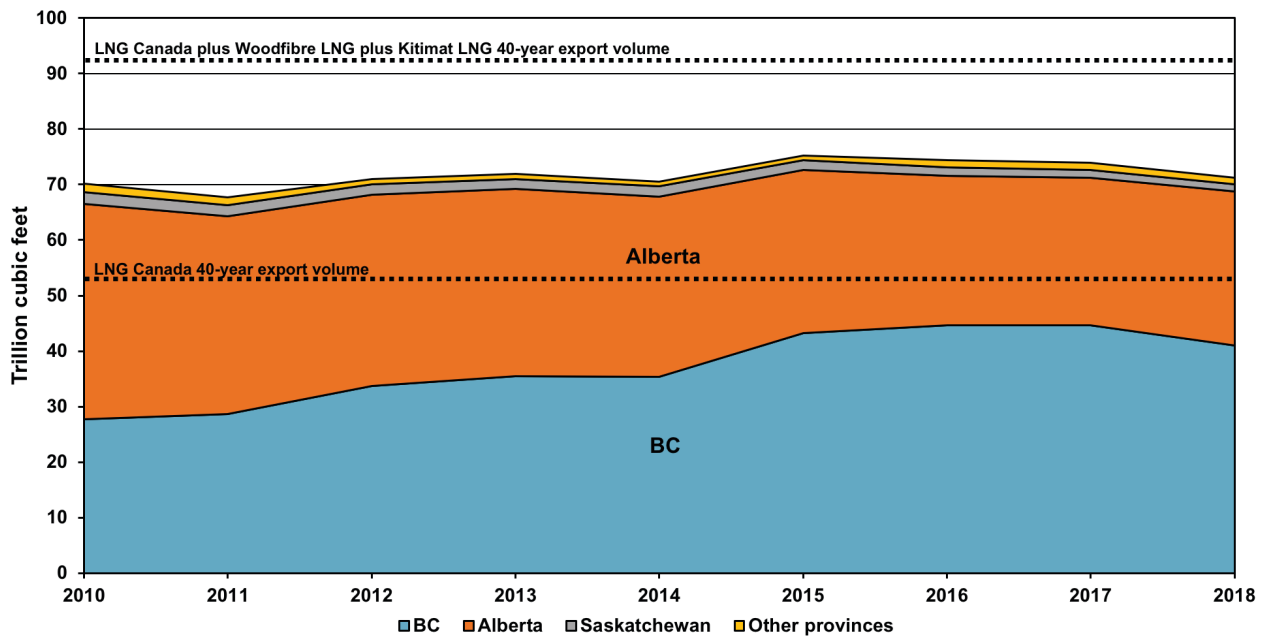
Those reserves recoverable under current technology and present and anticipated economic conditions, specifically proved by drilling, testing or production, plus that judgement portion of contiguous recoverable reserves that are interpreted to exist, from geological, geophysical or similar information, with reasonable certainty.¹⁰

⁹ National Energy Board Act, R.S.C., 1985, c. N-7, s. 118, <https://laws-lois.justice.gc.ca/eng/acts/n-7/page-27.html>.

¹⁰ Canadian Association of Petroleum Producers’ Statistical Handbook (Reserves: 02 Glossary of Reserves; accessed February 9, 2020), <https://www.capp.ca/publications-and-statistics/statistics/statistical-handbook>.

Figure 5 illustrates CAPP’s estimates of remaining established gas reserves in Canada from 2010 to 2018. Also shown is the required production over 40 years for the three LNG export terminals approved by CER (listed in Table 1). These approvals total 92.1 trillion cubic feet (tcf), which exceed 2018 established gas reserves by 30 per cent. In addition, CER has forecasted that domestic consumption in Canada will be 94 tcf between 2019 and 2040, and if domestic consumption held constant after that at 2040 levels, domestic consumption would total 206 tcf by 2065, when the LNG Canada export licence would end (assuming a 2030 start-up, the Kitimat LNG and Woodfibre LNG export licenses would end in 2070). That would require a total of 298 tcf (206 tcf for domestic consumption through 2065 and 92 tcf for the three LNG export terminals through 2070), or more than four times the current estimate of established gas reserves.

Figure 5: Remaining established reserves of natural gas in Canada, 2010–2018. Also shown are the cumulative LNG export volumes over 40 years for the three projects in Table 1.



Source: Data from Canadian Association of Petroleum Producers’ Statistical Handbook (Reserves: 02 Glossary of Reserves; accessed February 2020).

Whereas established reserves are estimated based on drilling data with reasonable extrapolation from these data, the National Energy Board (now the Canada Energy Regulator) and the provinces developed unproven resource estimates, which have been used to justify the narrative that Canada’s gas resources are extremely large and therefore justify LNG and other export approvals. These estimates are based on sparse data extrapolated over large areas. The Montney, for example, was estimated to contain 449 tcf of “marketable gas” based on a 17-page report with little documentation.¹¹ The Liard play, which is penetrated by only four wells in northeast BC,

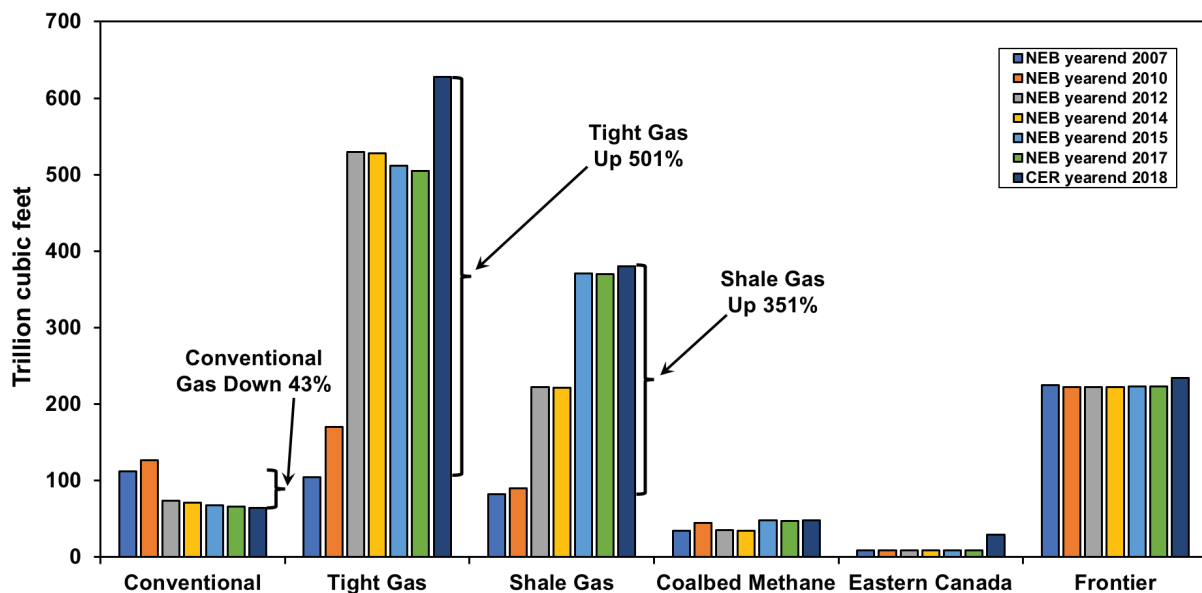
11 National Energy Board, *The Ultimate Potential for Unconventional Petroleum from the Montney Formation of British Columbia and Alberta—Energy Briefing Note* (Calgary, AB: National Energy Board, 2013), <https://www.cer-rec.gc.ca/nrg/sttstc/ntrlg/rprt/lmtptntlmntnyfrmtn2013/lmtptntlmntnyfrmtn2013-eng.html>.

was declared to have 167 tcf of “marketable gas” in a 16-page report with little documentation.¹² One has to look in the appendixes of these reports to learn that “no study has been undertaken to determine the economics for marketable resources.”

So, in approving large exports of gas, the National Energy Board has been basing its determinations of “reasonably foreseeable requirements for use in Canada” on highly uncertain and scantily documented estimates of unproven resources that have not been studied to see if they may ever be economically recoverable.

Figure 6 illustrates the escalation since 2007 of National Energy Board’s estimates of marketable gas resources. Notwithstanding that these resource estimates are unproven, have unknown economics and are based on uncertain evaluations of sparse data, they have been used by the NEB, CER and politicians to justify the narrative of virtually unlimited gas resources when approving LNG and other exports.

Figure 6: Escalation of unproven marketable gas resources in Canada, 2007–2018, based on estimates by the National Energy Board (now Canada Energy Regulator).¹³



Sources: Data from National Energy Board (accessed 2009, 2011, 2013, 2016 and 2018); and *Canada’s Energy Future 2019* report.

12 National Energy Board, *The Unconventional Gas Resources of Mississippian-Devonian Shales in the Liard Basin of British Columbia, the Northwest Territories, and Yukon—Energy Briefing Note* (Calgary, AB: National Energy Board, 2016), <https://www.cer-rec.gc.ca/nrg/sttstc/ntrlgs/rprt/lmtptntlbcnwtkn2016/index-eng.html>.

13 Tight gas reservoirs are less permeable than conventional gas reservoirs, but somewhat more permeable than shale gas reservoirs. Both tight gas and shale gas are produced using fracking. Frontier includes undeveloped resources offshore on the east and west coasts and in the Arctic.

The cost of producing gas resources depends on their remoteness from infrastructure and on well productivity. In its most recent outlook (see Figures 2 and 3), CER forecasted declining production from conventional gas, given the depleted nature of these resources; stable to declining production from Eastern Canada, coal-bed methane and older tight-gas plays; little production from shale gas despite CER's estimates of large unproven resources; no production from frontiers; and a vast ramp-up in tight gas production from the Montney.

Industry always targets the lowest-cost resources first to maximize profits. The reason that the main growth in CER's forecast is from the Montney (see Figure 3) is that it is the last perceived accumulation of low-cost gas, even though the quantity of accessible gas is highly uncertain, as outlined above. The future price of gas for Canadians is not a consideration in CER's approval of LNG and other exports, even though these export approvals will almost certainly mean higher gas prices for Canadians in the future. By approving LNG and other export licences, CER is relegating Canadians to pay more in the future for gas from higher-cost resources that may or may not exist.

How many wells are needed, and what would their environmental footprint be?

To increase field production, enough wells must be drilled to offset field decline and add production overall, and the higher the production grows, the more wells must be added each year just to offset field decline.

TABLE 2 ILLUSTRATES THE NUMBER AND STATUS OF WELLS IN THE MONTNEY and the rest of BC as of December 2019. Of the 4,950 wells drilled in the Montney, 78 per cent are active, whereas only 22 per cent of the 23,619 wells in the remainder of BC are active. Not every well drilled will be productive due to the variability of geology and other factors, although the success ratio of fracked wells using the latest technology is generally much higher than for older technology.

Table 2: Wells in the Montney and the rest of BC by well status, December 2019.

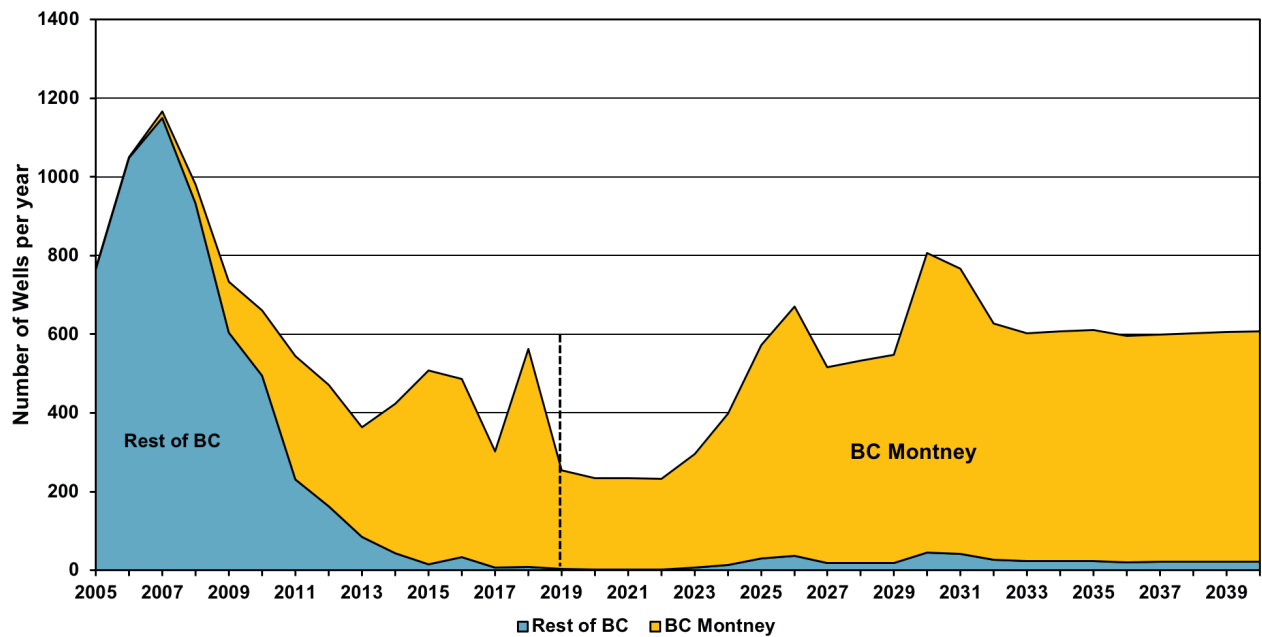
Well Status	Montney (BC)	Rest of BC	Total
Active	3,847	5,074	8,921
Borehole completed	148	1,587	1,735
Inactive	497	4,956	5,453
Plugged and abandoned	70	5,867	5,937
Suspended	388	6,135	6,523
Grand total	4,950	23,619	28,569

Source: Data from Enverus (formerly Drillinginfo) (accessed February 2020).

Once a well is drilled and completed, production begins to fall. This decline is steepest in early months and gradually flattens out as the wells age. On average, Montney wells decline 45 per cent in the first year, 62 per cent in the first two years and 69 per cent in the first three years.¹⁴ If no wells were drilled, Montney production would fall at an average rate of 26 per cent per year, which is termed the “field decline” (field production is made up of both older wells declining slowly and newer wells declining more quickly). To increase field production, enough wells must be drilled to offset field decline and add production overall, and the higher the production grows, the more wells must be added each year just to offset field decline.

CER estimated that a total of 11,518 wells will need to be drilled in BC between 2019 and 2040 to meet its forecasted production (illustrated in Figure 7).¹⁵ Of these, over 96 per cent are projected to be drilled in the Montney. Notwithstanding the fact that CER estimated that the Horn River and Liard plays of northeast BC contain very large (but unproven) shale gas resources (see also Figure 6), CER has projected almost no production from them through 2040, confirming the high cost and uncertain nature of these plays. By 2040, CER has projected that 96 per cent of BC gas production will come from the Montney.

