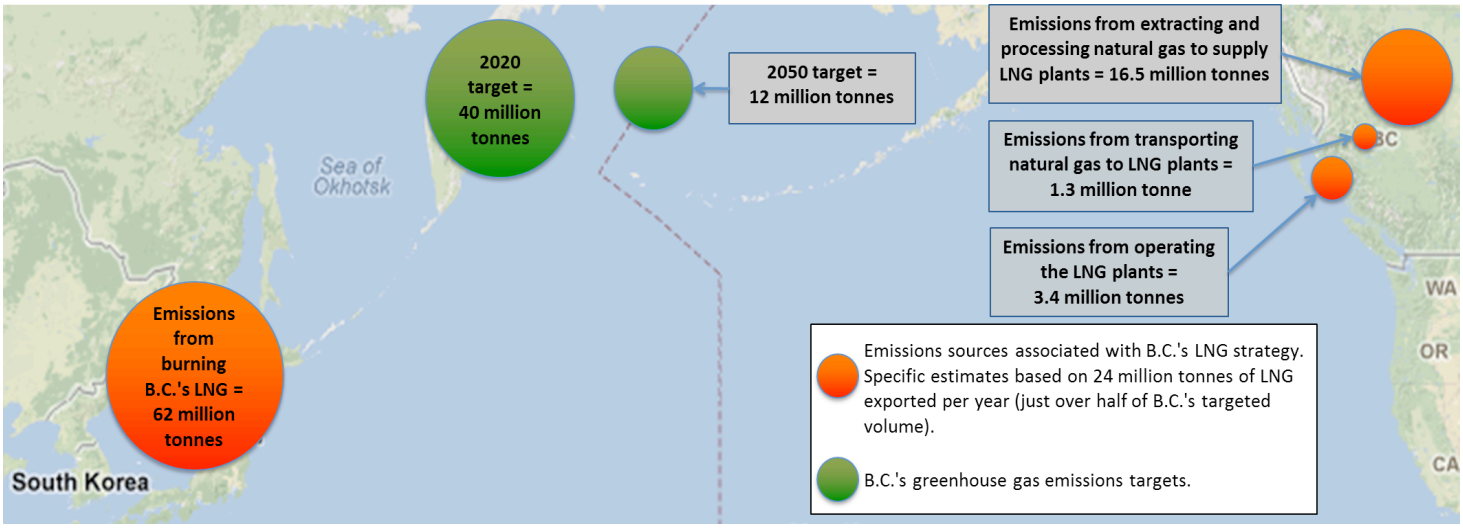
PEMBINA institute

BC LNG Proposals and GHG Emissions

With an increasing number of LNG projects being announced on B.C.'s coast, it is important to balance the economic arguments of these announcements with the associated risks. The emissions from LNG projects and the impact to B.C.'s climate targets are still unclear, but based on initial modeling done by the Pembina Institute using projected volumes of LNG, it is clear that even modest development will have a material impact to the overall emissions in the province. Three questions are addressed in this memo to provide context to the LNG debate and attempt to quantify the impacts based on currently available information.

The sources of emissions associated with LNG production and consumption are geographically dispersed. In order to get the full picture, we must look at the entire life cycle of the product. The figure below provides a representative picture of what the life cycle emissions from the LNG sector would look like if 24 million tonnes of LNG are exported annually. This is equivalent to just over half of B.C.'s targeted volume for export.



What does LNG mean for B.C.'s GHG reduction targets?

Extracting, processing, transporting and liquefying natural gas are all energy intensive processes that release greenhouse gases. These greenhouse gas emissions will all increase if LNG proceeds in B.C., and they will likely make achieving B.C.'s legislated GHG reduction targets impossible.

The government of B.C.'s Natural Gas Strategy outlines strategies for the expansion and development of natural gas and LNG[1] industries in the province while maintaining a commitment to meet the legislated greenhouse gas reduction targets of a 33% decrease from 2007 levels by

[1] http://www.gov.bc.ca/ener/natural_gas_strategy.html

2020 and 80% by 2050[2]. The government has also released a natural gas strategy update that summarizes the work done to date in this sector[3]. It is still unclear how many LNG terminals will get built and over what time frame, but meeting the GHG reduction targets will be very implausible[4] if even a few of the proposed LNG facilities are built.

The greenhouse gas emissions from LNG in B.C. will depend on the pace and scale of shale gas development which will supply gas to the LNG terminal; the sources of power for the refrigeration and compression requirements; the deployment of carbon capture and storage; and the actual methane leakage rates[5] throughout the natural gas supply chain. Assuming natural gas is the primary energy source for the LNG terminals and no carbon capture and sequestration (CCS) projects are implemented, estimates of the emissions from exporting LNG can be made based on the volumes of LNG production. The Pembina Institute has created a model to evaluate emission from LNG development and the following estimates are based on the results from this model.

An estimate of 24 million tonnes of LNG per year (equivalent to the initial phases of the Petronas[6] and Shell[7] proposals) would produce 21 million tonnes of GHGs per year — equivalent to 44% of the province's total targeted emissions for 2020. Based on B.C. government analysis, Pembina has created two additional production scenarios of 82 (equivalent to five operating facilities) and 120 million tonnes LNG per year. It is worth noting that, based on several conversations with industry, not many individuals outside of government consider these levels of development as likely. They are included here as they continue to be the scenarios referenced by the government and there are no other substantial scenarios being discussed. The model includes the upstream emissions associated with producing the natural gas, plus emissions from pipeline transportation and the liquefaction of the gas. Emissions associated