Figure 7: Drilling rates by formation in BC with Canada Energy Regulator forecast from 2019 to 2040.

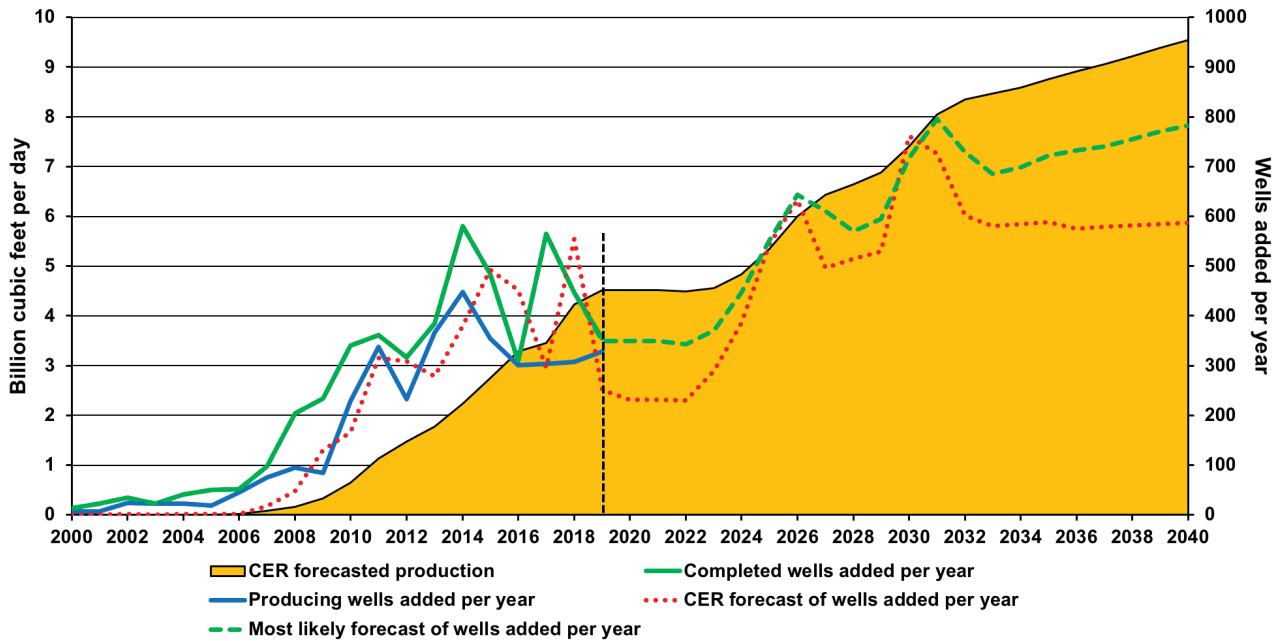


Source: Data from *Canada's Energy Future 2019* report (Supplement: Natural Gas Production).

14 Enverus data (accessed February 2020).

15 Canada Energy Regulator December 2019, *Canada's Energy Future 2019* (Supplement: Natural Gas Production), <https://www.cer-rec.gc.ca/nrg/ntgrtd/ft/2019ntrlgs/index-eng.html>.

Figure 8: BC Montney production and historical drilling rates in terms of wells added per year, and projections of drilling rates needed to meet CER's forecasted production from 2019 to 2040.



Source: Data from Enverus (accessed February 2020) and *Canada's Energy Future 2019* report.

In either the CER's or most likely cases, the number of wells in the BC Montney would have to more than triple the current levels (listed in Table 2) by 2040 to meet CER's forecast production.

Figure 8 illustrates CER's forecasted production for the Montney, and drilling rates which come from several sources. The number of completed wells and producing wells that were added per year come from Enverus's (formerly Drillinginfo) commercial database. (As expected, the number of completed wells exceed the number of producing wells, as not all drilled wells are productive.) CER's data for the historical number of wells are slightly different but of the same order of magnitude.

Also shown in Figure 8 are CER's projected number of wells needed to meet its forecasted production and a "most likely" number I calculated based on current well productivity, the field decline rate, and the production increase required to meet forecasted production. The number of wells needed to offset field decline at current production levels is about 350 per year (the present drilling rate). The number of wells required to more than double production from 2019 levels (from 4.52 to 9.55 billion cubic feet per day in 2040) includes wells needed to increase production and wells needed to offset progressively higher amounts of field decline as production grows. The "most likely" estimate assumed that productivity per new well would be stable—that is, there would be no deterioration in well quality as wells become more crowded and are extended into new areas.

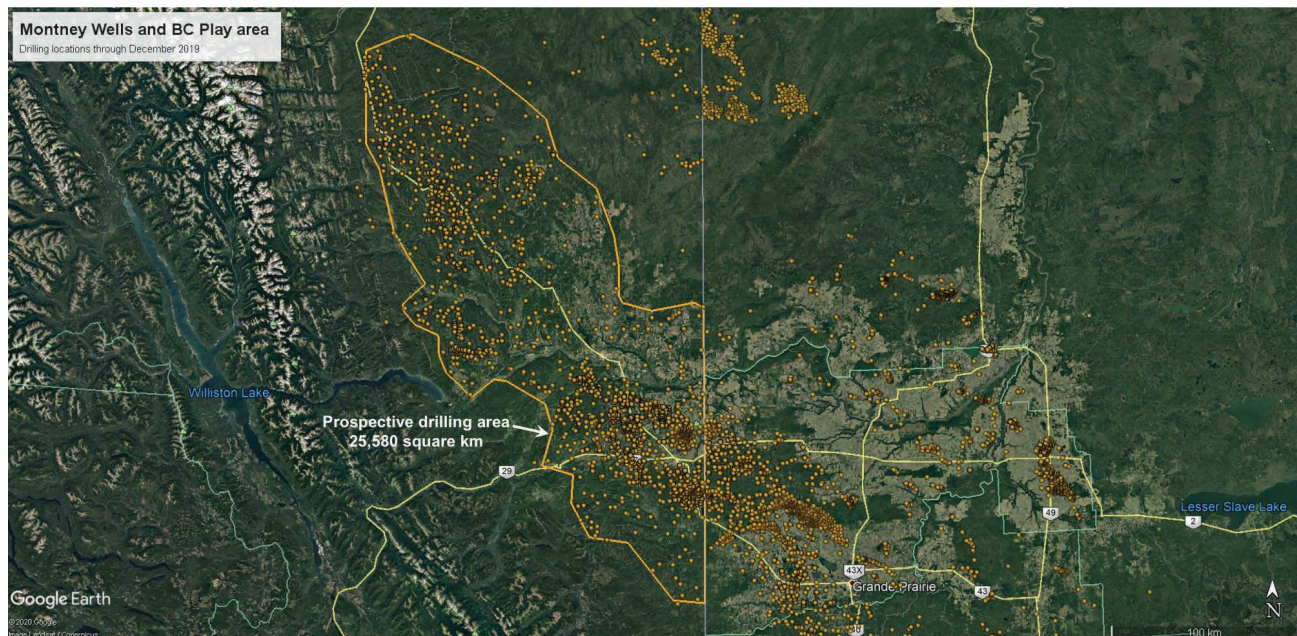
CER has estimated that 10,831 Montney wells would need to be drilled in BC between 2020 and 2040 to meet its forecasted production, whereas my most likely forecast estimates 12,957 wells, which is 20 per cent more. My most likely forecast should also be viewed as conservative as it assumes that every well drilled will be successful and produce at the rate of recent wells. In either the CER's or most likely cases, the number of wells in the BC Montney would have to more than triple the current levels (listed in Table 2) by 2040 to meet CER's forecast production.

Land disturbance related to CER's forecasted production

Figure 9 gives an overview of the distribution of Montney wells in BC and Alberta as of December 2019. Most of the locations shown are multi-well pads, which may have from two to 20-plus wells. Also shown is the "prospective drilling area," which is defined by wells that have significant Montney production and which will most likely be the area of future production. The prospective drilling area is used in the following section to determine the proportion of the area that would be disturbed by drilling the wells required to meet CER's forecasted Montney production.

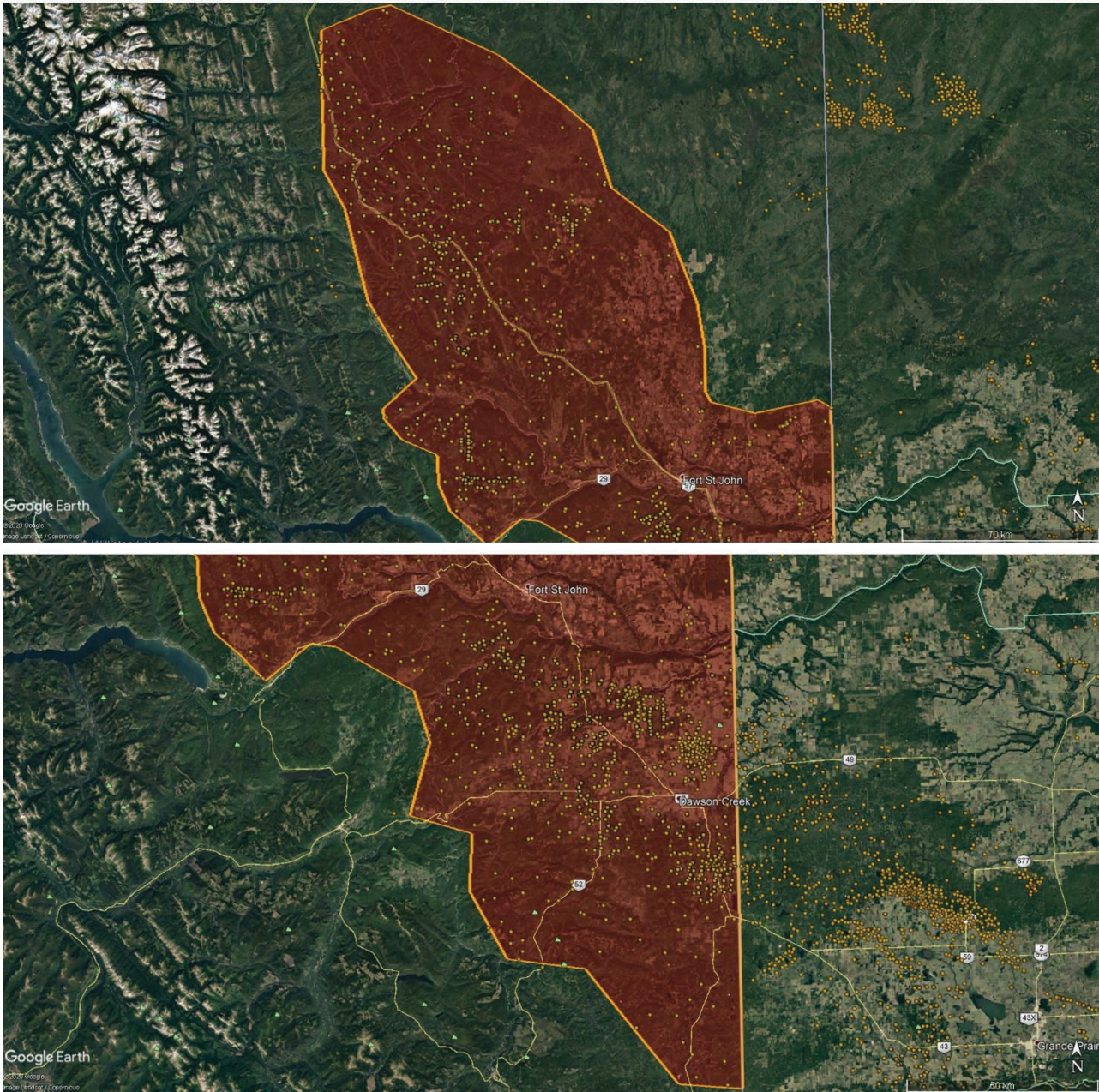
Figure 10 provides a closer view of the Northern Montney field located north of Fort St. John and the Peace River (upper) and the Heritage Montney field located to the south (lower).

Figure 9: Distribution of Montney wells in BC and Alberta and prospective BC drilling area.



Note: Distribution of Montney wells in BC and Alberta, and the prospective drilling area of the Montney in BC used to assess the impact of drilling the wells required to meet CER's forecasted production. The scale bar is on the lower right. Well data from Enverus and map data from Google Earth accessed February, 2020.

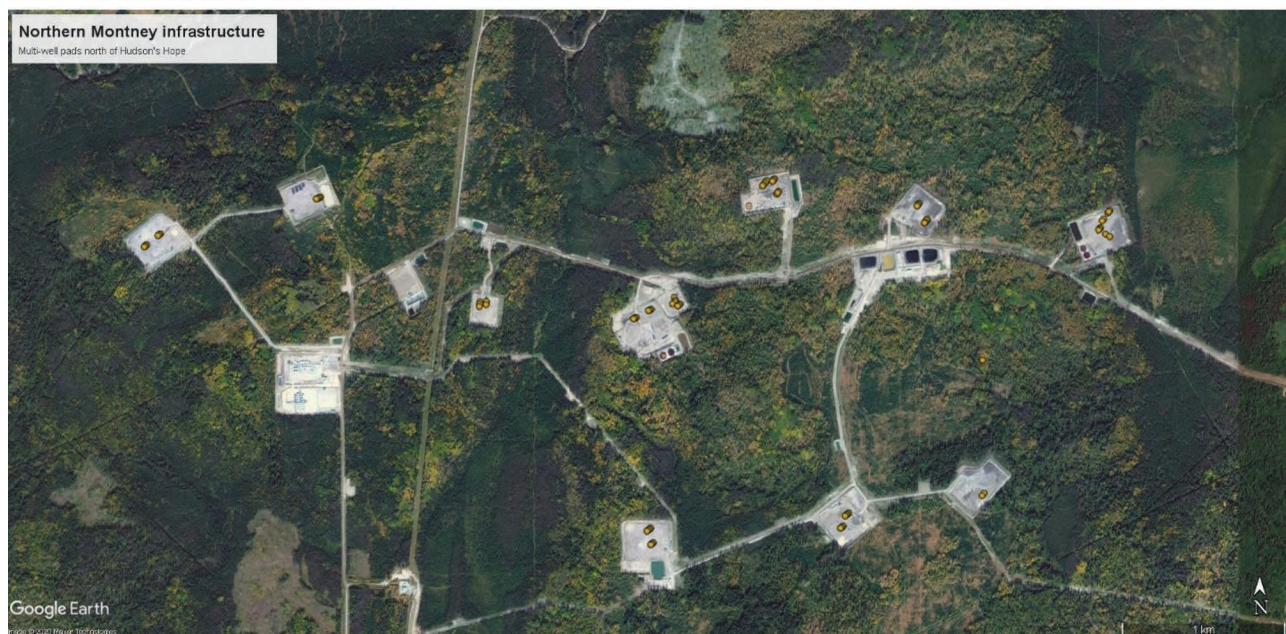
Figure 10: (Upper) Wells in the Northern Montney field, which is north of Fort St. John and the Peace River. (Lower) Wells in the Heritage Montney field, which is south of Fort St. John and the Peace River.



Note: The prospective drilling area (to assess the land disturbance impact of drilling the wells required to meet the CER's forecasted production) is shown in red. The scale bars are on the lower right. Well data from Enverus and map data from Google Earth accessed February, 2020.

Figures 11 and 12 provide close-up views of multi-well pads and other infrastructure in the Northern and Heritage Montney fields, respectively, to provide an understanding of the environmental footprint of the existing 4,950 wells in the BC Montney. These maps also provide an appreciation of what development might look like if the number of wells is increased by an additional 10,831 wells (the CER estimate) or 12,957 wells (my "most likely" estimate) by 2040, in order to meet CER's forecasted production.

Figure 11: (Upper) Close-up of multi-well pads and the gas production infrastructure in the central part of the Northern Montney field (north of Fort St. John). (Lower) Wells in the Northern Montney field north of Hudson's Hope.



Note: The two southernmost pads in the lower figure are 13 and 11 hectares, and each contains seven wells. The scale bars are on the lower right. Well data from Enverus and map data from Google Earth accessed February, 2020.

Figure 12: Multi-well pads in the Heritage Montney field.



Note: (Upper) Close-up of multi-well pads and the gas production infrastructure in the Heritage Montney field (southeast of Fort St. John). The northwest well pad is 7 hectares with 24 wells, and the northeast well pad is 17 hectares with 22 wells. (Lower) Close-up of a multi-well pad in the Heritage Montney field, which is 9 hectares with 18 wells. The scale bars are on the lower right. Well data from Enverus and map data from Google Earth accessed February, 2020.

There are discrepancies between the various estimates of the areal extent of the Montney play. In 2014, the BC Oil and Gas Commission (BCOGC) estimated that the area disturbed by Montney oil and gas development covered 29,589 square kilometres.¹⁶ The regional field boundaries of

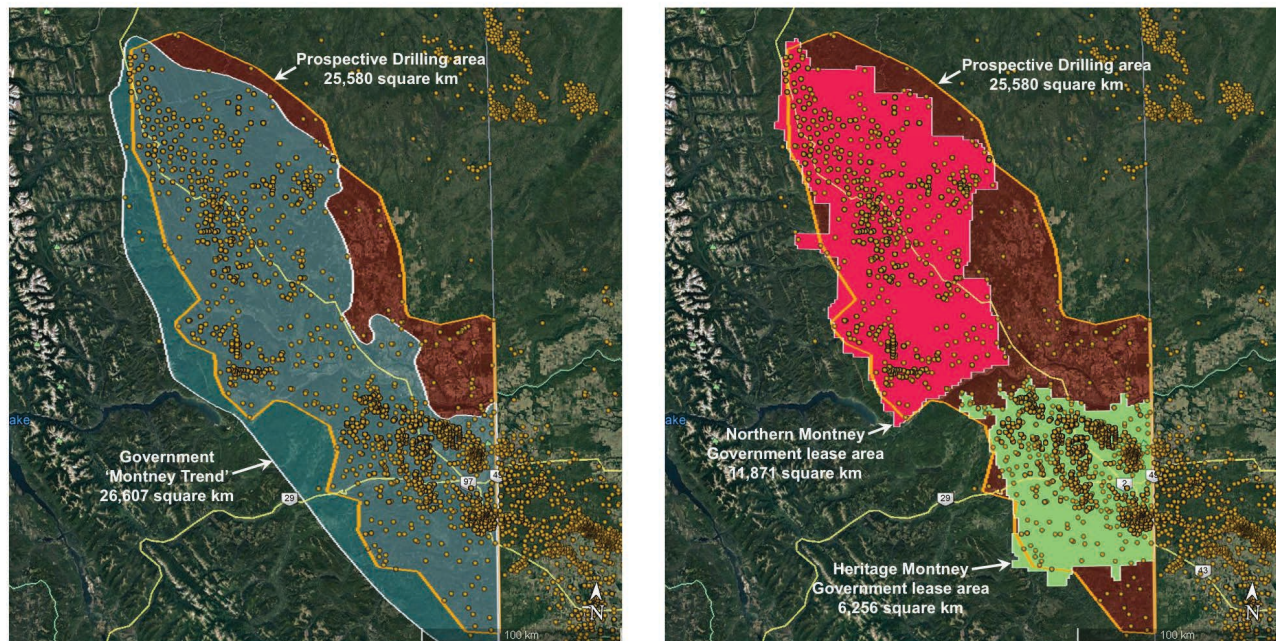
16 BC Oil and Gas Commission, *Oil and Gas Land Use in Northeast British Columbia* (Fort St. John, BC: BC Oil and Gas Commission, 2014). <https://www.bco.gc.ca/node/12908/download>.

the Heritage and Northern Montney fields (which can be downloaded from BCOGC’s open data website) have a combined area of 18,127 square kilometres,¹⁷ whereas the Montney unconventional play trend (also downloadable) has an area of 26,607 square kilometres.¹⁸ These discrepancies are compiled in Table 3. In this study, a prospective drilling area of 25,580 square kilometres (shown in Figure 9) is used to determine the area that will be impacted by drilling the wells needed to meet CER’s forecasted production.

Table 3: Various estimates of the areal extent of the Montney play.

Source	Area	Estimate (km2)
BC Oil and Gas Commission	Regional fields	18,127
BC Oil and Gas Commission	Unconventional play trend	26,607
BC Oil and Gas Commission	Disturbed area	29,589
This study	Prospective drilling area	25,580

Figure 13: The various estimates of the areal extent of the Montney play from the BC Oil and Gas Commission.



Note: Left, “unconventional play trend”; right, the Heritage and Northern Montney regional fields, and the “prospective drilling area” used in this study to assess the land disturbance impact of future drilling. The scale bar is on the lower right. Well data from Enverus and map data from Google Earth accessed February, 2020.

17 BC Oil and Gas Commission Open Data Portal (GIS download of regional fields; accessed February 2020), https://data-bcogc.opendata.arcgis.com/datasets/2e34e8d9065a46929a9dfdbf97ad3838_1/data.

18 BC Oil and Gas Commission Open Data Portal (GIS download of unconventional play trends; accessed February 2020), https://data-bcogc.opendata.arcgis.com/datasets/1fa73f091aac4ff1b8b0deee2fa6ff39_1.

The existing footprint of the oil and gas industry on agricultural land is already a concern, let alone the massive increase in development that will be required to meet CER's forecasted production and LNG exports.

Much of the southeast portion of the BC Montney, and nearly all of the Heritage Field portion of the Montney, overlies prime agricultural land. In 2018, the BC Minister of Agriculture's Advisory Committee for Revitalizing the Agricultural Land Reserve, and the Agricultural Land Commission pointed out:¹⁹

The development of the energy sector has exceeded the capacity of the current regulatory environment to protect farmland. The impacts of oil and gas extraction on agricultural land and farm businesses in Northeast BC have reached a breaking point. Cumulative impacts over the last decade from accelerating oil and gas development have rendered portions of agricultural lands unusable and others difficult to farm. With continued changes in extraction and processing methods along with the pace and scale of development, these activities that were once considered temporary are no longer. Instead they are permanent industrial sites built on farmland and next to farm communities.

Thus, the existing footprint of the oil and gas industry on agricultural land is already a concern, let alone the massive increase in development that will be required to meet CER's forecasted production and LNG exports.

The extent of land disturbance in the Montney due to oil and gas development prior to 2015 has been estimated by BCOGC.²⁰ Table 4 estimates the land disturbance of wells drilled from 2015 to 2019 and of wells that will have to be drilled to meet CER's forecasted production from 2020 to 2040. These estimates assume that BCOGC's average well-pad size of 1.44 hectares per well is correct (it seems roughly correct given spot checks and well pads illustrated in Figures 11 and 12), and keeping the ratio between well-pad area and the area of pipelines, roads, facilities, geophysical disturbance (such as seismic work), and other oil and gas activities constant for additional wells. The pre-2015 disturbance areas in Table 4 are from BCOGC and were used to establish the ratios for future land disturbance, with the exception that geophysical disturbance was reduced by 20 per cent to reflect the fact that much seismic work has already been done and therefore it is likely less will be needed in the future. The BCOGC also reduced the "total area used for oil and gas activities" by 11 per cent to get what it calls the "net area used for oil and gas activities" by eliminating areas of overlap. The figures in Table 4 reflect this reduction.

19 Advisory Committee for Revitalizing the Agricultural Land Reserve and the Agricultural Land Commission, *Revitalizing the Agricultural Land Reserve and the Agricultural Land Commission: Final Committee Report to the Minister of Agriculture; Recommendations for Revitalization* (Victoria, BC: Ministry of Agriculture, 2018), https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/agriculture-and-seafood/agricultural-land-and-environment/agriculture-land-reserve/final-committee-report-to-the-minister-of-agriculture-recommendations-for-revitalization-december-4-2018_optimized.pdf.

20 BC Oil and Gas Commission, *Oil and Gas Land Use*.

Table 4: Land disturbance in the BC Montney play, to 2040.

Land disturbance in hectares								
Disturbance period	Number of wells added	Well pads	Pipelines	Roads	Facilities	Geophysical disturbance	Other oil and gas activities	Total
pre-2015	n/a	14,984	16,520	13,954	1,091	58,434	6,122	111,105
2015–2019	2,161	2,783	3,068	2,592	203	8,682	1,137	18,463
2020–2040	12,957	16,685	18,395	15,539	1,215	52,053	6,817	110,703
Total	15,118	34,451	37,983	32,085	2,508	119,168	14,076	240,271

Land disturbance by percentage of the BC Montney play								
Disturbance period	Number of wells added	Well pads	Pipeline	Roads	Facilities	Geophysical disturbance	Other oil and gas activities	Total
pre-2015	n/a	0.59%	0.65%	0.55%	0.04%	2.28%	0.24%	4.34%
2015–2019	2,161	0.11%	0.12%	0.10%	0.01%	0.34%	0.04%	0.72%
2020–2040	12,957	0.65%	0.72%	0.61%	0.05%	2.03%	0.27%	4.33%
Total	15,118	1.35%	1.48%	1.25%	0.10%	4.66%	0.55%	9.39%

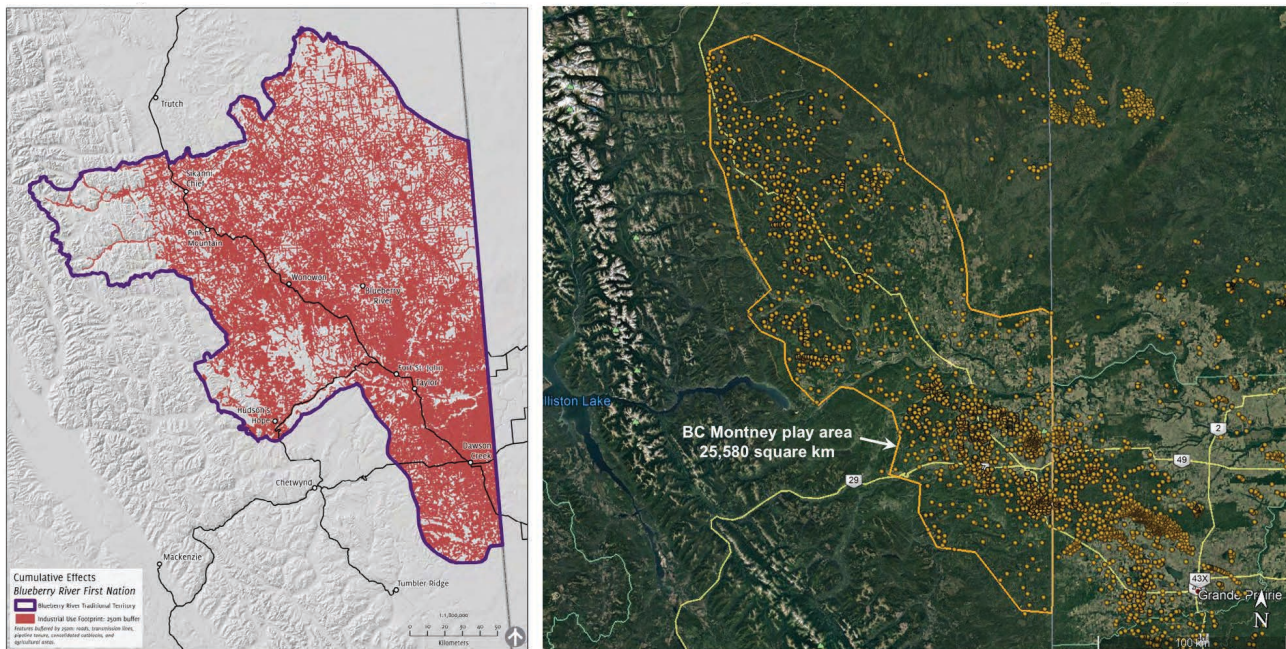
Note: The percentage of the land area disturbed in this table is based on the prospective drilling area which is 25,580 square kilometres.

Based on this analysis, the cumulative land disturbance in the Montney will have to nearly double from current levels to accommodate the wells needed to meet CER’s forecasted production through 2040. Cumulative land disturbance by 2040 will total 2,403 square kilometres, or 9.4 per cent of the prospective drilling area in the Montney.

Disturbance of First Nations land by oil and gas development has long been a point of contention between First Nations and the BC government. Most of the prospective drilling area lies on Blueberry River First Nation lands (see Figure 14). In 2015, the Blueberry River First Nation sued the provincial government over cumulative land disturbance, and after a temporary settlement, went back to court in May 2019.²¹ A decision on this latest court case is expected in mid-2020, and may severely restrict the capacity of the BC government to double land disturbance on Blueberry River First Nation lands by 2040, let alone the additional land disturbance after 2040 from the drilling required to meet the needs of the three approved 40-year LNG export licences that end between 2065 and 2070.

21 Christopher Pollon, “Stung by Derailed Negotiations with B.C., Blueberry River First Nations Return to Court,” *Narwhal*, May 24, 2019, <https://thenarwhal.ca/stung-by-derailed-negotiations-with-b-c-blueberry-river-first-nations-return-to-court/>.

Figure 14: Blueberry River First Nation lands (left) and prospective Montney drilling area (right).



Note: There is a high degree of overlap between Blueberry River First Nation lands (left) and the prospective drilling area in the Montney (right). The map on the left illustrates disturbed lands, mainly from oil and gas development, with a 250-metre buffer. Source (left): Eliana Macdonald, *Atlas of Cumulative Landscape Disturbance in the Traditional Territory of Blueberry River First Nations: 2016* Vancouver, BC: David Suzuki Foundation and Ecotrust Canada, 2016. Well data (right) from Enverus and map data (right) from Google Earth accessed February, 2020.

Land disturbance related to LNG development

As noted earlier (and presented in Table 1), CER has approved 40-year export licences for three LNG export terminals in BC, and one of these, LNG Canada, is under construction. In its projection of gas production through 2040 (see Figure 4), CER has assumed that the gas exported from LNG Canada would come primarily from the BC Montney, which is forecasted to have strong production growth, and that gas production from all other BC sources would decline. Gas production for the other two approved 40-year export licences, Kitimat LNG and Woodfibre LNG, would have to come from additional production not included in CER's forecast, given that LNG exports in the CER forecast are *only sufficient to meet the requirements of LNG Canada*. Given that CER forecasts a lack of production growth outside of BC, it is likely (assuming there remained accessible resources after supplying LNG Canada) that gas for these projects would also come primarily from the BC Montney (although Chevron, one of the owners of Kitimat LNG, has exploration rights in the more remote Horn River and Liard plays which could possibly contribute).

Table 5 illustrates land disturbance from the drilling required to provide gas for the three LNG export projects through 2070, when licences for Kitimat LNG and Woodfibre LNG would end (the LNG Canada licence would end in 2065, 40 years after its 2025 start-up).

Table 5: Land disturbance in the BC Montney play with and without LNG projects, to 2070.

Land disturbance in hectares								
Disturbance period	Number of wells added	Well pads	Pipelines	Roads	Facilities	Geophysical disturbance	Other oil and gas activities	Total
pre-2015	n/a	14,984	16,520	13,954	1,091	58,434	6,122	111,105
2015–2019	2,161	2,783	3,068	2,592	203	8,682	1,137	18,463
2020–2040 w/o LNG Canada	9,260	11,924	13,146	11,105	868	37,200	4,872	79,115
2041–2070 w/o LNG Canada	13,621	17,540	19,338	16,335	1,277	54,721	7,166	116,377
2025–2040 LNG Canada	3,698	4,761	5,249	4,434	347	14,855	1,945	31,592
2041–2065 LNG Canada	7,122	9,171	10,111	8,541	668	28,612	3,747	60,850
2030–2070 Kitimat LNG	7,972	10,265	11,318	9,560	747	32,027	4,194	68,112
2030–2070 Woodfibre LNG	1,072	1,380	1,522	1,286	101	4,307	564	9,159

Land disturbance by percentage of the BC Montney play								
Disturbance period	Number of wells added	Well pads	Pipelines	Roads	Facilities	Geophysical disturbance	Other oil and gas activities	Total
pre-2015	n/a	0.59%	0.65%	0.55%	0.04%	2.28%	0.24%	4.34%
2015–2019	2,161	0.11%	0.12%	0.10%	0.01%	0.34%	0.04%	0.72%
2020–2040 w/o LNG Canada	9,260	0.47%	0.51%	0.43%	0.03%	1.45%	0.19%	3.09%
2041–2070 w/o LNG Canada	13,621	0.69%	0.76%	0.64%	0.05%	2.14%	0.28%	4.55%
2025–2040 LNG Canada	3,698	0.19%	0.21%	0.17%	0.01%	0.58%	0.08%	1.24%
2041–2065 LNG Canada	7,122	0.36%	0.40%	0.33%	0.03%	1.12%	0.15%	2.38%
2030–2070 Kitimat LNG	7,972	0.40%	0.44%	0.37%	0.03%	1.25%	0.16%	2.66%
2030–2070 Woodfibre LNG	1,072	0.05%	0.06%	0.05%	0.00%	0.17%	0.02%	0.36%
Total 2020–2070	42,745	2.15%	2.37%	2.00%	0.16%	6.71%	0.88%	14.28%
Total pre-2020	4,950	0.69%	0.77%	0.65%	0.05%	2.62%	0.28%	5.07%
Grand total to 2070	47,695	2.85%	3.14%	2.65%	0.21%	9.34%	1.16%	19.34%

Note: The percentage of the land area disturbed in this table is based on the prospective drilling area which is 25,580 square kilometres.

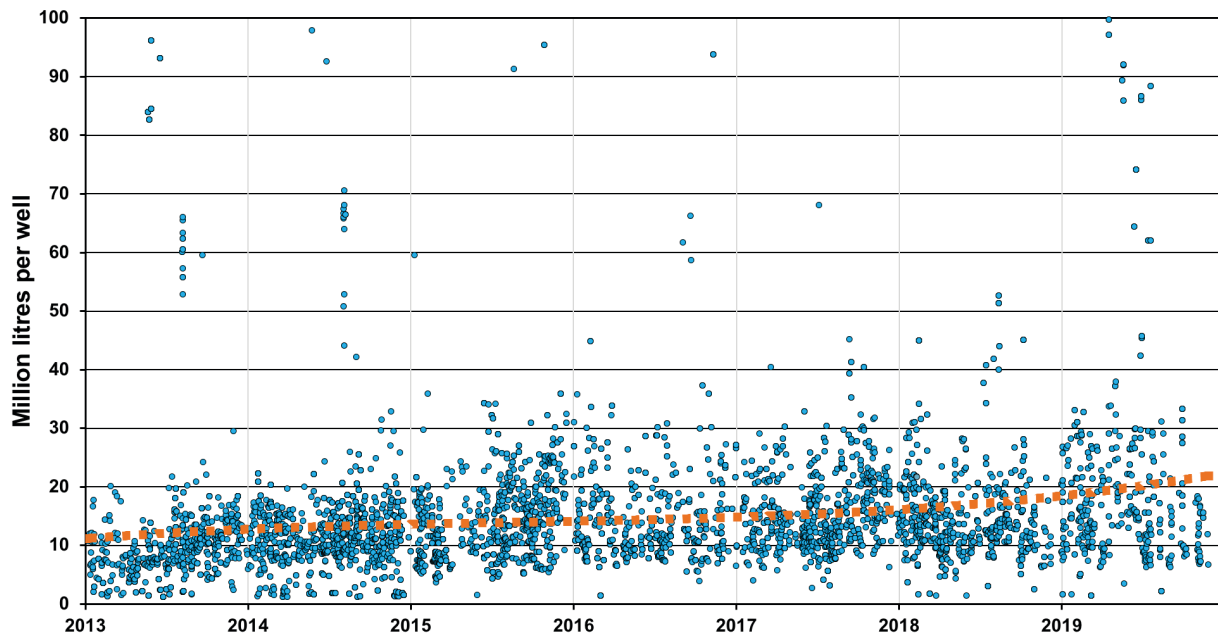
Table 6 illustrates the cumulative land disturbance with the three LNG projects through the end of their 40-year licensed periods of operation. As of 2020, approximately 5 per cent of the prospective drilling area in the Montney had been impacted by oil and gas development. Even without LNG exports, by 2070, nearly 13 per cent of the area would be impacted through drilling the 22,881 wells needed for the non-LNG Montney supply in CER's forecasted production. In order to meet the requirements of the three 40-year export licences, 19,864 additional wells would be needed, and the disturbed area would rise to nearly 20 per cent, or four times the current impacted area.

Table 6: Cumulative land disturbance under various scenarios of LNG development in the Montney.

	Cumulative area in hectares	Cumulative disturbance as percentage of the BC Montney play
To 2020	129,568	5.07%
To 2040 without the 3 LNG projects	208,683	8.16%
To 2070 without the 3 LNG projects	325,060	12.71%
Plus LNG Canada to 2065	417,502	16.32%
Plus Kitimat LNG to 2070	485,614	18.98%
Plus Woodfibre LNG to 2070	494,773	19.34%

Note: The percentage of the land area disturbed in this table is based on the prospective drilling area which is 25,580 square kilometres.

Figure 15: Water-injection volumes per well in BC, 2013–2019.



Source: Data from BC Oil and Gas Commission FracFocus database (accessed February 2020).

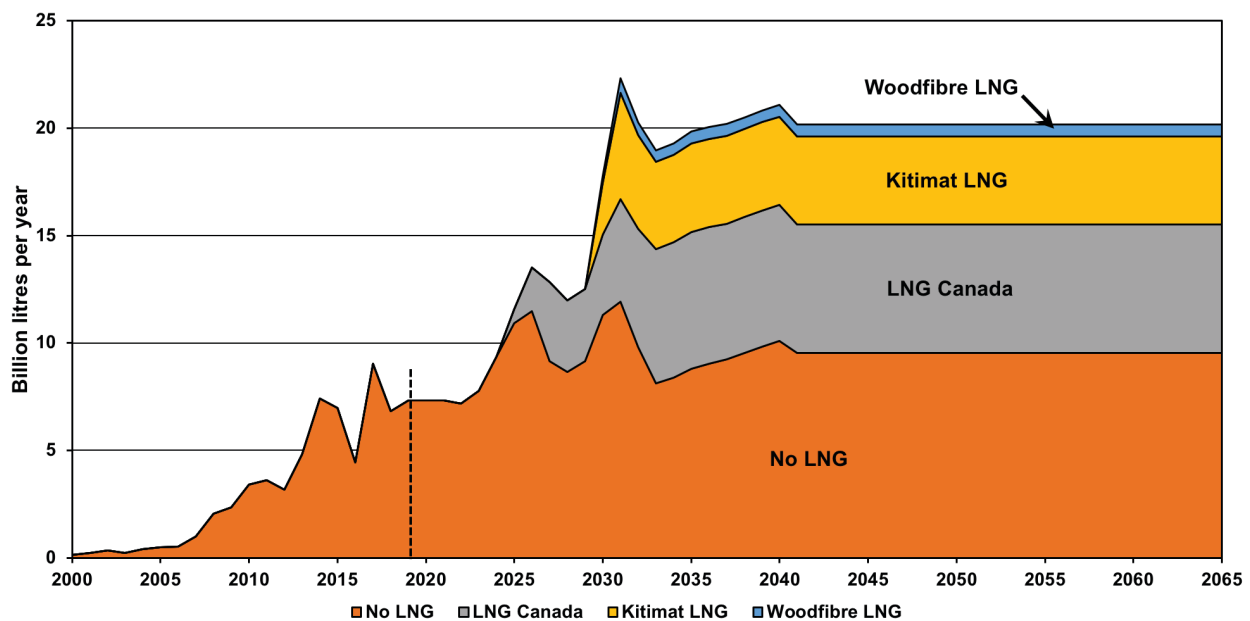
Note: The orange line is the average water-injection volume.

Water consumption

Fracking (hydraulic fracturing in conjunction with horizontal drilling) has allowed the Montney to become the main source of gas production growth in BC since the late 2000s. There has been an evolution in fracking technology over the past decade, with longer horizontal laterals and increasing amounts of water and proppant injection. In the BC Montney, horizontal laterals have increased by about 25 per cent since 2012 to 2.15 kilometres on average,²² and water injection has increased by 67 per cent since 2013, to an average of 21 million litres per well (although some wells have exceeded 100 million litres).²³ Figure 15 illustrates water-injection volumes of individual wells in BC and the increase in average water-injection volume since 2013.

Figure 16 illustrates the water consumption required for the drilling rates needed to meet CER's forecasted production assuming an average consumption of 21 million litres per well. If all three LNG export terminals are built, total water consumption would reach 20 billion litres per year after 2030. To put this in perspective, in 2016 the 648,000 residents of the city of Vancouver each consumed 500 litres per day, for a total consumption of 118.2 billion litres.²⁴ So the water consumption for fracking per year would equal about two months of consumption of the city of Vancouver.

Figure 16: Total water-injection volumes for the drilling rates needed to meet CER's forecasted production and to provide additional gas for Kitimat LNG and Woodfibre LNG.



Sources: Data from Enverus (accessed February 2020); and BC Oil and Gas Commission FracFocus database (accessed February 2020).

Note: Production in the 'No LNG' case is held flat after 2040 at the 2040 rate projected by CER.

22 Enverus data (accessed February 8, 2020).

23 BC Oil and Gas Commission FracFocus database (accessed January 2020).

24 Vancouver Water Services Department, 2016 *Water Consumption Statistics Report* (Vancouver, BC: City of Vancouver, 2017), http://www.metrovancouver.org/services/water/WaterPublications/2016_Water_Consumption_Statistics_Report.pdf.

At peak production after 2030, if all three LNG export terminals are built, seven billion litres of flowback water per year will need to be disposed of, which is roughly double the current level.

Another concern with fracking is the disposal of contaminated fracking water injected when the well is first completed (roughly one-third of the injected water comes back to the surface as flowback), and also of formation water²⁵ that is produced over a well's productive lifetime. Although some of this highly contaminated water is treated and reused, most of it is injected into disposal wells. At peak production after 2030, if all three LNG export terminals are built, seven billion litres of flowback water per year will need to be disposed of, which is roughly double the current level.

Disposal of produced formation water represents an even bigger disposal problem than the disposal of flowback water. In 2019, 3,314 active BC Montney wells produced 6.6 billion litres of formation water in the previous 12 months (each of these wells had more than 12 months of production).²⁶ Including flowback water from wells drilled in the Montney in 2019, this represents a total of 10 billion litres of contaminated water that must be disposed of. In order to meet CER's forecasted production, which includes LNG Canada, 31,430 new wells (see Table 5) must be drilled from 2020 to 2065 (assuming production remains flat at 2040 levels from 2041 to 2065). This could raise the disposal of formation water problem by a factor of 10, to 66 billion litres per year, which, when combined with five billion litres per year of flowback water, would require disposal of seven times as much contaminated water per year in 2065 at the end of LNG Canada's life as at present.

If Kitimat LNG and Woodfibre LNG were also built, an additional 9,044 wells would be required by 2070 (see Table 5), making the water disposal problem even worse.

25 Formation water is the water contained in the reservoir rocks that is produced along with the gas, as opposed to the water injected during the fracking process.

26 Enverus data (accessed February 8, 2020).

What are the emissions implications, and how do they relate to pledged targets?

IN 2018, THE BC GOVERNMENT INTRODUCED ITS CLEANBC PLAN, which pledged to reduce emissions by 40 per cent from 2007 levels by 2030 and 80 per cent by 2050.²⁷ In 2015, the federal government pledged to reduce emissions by 30 per cent from 2005 levels by 2030 (in the Paris Agreement²⁸) and has recently pledged that Canada will have “net zero” emissions by 2050.²⁹

At about the same time as the CleanBC plan was announced, the BC and federal governments celebrated the final investment decision of LNG Canada to construct an export terminal at Kitimat, stating the project was the “single largest private sector investment project in Canadian history.”³⁰ Little mention was made of the obvious conflict between the government’s emissions-reduction goals and the upstream and downstream emissions that will be produced by this project.³¹

Emissions of greenhouse gases occur throughout the natural gas supply chain. These include combustion emissions from drilling, fracking, flaring, venting, compression and cleanup, as well

Little mention was made of the obvious conflict between the government’s emissions-reduction goals and the upstream and downstream emissions that will be produced by this project.

27 Government of BC, *CleanBC* (Victoria, BC: Government of BC, 2018), https://www2.gov.bc.ca/assets/gov/environment/climate-change/action/cleanbc/cleanbc_2018-bc-climate-strategy.pdf.

28 “The Paris Agreement,” UN climate change conference, Government of Canada, <https://www.canada.ca/en/environment-climate-change/services/climate-change/paris-agreement.html>.

29 Amanda Connolly, “Liberals Pledge Canada Will Have Net-Zero Emissions by 2050 — but Details Are Scarce,” *Global News*, September 24, 2019, <https://globalnews.ca/news/5943543/canada-net-zero-emissions-2050/>.

30 “Massive LNG Canada Project in B.C. Gets Green Light from Shareholders,” *Calgary Herald*, October 2, 2018, <https://calgaryherald.com/business/business-wire/lng-canada-project-in-british-columbia-given-final-approval-by-shareholders>.

31 Upstream emissions refer to those from gas production, processing and transportation; whereas downstream emissions refer to those from liquefaction, tanker transport, regasification and combustion.

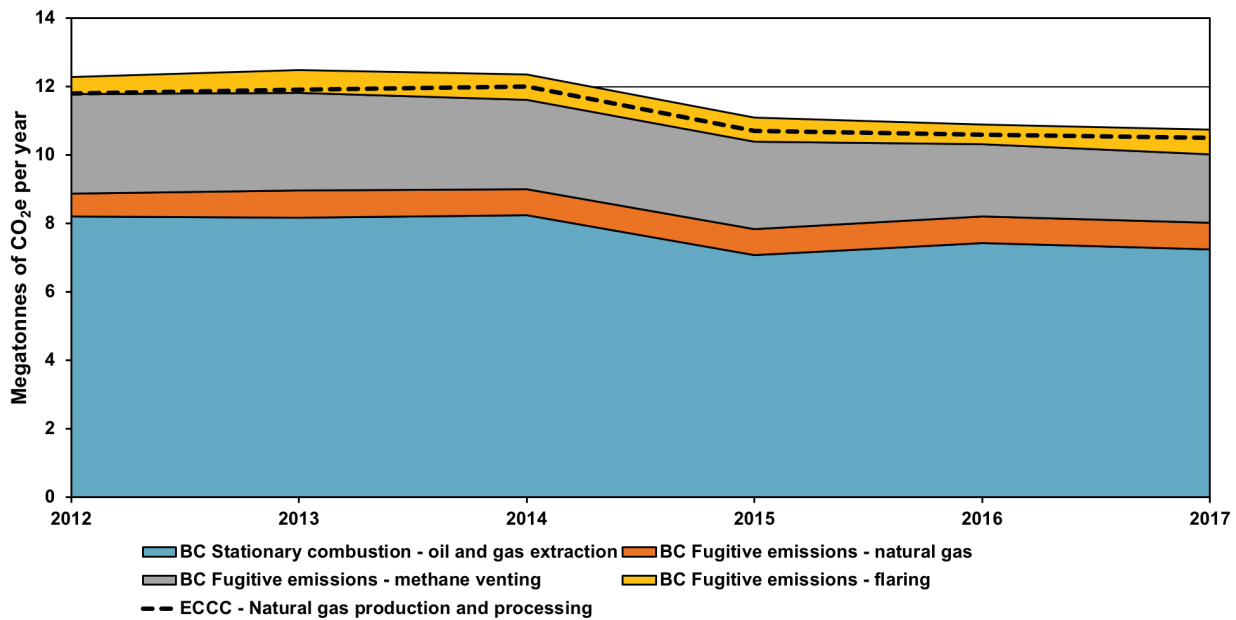
as methane emissions from venting, from equipment leakages and during the initial flowback from well completions. They also include emissions from the liquefaction terminal itself.

Each year, Environment and Climate Change Canada (ECCC) submits a *National Inventory Report* to the United Nations Framework Convention on Climate Change (UNFCCC). The most recent inventory of emissions by Canadian economic sector was published in April 2020, and includes emissions through 2018.³² BC also reports emissions with a slightly different breakdown in its Provincial Greenhouse Gas Emissions Inventory data sets and reports.³³

Figure 17 compares the emissions of natural gas production in BC in these two inventories for the most recent five years. The total emissions are similar, with BC identifying emissions from flaring and venting natural gas and combustion separately.

Methane is of particular concern as it is a much more potent greenhouse gas than carbon dioxide. The BC emissions inventory indicates that methane venting is responsible for about 20 per cent of emissions from natural gas production (shown in Figure 17). Table 7 illustrates the potency of methane compared with carbon dioxide as a greenhouse gas over 20- and 100-year periods as documented by the Intergovernmental Panel on Climate Change (IPCC) in its fourth and fifth assessment reports.

Figure 17: Emissions from natural gas production in BC calculated by Environment and Climate Change Canada and BC’s Greenhouse Gas Emissions Inventory.



Sources: See footnotes 31 and 32.

32 Environment and Climate Change Canada, *National Inventory Report 1990–2018: Greenhouse Gas Sources and Sinks in Canada* (Ottawa, ON: Environment and Climate Change Canada, 2020), <https://unfccc.int/documents/224829>.

33 “Provincial Greenhouse Gas Emissions Inventory,” Data & Inventories, Government of BC, accessed February 2020, <https://www2.gov.bc.ca/gov/content/environment/climate-change/data/provincial-inventory>.

Table 7: The global warming potential of methane compared with carbon dioxide over 20 years and 100 years, according to the Intergovernmental Panel on Climate Change (IPCC).

Measurement basis	IPCC's fourth assessment report (2007) (global warming potential)	IPCC's fifth assessment report (2014) (global warming potential)
Methane, over 20 years <i>without</i> feedback	72	84
Methane, over 100 years <i>without</i> feedback	25	28
Methane, over 20 years <i>with</i> feedback		86
Methane, over 100 years <i>with</i> feedback		34

Sources: Data from Intergovernmental Panel on Climate Change, *Fourth Assessment Report* (Geneva, Switzerland: IPCC, 2007); and *Fifth Assessment Report* (Geneva, Switzerland: IPCC, 2014).

Using a convention of the United Nations Framework Convention on Climate Change, the ECCC and BC emissions inventories are based on the lowest global warming potential for methane of 25 times that of carbon dioxide over 100 years (from the IPCC's 2007 IPCC AR4 report). This means the actual global warming impacts of methane emissions in the first few decades after emission are underestimated by a factor of more than three.

In order to address the methane problem, both the federal and BC governments have pledged to reduce methane emissions. The federal pledge is to reduce emissions by 40 to 45 per cent from 2012 levels by 2025,³⁴ and the BC pledge is to reduce emissions by 45 per cent from 2014 levels by 2025.³⁵

Both the federal and provincial governments have also proposed electrifying the upstream gas industry to the extent possible, but beyond a press release it is unclear what has been done, if anything.³⁶ In practice, electrification would largely be limited to gas plants, some of which have already been electrified, and economics would depend on the costs of building transmission lines and other infrastructure for particular facilities. Although there are a few electric fracking rigs in the Permian Basin in the US, these typically use electricity generated on site by natural gas, which is a very low-cost energy source in that area, and do not significantly reduce emissions.

Methane is of particular concern as it is a much more potent greenhouse gas than carbon dioxide.

34 "Regulations for the Reduction of Methane Releases in the Upstream Oil and Gas Sector: Frequently Asked Questions," last modified October 8, 2019, Canadian Environmental Protection Act Registry, Government of Canada, <https://www.canada.ca/en/environment-climate-change/services/canadian-environmental-protection-act-registry/methane-upstream-oil-gas-regulations-questions.html>.

35 "New Methane Emissions Reduction Rules in Force in B.C.," *JWN Energy*, January 2, 2019, <https://www.jwnenergy.com/article/2020/1/new-methane-emissions-reduction-rules-force-bc/>.

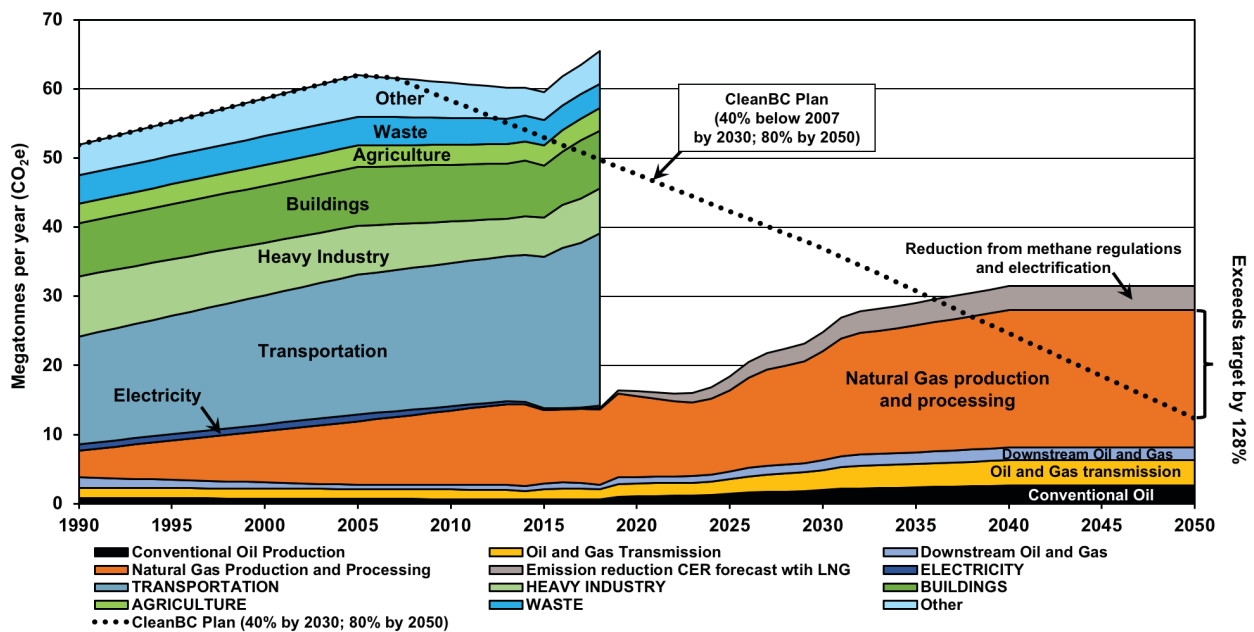
36 "Ottawa, B.C. to Push Electrification of Natural Gas Industry to Cut Carbon Emissions," *Vancouver Sun*, August 29, 2019, <https://vancouversun.com/business/energy/ottawa-b-c-to-push-electrification-of-natural-gas-industry-to-cut-carbon-emissions>.

If realized, the methane reduction targets would reduce overall emissions from natural gas production by about 9 per cent from what they would otherwise be in 2025 (given that methane venting is currently responsible for about 20 per cent of natural gas production emissions according to BC’s estimates— see Figure 17). If electrification of some facilities also proceeds, perhaps a further 6 per cent reduction in emissions from what they might otherwise be could be achieved by 2025, for a reduction of 15 per cent in total emissions from current levels.

Figure 18 shows a projection of emissions from future oil and gas production in BC based on CER’s production forecast using the average emissions per unit of production of the most recent four years for which both emissions and production data are available (2015 to 2018). Also shown in Figure 18 is the effect of a 15 per cent reduction in overall emissions from natural gas production by 2025 as a result of methane reduction and electrification initiatives. Reducing methane and increasing electrification would reduce overall emissions from CER’s forecasted production by 3.5 megatonnes per year in 2040. Nonetheless, emissions from oil and gas production, transmission and processing would exceed the CleanBC plan’s 2050 target by 128 per cent in 2050, even if all other parts of BC’s economy reduced emissions to zero by 2038.

As illustrated in Figure 4, gas production to be exported as LNG will come primarily from BC’s Montney play, according to CER. Figure 19 illustrates emissions in a scenario without LNG exports (where CER’s forecasted production for LNG exports has been subtracted from the overall

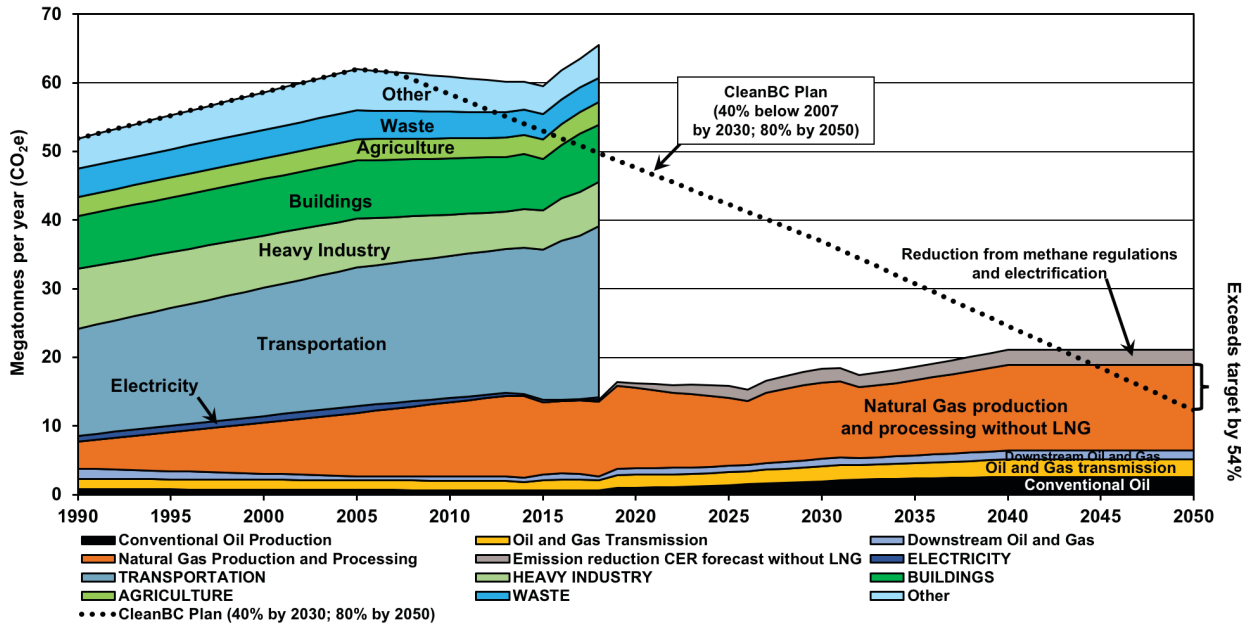
Figure 18: BC emissions by Canadian economic sector to 2018, with a 2019–2050 projection of emissions from oil and gas production.



Sources: Data from Environment and Climate Change Canada, *National Inventory Report 1990–2018: Greenhouse Gas Sources and Sinks in Canada* (Ottawa, ON: Environment and Climate Change Canada, 2020); and *Canada’s Energy Future 2019* report.

Note: Projected emissions from oil and gas production are based on CER’s forecasted production in BC (see Figure 4), and are held constant at 2040 levels through 2050. Projected emissions from natural gas production and processing have been reduced by 15 per cent after 2025, given methane reduction and electrification initiatives. Also shown is the emissions-reduction target in the CleanBC plan.

Figure 19: Projected oil and gas emissions in BC based on CER's forecasted production, but without LNG exports.



Sources: Data from Environment and Climate Change Canada, *National Inventory Report 1990-2018: Greenhouse Gas Sources and Sinks in Canada*; and *Canada's Energy Future 2019* report.

forecast). In this case, even assuming improvements from methane reduction and electrification initiatives, emissions from oil and gas production would exceed the CleanBC plan's target in 2050 by 54 per cent, even if all other parts of BC's economy reduced emissions to zero by 2042. Clearly, the oil and gas production projected by CER, even without increasing production to accommodate LNG exports, is incompatible with the CleanBC plan.

The scenario in Figure 19 would still allow production of four times more gas than BC uses domestically (see Figure 4 for domestic consumption). Gas in excess of BC's domestic needs would be exported to Alberta and to the US Pacific Northwest, which is dependent on Canadian gas for more than half of its requirements. As noted earlier, according to CER, BC is projected to provide most of the growth in Canadian gas production through 2040, so reducing gas production beyond eliminating LNG exports may compromise the needs of other Canadians and the US northwest.

Emissions within BC from LNG exports include upstream emissions from producing the gas and transporting it to the LNG liquefaction terminal, and emissions at the terminal itself for liquefaction. BC has established a Liquefied Natural Gas Environmental Incentive Program, which specifies a goal of 0.16 tonne of greenhouse gas emissions per tonne of LNG produced

Emissions within BC from LNG exports include upstream emissions from producing the gas and transporting it to the LNG liquefaction terminal, and emissions at the terminal itself for liquefaction.

(tCO₂e/tLNG).³⁷ According to its Canadian Environmental Assessment Agency approval,³⁸ the LNG Canada project will achieve this goal with emissions of 0.15 tCO₂e/tLNG, making it the lowest-emitting LNG terminal in the world.³⁹ Notwithstanding this, the LNG Canada terminal will still emit 3.96 megatonnes per year at full development in 2030.⁴⁰

Political discussion of emissions from the LNG Canada project has emphasized emissions from the terminal itself, not the upstream emissions of producing the gas and transporting it to the terminal, which are considerably larger.

Political discussion of emissions from the LNG Canada project has emphasized emissions from the terminal itself, not the upstream emissions of producing the gas and transporting it to the terminal, which are considerably larger. Figure 20 illustrates both the emissions from producing the gas for and transporting the gas to the LNG Canada terminal, and the emissions from the terminal itself, assuming it achieves the target of 0.15 tCO₂e/tLNG. In this case, even with the lowest-emitting LNG terminal in the world, emissions from oil and gas production and liquefaction would exceed the CleanBC target in 2050 by 160 per cent, even if all other parts of BC's economy reduced emissions to zero by 2035. Clearly, the LNG Canada project makes an untenable situation even worse if BC is serious about meeting its CleanBC target by 2050. Emissions to produce and supply gas to the LNG Canada terminal, and emissions from the terminal itself, would alone total 13.0 megatonnes in 2050, compared with the CleanBC target for all sectors of the economy of 12.3 megatonnes.

In addition to LNG Canada, CER has approved 40-year export licences for the Kitimat LNG and Woodfibre LNG projects. Although Woodfibre LNG is relatively small, requiring just 0.32 billion cubic feet per day (bcfd) of gas, Kitimat LNG would require 2.38 bcf, and together these projects would require 2.7 bcf, which is equivalent to 75 per cent of the gas required by LNG Canada.

Given that CER's forecasted production only includes the gas required for LNG Canada, Kitimat LNG and Woodfibre LNG would require additional production from other sources, which are not part of CER's forecast. Chevron, one of the owners of the Kitimat LNG project, has stated that the gas would be sourced from the more remote Liard and Horn River basins of BC, where it has exploration rights. Given that both of these projects have yet to reach a final investment decision, the earliest they would be online is assumed to be 2030, for the purpose of calculating their emissions implications. Note that Woodside and Chevron, the owners of the Kitimat LNG, are both trying to sell all or portions of their interest in the project.⁴¹

37 BC Ministry of Environment, *Liquefied Natural Gas Environmental Incentive Program* (Victoria, BC: Ministry of Environment, 2019), <https://www2.gov.bc.ca/assets/gov/environment/climate-change/ind/lng/lng-env-incentive-program.pdf>.

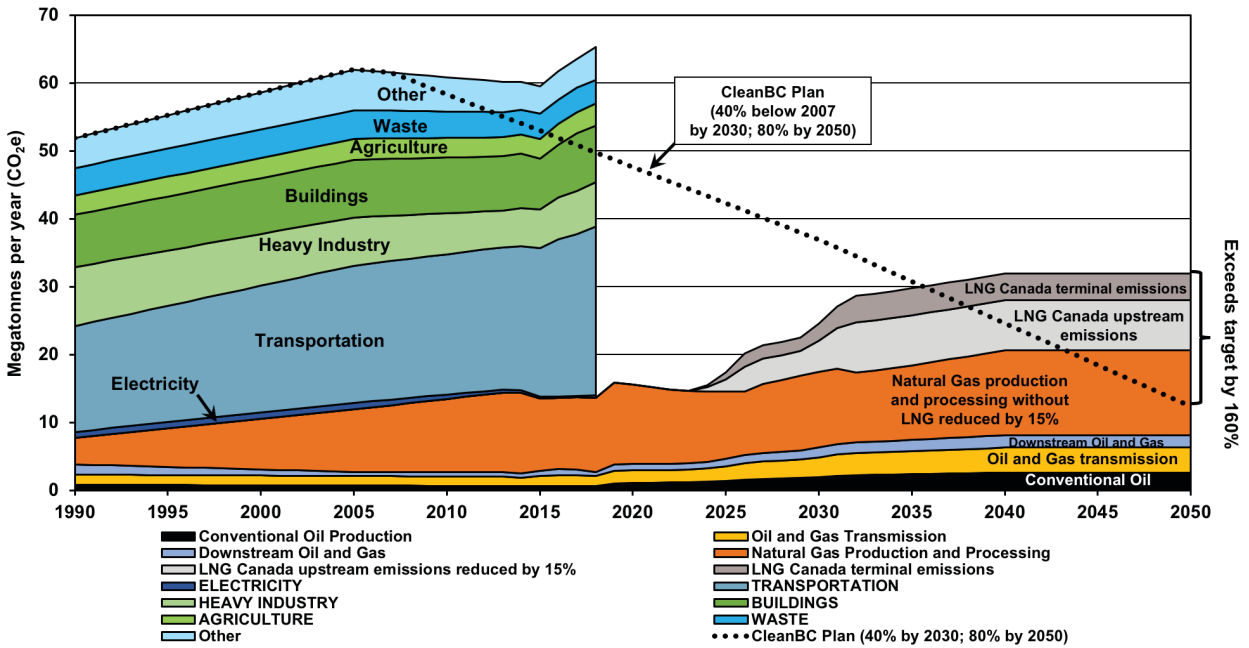
38 Environmental Assessment Office, *LNG Canada Export Terminal Project Assessment Report* (Victoria, BC: Environmental Assessment Office, 2015), <https://iaac-aeic.gc.ca/050/documents/p80038/101852E.pdf>, 61, table 5-1.

39 Canadian Society for Unconventional Resources and JWN Energy, *Canada's Green LNG Advantage, special report 2, Canada and the Natural Gas Economy* (Calgary, AB: Canadian Society for Unconventional Resources and JWN Energy, 2019), https://s3.amazonaws.com/media.dailyoilbulletin.com/pdf/LNG_Special+Report_2.pdf.

40 Environmental Assessment Office, *LNG Canada Export Terminal Project*, 61, table 5-1, <https://iaac-aeic.gc.ca/050/documents/p80038/101852E.pdf>

41 Geoffrey Morgan, "'Really Exciting': Canadian Gas Sector Cheers Woodside's Decision to Sell Partial Kitimat LNG Stake," *Financial Post*, September 10, 2019, <https://business.financialpost.com/commodities/really-exciting-canadian-gas-sector-cheers-woodsides-decision-to-sell-partial-kitimat-lng-stake>; and Dan Healing, "Chevron Cutting Funding to Kitimat LNG Project," *National Observer*, January 20, 2020, <https://www.nationalobserver.com/2020/01/28/news/chevron-cutting-funding-kitimat-lng-project>.

Figure 20: Projected oil and gas emissions in BC based on CER's forecasted production, with additional emissions to supply gas to the LNG Canada terminal and emissions from the terminal itself.



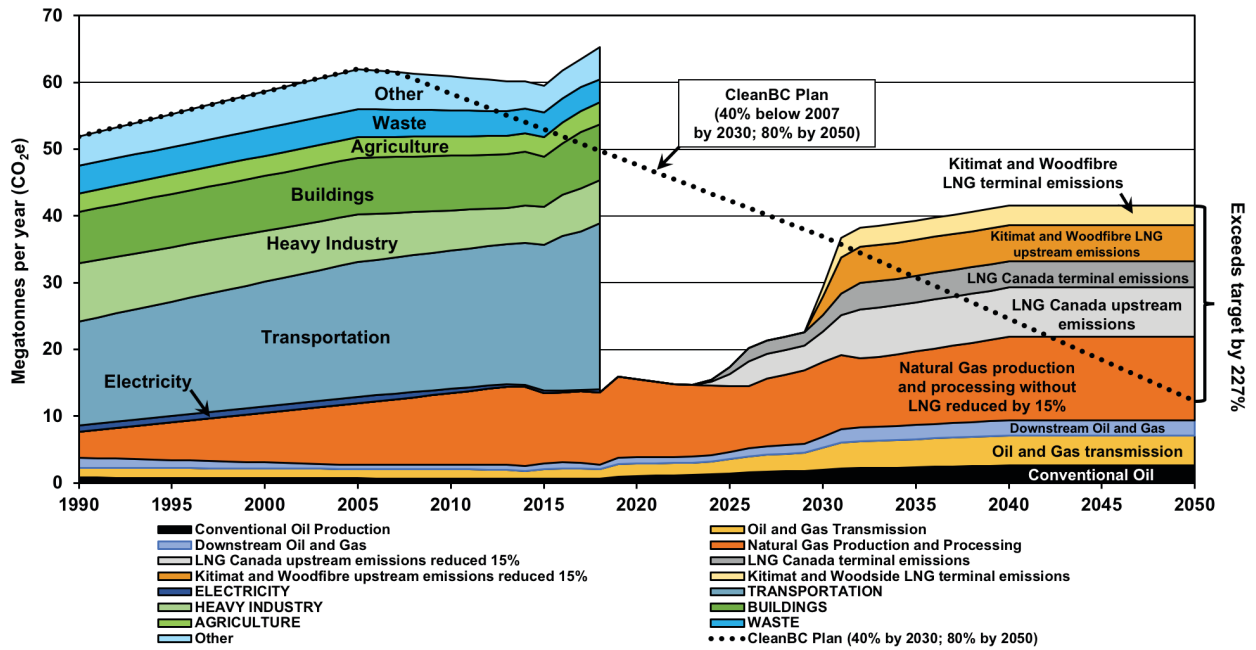
Sources: Data from Environment and Climate Change Canada, *National Inventory Report 1990-2018: Greenhouse Gas Sources and Sinks in Canada*; and Canada Energy Regulator's *Canada's Energy Future 2019* report (CER's 2040 production forecast is held flat through 2050).

Note: See Figure 4 for CER's forecasted production. Projected emissions from natural gas production and processing have been reduced by 15 per cent after 2025, given methane reduction and electrification initiatives.

Figure 21 illustrates emissions from all three LNG projects through 2050. Emissions from the Kitimat LNG and Woodfibre LNG terminals are assumed to equal the 0.15 tCO₂e/tLNG⁴² target set by LNG Canada. Gas is assumed to be sourced within BC, as stated by Chevron in its application. In this case, emissions from oil and gas production would exceed the CleanBC target in 2050 by 227 per cent, even if all other parts of BC's economy reduced emissions to zero by 2031. Clearly, these projects present an impossible hurdle if BC is serious about meeting its CleanBC target by 2050. Emissions to produce and supply gas to the three LNG projects, and emissions from the terminals themselves, would alone total 22.6 megatonnes in 2050, compared with the CleanBC target for all sectors of the economy of 12.3 megatonnes.

42 0.15 tonne of greenhouse gas emissions per tonne of LNG produced.

Figure 21: Projected oil and gas emissions in BC based on CER's forecasted production, including emissions to produce and supply gas to the LNG Canada, Kitimat LNG and Woodfibre LNG terminals, and emissions from the terminals themselves.



Sources: Data from Environment and Climate Change Canada, *National Inventory Report 1990-2018: Greenhouse Gas Sources and Sinks in Canada*; and *Canada's Energy Future 2019* report.

Note: Projected emissions from natural gas production and processing have been reduced by 15 per cent after 2025, given methane reduction and electrification initiatives.

Are government assertions on reducing global emissions by turning to LNG credible?

A KEY NARRATIVE IN MESSAGING BY INDUSTRY AND GOVERNMENT IS THAT BC LNG will reduce global emissions by displacing coal-fired electricity in China and elsewhere in Asia.⁴³ While it is true that at the burner tip, natural gas emits only 54 per cent of the emissions of coal per unit of heat provided,⁴⁴ full-cycle greenhouse gas emissions from LNG include emissions from production and processing of the natural gas, pipeline transportation, liquefaction, shipping and regasification.

In replacing older, low-efficiency coal power plants, a country such as China has a choice of technologies, including renewable energy, combined-cycle natural gas, and best-in-class ultra-supercritical coal plants. China is investing in all of these: it is the world's largest installer of renewable energy, it is importing gas by pipeline from Russia as well as LNG, and it is building ultra-efficient coal plants. As the International Energy Agency points out, "China has a large, young, and highly efficient coal-fired fleet," and "Potential savings of around 100 Mt CO₂ from switching [from coal to gas] are small relative to China's overall power sector emissions of 4,500 Mt CO₂."⁴⁵ The agency also points out that gas is not competitive with coal in China unless the price is below US\$4 per million BTU, which is below the cost of producing and shipping Canadian LNG to China. New coal capacity in China uses ultralow emission plants,⁴⁶ and that is

While it is true that at the burner tip, natural gas emits only 54 per cent of the emissions of coal per unit of heat provided, full-cycle greenhouse gas emissions from LNG include emissions from production and processing of the natural gas, pipeline transportation, liquefaction, shipping and regasification.

43 Peter Kenter, "LNG Canada's Export Terminal Will Enable Coal-Reliant Customer Nations to Reduce GHG Emissions," *Vancouver Sun*, December 13, 2018, <https://vancouversun.com/sponsored/news-sponsored/lng-canadas-export-terminal-will-enable-coal-reliant-customer-nations-to-reduce-ghg-emissions>.

44 "How Much Carbon Dioxide Is Produced When Different Fuels Are Burned?," US Energy Information Administration, accessed February 2020, <https://www.eia.gov/tools/faqs/faq.php?id=73&t=11>.

45 International Energy Agency, *The Role of Gas in Today's Energy Transitions*, <https://www.iea.org/reports/the-role-of-gas-in-todays-energy-transitions>, 12.

46 Charles Kennedy, "China to Add More Coal Power in 2019 and 2020 to Meet Energy Demand," *OilPrice.com*, July 18, 2019, <https://oilprice.com/Latest-Energy-News/World-News/China-To-Add-More-Coal-Power-In-2019-And-2020-To-Meet-Energy-Demand.html>.

what Canadian LNG must compete against both financially and in terms of any emissions-reduction benefits.

In comparing emissions in Asia from best-technology coal to best-technology gas using BC LNG, the following factors are key:

- *The efficiency of new plants being added.* Ultra-supercritical coal technology has typical efficiencies of 45 per cent, with the newest plants capable of 49 per cent.⁴⁷ By comparison, new large-capacity (>500 megawatt) combined-cycle gas plants in the US have heat rates of about 7,500 BTU, which translates to an efficiency of 46 per cent.⁴⁸
- *The leakage rate of methane in the production and transportation of gas and coal.* Methane is a potent greenhouse gas that has 34 times the impact of carbon dioxide over a 100-year period and 86 times the impact over a 20-year period (see Table 7).⁴⁹ An overall leakage rate of about 1.4 per cent for natural gas had been assumed by the US Environmental Protection Agency, but this has been revised upward in a comprehensive peer-reviewed report by Alvarez et al. (2018) to 2.3 per cent.⁵⁰ The authors state that of these emissions, “roughly 85%...are from production, gathering, and processing sources,” or approximately 2 per cent of total natural gas production. Howarth (2014) estimated that fugitive methane emissions from unconventional gas, such as in the Montney where BC LNG would be sourced, are considerably higher, at between 2.2 and 4.3 per cent (with an average of 3.3 per cent).⁵¹
- *The global warming potential (GWP) assumed for methane.* As noted above, the latest GWP estimates of the Intergovernmental Panel on Climate Change (2014) for methane are 34 times carbon dioxide over 100 years and 86 times over 20 years. Environment and Climate Change Canada’s *National Inventory Report* submission for 2020 used the older estimate of 25 times carbon dioxide over 100 years from the Intergovernmental Panel’s 2007 report,⁵² per the protocol of the United Nations. This means that the actual global warming severity of emissions over 100 years has been underestimated in Figures 18 to 21 above, and vastly underestimated if the global warming potential of methane over 20 years is considered.
- *The emissions from the rest of the supply chain.* This includes pipeline transport, liquefaction, shipping and regasification in the case of BC LNG; and mining and transport in the case of coal.

New coal capacity in China uses ultralow emission plants, and that is what Canadian LNG must compete against both financially and in terms of any emissions-reduction benefits.

47 “Driving Your Plant Towards 50% Efficiency,” SteamH, GE Power, accessed July 30, 2019, <https://web.archive.org/web/20190620205943/https://www.ge.com/power/steam/steam-power-plants/steamh>.

48 “Power Blocks in Natural Gas-Fired Combined-Cycle Plants Are Getting Bigger,” Today in Energy (blog), US Energy Information Administration, February 12, 2019, <https://www.eia.gov/todayinenergy/detail.php?id=38312#>.

49 Intergovernmental Panel on Climate Change, *Fifth Assessment Report* (Geneva, Switzerland: IPCC, 2014), <https://www.ipcc.ch/assessment-report/ar5/>, table 8-7.

50 Ramón A. Alvarez et al., “Assessment of Methane Emissions from the U.S. Oil and Gas Supply Chain,” *Science* 361, no. 6398 (2018), https://www.researchgate.net/publication/325916333_Assessment_of_methane_emissions_from_the_US_oil_and_gas_supply_chain.

51 Robert W. Howarth, “A Bridge to Nowhere: Methane Emissions and the Greenhouse Gas Footprint of Natural Gas,” *Energy Science and Engineering* 2, no. 2 (2014), <https://onlinelibrary.wiley.com/doi/abs/10.1002/ese3.35>.

52 Intergovernmental Panel on Climate Change, *Fourth Assessment Report* (Geneva, Switzerland: IPCC, 2007), <https://www.ipcc.ch/assessment-report/ar4/>.

The National Energy Technology Laboratory of the US Department of Energy analyzed life-cycle emissions of the supply chain for US LNG in 2014⁵³ and updated its analysis in 2019.⁵⁴ They looked at all phases of the LNG supply chain compared with coal in China, which included upstream emissions from gas production, processing and transportation to the terminal, liquefaction, tanker transport and regasification, as well as coal mining and transport. Although they underestimated fugitive methane emissions and the efficiency of best-technology coal power plants, it provided a useful framework from which to evaluate the life-cycle emissions of LNG versus coal in China.

Table 8 compares greenhouse gas emissions between a BC-LNG-fuelled combined-cycle gas power plant (“LNG from Kitimat to Shanghai, China”) and an ultra-supercritical coal power plant (“Chinese regional coal”). These plants are assumed to have efficiencies of 46 per cent and 45 per cent, respectively. Fugitive emissions of methane from upstream production and processing of natural gas are assumed to be two per cent of total production based on the estimate of Alvarez et al. (2018) for combined conventional and unconventional gas, as discussed above. Emissions from the Canadian Environmental Assessment Agency evaluation of the LNG Canada terminal, which are projected to be the lowest of any terminal in the world, are assumed. The assumed pipeline distance has been shortened given that the Coastal GasLink pipeline to supply LNG Canada is only 670 kilometres compared with the 971 kilometres assumed by the National Energy Technology Laboratory. The assumed tanker voyage has also been shortened to 4,794 nautical miles to reflect the distance from Kitimat to Shanghai, rather than the 10,013 nautical miles assumed by National Energy Technology Laboratory from New Orleans to Shanghai via the Panama Canal.⁵⁵

Table 8: Life-cycle emissions from BC LNG-fuelled power generation in China compared with best-technology coal generation, assuming upstream fugitive methane emissions of two per cent.

Life-cycle process (kg CO ₂ e/MWh)	100-year global warming potential		20-year global warming potential	
	LNG from Kitimat to Shanghai, China	Chinese regional coal	LNG from Kitimat to Shanghai, China	Chinese regional coal
Natural gas extraction, processing and pipelines/Coal extraction and processing	172.7	9.0	301.8	14.0
Liquefaction of LNG	23.0	n/a	23.0	n/a
Tanker/rail transport	36.4	11.0	43.6	11.0
Regasification of LNG	4.0	n/a	5.0	n/a
Combustion at power plant	393.7	739.5	393.7	739.5
Electricity transmission	2.0	2.0	1.0	1.0
Total	631.8	761.5	768.1	765.5

Note: Other assumptions are noted in the text.

53 National Energy Technology Laboratory, *Life Cycle Greenhouse Gas Perspective on Exporting Liquefied Natural Gas from the United States* (Washington, DC: US Department of Energy, 2014), <https://www.energy.gov/sites/prod/files/2014/05/f16/Life%20Cycle%20GHG%20Perspective%20Report.pdf>.

54 Selina Roman-White et al., *Life Cycle Greenhouse Gas Perspective on Exporting Liquefied Natural Gas from the United States: 2019 Update* (Washington, DC: National Energy Technology Laboratory, US Department of Energy, 2019), <https://www.energy.gov/sites/prod/files/2019/09/f66/2019%20NETL%20LCA-GHG%20Report.pdf>.

55 Voyage distance from the Sea Distances website (<https://sea-distances.org>), accessed February, 2020.

In this case, BC LNG would have 0.3 per cent greater emissions than coal over a 20-year time frame and 17 per cent less emissions than coal over a 100-year time frame, meaning that exporting BC LNG would make the global emissions problem worse for at least the first 25 years after constructing a power plant in China to burn it.

Given that much or all of the supply for LNG Canada and Kitimat LNG would come from the Montney and other unconventional gas plays in northeast BC, a more realistic value for fugitive methane emissions is 3.3 per cent for unconventional gas, as estimated by Howarth (2014).⁵⁶ In this case, as shown in Table 9, best-technology coal would have 18.5 per cent fewer emissions than BC LNG over a 20-year time frame and 9.8 per cent greater emissions over a 100-year time frame. The break-even point at which BC LNG would actually emit less greenhouse gas than best-technology coal would be 60 years in the future, at which point the plants burning it would be past their designed lifetime. Before 60 years have elapsed, BC LNG would make the emissions problem and climate change worse.

Table 9: Life-cycle emissions from BC LNG-fuelled power generation in China compared with best-technology coal generation, assuming upstream fugitive methane emissions of 3.3 per cent

Life-cycle process (kg CO ₂ e/MWh)	100-year global warming potential		20-year global warming potential	
	LNG from Kitimat to Shanghai, China	Chinese regional coal	LNG from Kitimat to Shanghai, China	Chinese regional coal
Natural gas extraction, processing and pipelines/Coal extraction and processing	227.6	9.0	440.6	14.0
Liquefaction of LNG	23.0	n/a	23.0	n/a
Tanker/rail transport	36.4	11.0	43.6	11.0
Regasification of LNG	4.0	n/a	5.0	n/a
Combustion at power plant	393.7	739.5	393.7	739.5
Electricity transmission	2.0	2.0	1.0	1.0
Total	686.7	761.5	906.9	765.5

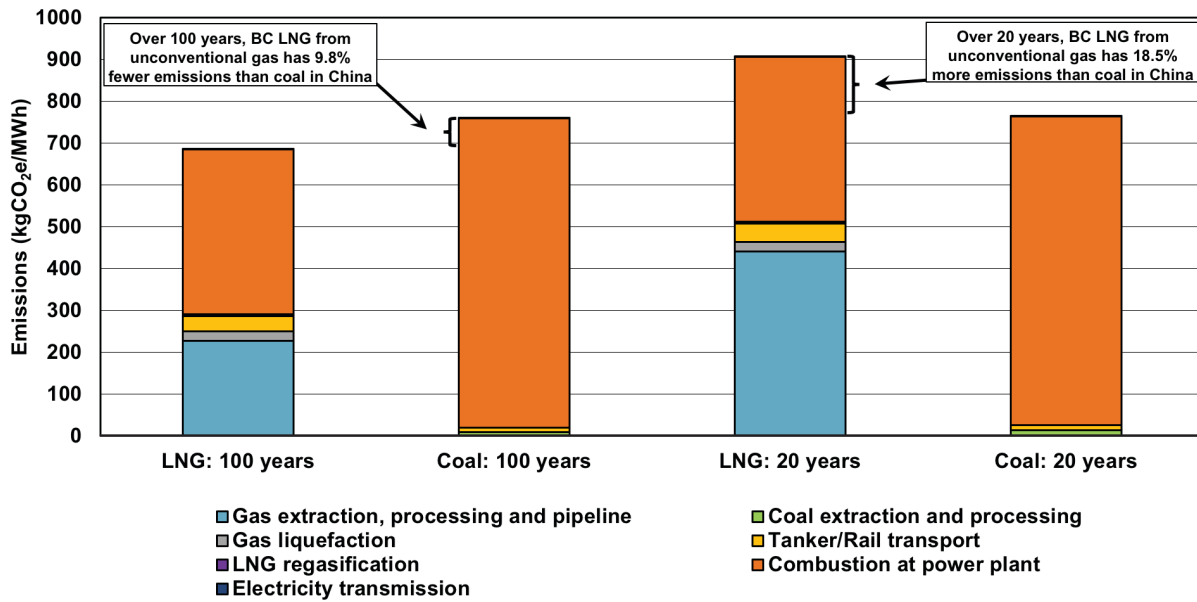
Note: Other assumptions are noted in text.

Figure 22 illustrates the BC LNG versus coal comparison of Table 9, which assumes fugitive methane emissions of 3.3 per cent for the production, processing and transport of unconventional gas upstream of the LNG terminal. (Note that Tables 8 and 9 and Figures 20 to 22 are conservative, as the upstream emissions of gas produced and burned at the terminal—which amounts to 6 per cent of the LNG shipped—have not been included in the totals.) This optimistically allows for potential further decreases in upstream emissions, which may or may not happen. If there are no decreases, that would make these tables and figures overly optimistic for not including the additional 6 per cent in emissions, and BC LNG would be even worse than depicted.

⁵⁶ Howarth, "Bridge to Nowhere."

Clearly, the narrative of industry and government that BC LNG will reduce global emissions from coal in Asia is based on 100-year estimates of the GWP of methane. However, BC LNG will make global greenhouse gas emissions and climate change considerably worse over the critical next few decades if the 20-year GWP of methane is considered.

Figure 22: Comparison of BC LNG for power generation in China with best-technology coal, assuming fugitive methane emissions of 3.3 per cent.



Sources: Data about emissions from LNG terminals from Environmental Assessment Office, *LNG Canada Export Terminal Project Assessment Report* (Victoria, BC: Environmental Assessment Office, 2015); and data about pipeline and ocean voyage distances (modified) from National Energy Technology Laboratory, *Life Cycle Greenhouse Gas Perspective on Exporting Liquefied Natural Gas from the United States* (Washington, DC: US Department of Energy, 2014).

Are LNG exports economically viable?

The landed price of LNG in Asia just prior to the coronavirus pandemic was between US\$3.90 and US\$5.42 per million BTU, far below the break-even price of BC LNG, even with more government incentives.

THE COST OF LIQUEFYING CANADIAN NATURAL GAS AND SHIPPING IT TO ASIA has been estimated at between US\$8.99⁵⁷ and US\$10.00⁵⁸ per million BTU. To break even, the lower price would require an \$80-per-barrel Brent oil price for long-term oil-linked contracts (whereas CER's forecast projects Brent prices at or below \$75 through 2040). The Canadian Energy Research Institute suggested that, with additional government incentives and scale, the landed price of Western Canadian LNG in Asia (the cost of production, liquefaction and shipping) could perhaps be reduced to US\$7.55 per million BTU,⁵⁹ which would require a Brent oil price of \$65.

Meanwhile, the landed price of LNG in Asia just prior to the coronavirus pandemic was between US\$3.90 and US\$5.42 per million BTU, far below the break-even price of BC LNG, even with more government incentives.⁶⁰ (Current prices in Asia are less than US\$2.00 due to the pandemic.) Although the first phase of LNG Canada will not be completed until 2025 and the company is doubtless counting on much higher prices by then, there are more LNG projects under construction around the world, and there is currently a global LNG glut.⁶¹ Furthermore, Russia has just completed a massive pipeline to China, which will reach full capacity in 2025, just as LNG Canada comes on stream.⁶² In summary, at current and medium-term projected landed LNG

57 Canadian Energy Research Institute, *Competitive Analysis of Canadian LNG* (Calgary, AB: Canadian Energy Research Institute, 2018), https://ceri.ca/assets/files/Study_172_Full_Report.pdf.

58 Howard Rogers, *The LNG Shipping Forecast: Costs Rebounding, Outlook Uncertain* (Oxford, UK: Oxford Institute for Energy Studies, 2018), <https://www.oxfordenergy.org/wpcms/wp-content/uploads/2018/02/The-LNG-Shipping-Forecast-costs-rebounding-outlook-uncertain-Insight-27.pdf>, figure 12.

59 Canadian Energy Research Institute, *Competitive Analysis*.

60 Jessica Jaganathan, "Update 2: Asian LNG Spot Prices Drop to Multi-year Lows Below \$4/mmBtu," *Reuters*, January 21, 2020, <https://www.reuters.com/article/asia-lng-prices/update-2-asian-lng-spot-prices-drop-to-multi-year-lows-below-4-mmbtu-idUSL4N29Q2RX>. See also Federal Energy Regulatory Commission, World Estimated LNG Landed Prices: Dec-2019, <https://www.ferc.gov/market-assessments/mkt-gas/overview/ngas-ovr-lng-wld-pr-est.pdf>.

61 Naureen S. Malik and Anna Shiryaevskaya, "Has a Global LNG Glut Forced the U.S. to Become the Swing Producer?" *World Oil*, November 25, 2019, <https://www.worldoil.com/news/2019/11/25/has-a-global-lng-glut-forced-the-us-to-become-the-swing-producer>.

62 Victor Ferreira, "While Canada Hesitates, Russia Builds 3,000 km Gas Pipeline to China in Just Five Years," *Financial Post*, December 3, 2019, <https://business.financialpost.com/commodities/while-canada-hesitates-russia-builds-3000-km-gas-pipeline-to-china-in-just-five-years>.

prices, BC LNG exports don't make any economic sense. Landed LNG prices in Asia would have to increase dramatically for Canadian LNG exports to be profitable.

In addition to the questionable economics, the BC and federal governments have announced a series of incentives and tax deductions that will mean substantially less revenue for Canadians from LNG exports even if they proved economically viable. These include:

- A \$275 million contribution for LNG Canada infrastructure by the federal government.⁶³
- \$375 million from the federal government in foregone revenue from waived import tariffs on steel imported from China for the LNG Canada terminal.⁶⁴
- A BC government initiative to provide discounted electricity prices (at a cost of \$32 million to \$59 million per year).⁶⁵
- Exemptions from increases in the carbon tax (at a cost of \$62 million per year).
- A discounted corporate income tax rate (reduced from 12 per cent to 9 per cent).⁶⁶
- A deferral of provincial sales tax on construction (at a cost of \$21 million per year).⁶⁷

63 "Feds Announce \$275M for 'Largest Private Sector Investment in Canadian History' — Kitimat, B.C.'s LNG Project," *CBC News*, June 24, 2019, <https://www.cbc.ca/news/canada/british-columbia/275m-federal-government-lng-canada-kitimat-1.4649654>.

64 Canadian Institute of Steel Construction, "The Liberal Government Hands \$42 Billion in Construction Projects to China at Expense of Canadians," news release, *GlobeNewswire*, August 19, 2019, <https://www.globenewswire.com/news-release/2019/08/20/1904294/0/en/The-Liberal-Government-Hands-42-Billion-in-Construction-Projects-to-China-at-Expense-of-Canadians.html>.

65 Marc Lee, *A Critical Look at BC's New Tax Breaks and Subsidies for LNG* (Vancouver, BC: Canadian Centre for Policy Alternatives–BC Office, 2019), <https://www.policyalternatives.ca/newsroom/updates/critical-look-bc%E2%80%99s-new-tax-breaks-and-subsidies-lng>.

66 Ibid.

67 Ibid.

What about jobs and revenue for health care and schools?

The history of government revenue generated by natural gas production has been one of declining revenue from taxes, royalties and land sales, even though production is at record levels.

ONE OF THE BC GOVERNMENT'S PURPORTED BENEFITS OF LNG CANADA is "up to 10,000 jobs for people during construction and 950 permanent jobs."⁶⁸ Although LNG Canada and Woodfibre LNG will together provide several thousand jobs during their construction phases, permanent jobs at LNG Canada are estimated at only 350-550 by the company when both phases are complete, with perhaps 100 permanent jobs at Woodfibre LNG.

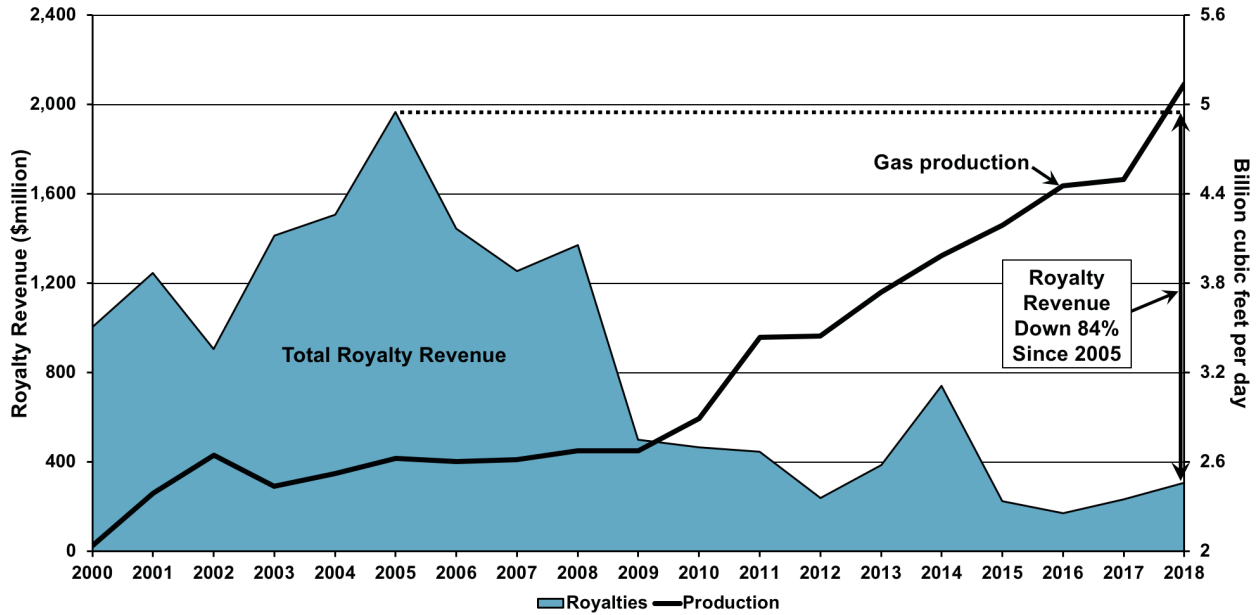
Another of the BC government's purported benefits of LNG exports is the provision of "new resources for health care, schools, child care and other government-supported services."⁶⁹ In fact, the history of government revenue generated by natural gas production has been one of declining revenue from taxes, royalties and land sales, even though production is at record levels. Figure 23 illustrates royalty revenue from natural gas sales over the last two decades. Even though production has doubled since 2005, total royalty revenue is down 84 per cent. In 2005, royalties paid constituted 21.7 per cent of the sales price, whereas in 2018 royalties constituted just 5 per cent. In 2005, the BC government received \$2.05 in royalties for each thousand cubic feet of gas sold. In 2018, the government received just 16 cents.

Given all of the government incentives for LNG exports noted above, along with the history of declining revenues to government from expanded gas production, the claim that LNG exports will provide a windfall to fund vital government services is highly questionable.

68 "LNG Canada," LNG Projects, Farming, Natural Resources & Industry, Government of BC, accessed January 2020, <https://www2.gov.bc.ca/gov/content/industry/natural-gas-oil/lng/lng-projects/lng-canada>.

69 Ibid.

Figure 23: BC gas production and total royalty revenue paid on BC natural gas sales, 2000–2018.



Sources: Data from Canadian Association of Petroleum Producers’ Statistical Handbook (accessed February 2020); and Canada Energy Regulator (accessed October 22, 2019).

Conclusion

Natural gas is a finite, non-renewable resource, and Canada is a well-explored petroleum region. Despite government claims that unproven resources are vast, the three 40-year LNG export licences already approved will alone exceed current proven Canadian gas reserves by 30 per cent if the approved volumes are exported.

THERE ARE SERIOUS QUESTIONS AND CONSIDERATIONS surrounding the current enthusiasm for developing a Canadian LNG export industry:

- Canada currently produces much more gas than it consumes domestically, although because of geography, Eastern Canada is a net importer from the US and Western Canada is a net exporter to the US.
- Despite a desire to eventually eliminate fossil fuels and become net zero on emissions, Canada, being a northern country, is likely to need natural gas at some level for the foreseeable future.
- Natural gas is a finite, non-renewable resource, and Canada is a well-explored petroleum region. Despite government claims that unproven resources are vast, the three 40-year LNG export licences already approved will alone exceed current proven Canadian gas reserves by 30 per cent if the approved volumes are exported. Although more drilling is likely to prove additional reserves, government estimates of unproven resources have been inflated drastically in recent years, and there have been no economic analyses to prove that these purported resources are economically viable.
- Industry always targets the lowest-cost resources first. According to CER's forecasted production, LNG exports will come primarily from low-cost reserves in the Montney of British Columbia. Exhausting the lowest-cost reserves for exports means that Canadians will pay higher prices for gas from more remote, higher-cost resources in the future.
- There is no free lunch when it comes to developing energy resources. The Blueberry River First Nation, whose lands overlie much of the BC Montney deposit (which will be the source of most of the LNG exports), has already filed lawsuits about the size of the existing oil and gas industry footprint. The current footprint of well pads, roads, pipelines and other infrastructure is, however, a mere 5.1 per cent of the Montney area. Even without LNG exports, the Montney footprint will be increased to 8 per cent by 2040, according to CER's forecasted production, and 12.7 per cent by 2070. With the three 40-year export licences already approved, the footprint would be quadrupled from current levels to 19.3 per cent by the time they expire in 2070. Meeting CER's forecasted production, along with the requirements of LNG exports, would require the addition of 42,745 new wells by 2070 (more than doubling the 28,569 wells that have been drilled since the 1940s).

- Perhaps the most serious problem with LNG exports is the emissions created in producing and liquefying the gas. The CleanBC plan requires an 80 per cent reduction in emissions by 2050 from 2007 levels, and the federal government has claimed Canada will be “net zero” by 2050. Even without LNG exports, and assuming a 15 per cent reduction in emissions through reduced fugitive methane and through electrification, emissions from oil and gas production would exceed BC’s 2050 target by 54 per cent given CER’s forecast—and that is if all other sectors of BC’s economy reached zero emissions by 2045. LNG Canada would add a total of 13.0 megatonnes per year, including the company’s estimate of 3.96 megatonnes from the terminal itself. With LNG Canada, emissions from oil and gas production alone would exceed BC’s 2050 target by 160 per cent, even if emissions from the rest of the economy were reduced to zero by 2035. If Kitimat LNG and Woodfibre LNG were also built, total LNG production emissions would amount to 22.6 megatonnes and BC’s 2050 target would be exceeded by 227 per cent, even if all other sectors of BC’s economy reached zero emissions by 2031.
- The industry and government narrative that BC LNG exports will reduce emissions from coal in China is not credible if the much higher potency of methane as a greenhouse gas over 20 years is considered. BC LNG exports will increase emissions compared with best-technology coal in China by up to 18 per cent over the next few decades, which is a very critical period in addressing the global warming problem.
- LNG export projects in BC are not economic at current Asian prices according to studies by Canadian Energy Research Institute and the Oxford Institute for Energy Studies. The prospect of much higher prices in 2025 when Canada’s first terminal comes online are highly uncertain, given other LNG projects under development around the world, the current global LNG glut, and lower-cost pipeline-based supply being developed in Asia.
- Despite the doubling of gas production in BC since 2005, total royalty revenue has declined by 84 per cent. Although increasing gas production may increase government revenues somewhat, this decline in royalty revenue, along with the other taxpayer-funded incentives to spur LNG exports, represents a giveaway of finite, non-renewable resources that Canadians will need at some level in the future. Permanent jobs that will be created by LNG Canada are, according to the company, just half of the 950 estimated by government.

No amount of wishful thinking can overcome the math on the emissions generated by increased oil and gas production and the proposed LNG exports.

Government narratives have stated that reducing Canada’s emissions and expanding oil and gas production go hand in hand. Unfortunately, no amount of wishful thinking can overcome the math on the emissions generated by increased oil and gas production and the proposed LNG exports. Nor can wishful thinking overcome the impacts on the land surface by the increase in well pads, roads, pipelines and other infrastructure that comes with increased production.

As outlined earlier, Canada’s practice of ramping up oil and gas production in the hope of financial gain is not a credible plan to meet the long-term energy needs and emissions-reduction goals of its citizens.⁷⁰

The projections of BC greenhouse gas emissions in this report are conservative, as they incorporate the older estimates of the 100-year global warming potential of methane used by Canada in its emissions submission to the United Nations. The projections also assume that

⁷⁰ J. David Hughes, *Canada’s Energy Outlook: Current Realities and Implications for a Carbon-Constrained Future* (Vancouver, BC: Canadian Centre for Policy Alternatives–BC Office, 2018), <https://www.policyalternatives.ca/energy-outlook>.

initiatives to reduce fugitive methane and electrify gas production will reduce emissions further in the future. Even so, they demonstrate that growing oil and gas production is completely incompatible with achieving promised emissions reduction targets. Growth in oil and gas production for export is also incompatible with the long-term energy security of Canadians at affordable prices, and the desire of First Nations to protect the environmental integrity of their lands. Canada needs a viable energy strategy to address these issues and to have any hope of meeting its emissions-reduction targets.



This report is part of the Corporate Mapping Project (CMP), a research and public engagement initiative investigating the power of the fossil fuel industry. The CMP is jointly led by the University of Victoria, Canadian Centre for Policy Alternatives BC and Saskatchewan Offices, and Parkland Institute. The initiative is a partnership of academic and community-based researchers and advisors who share a commitment to advancing reliable knowledge that supports citizen action and transparent public policy making. This research was supported by the Social Sciences and Humanities Research Council of Canada (SSHRC).

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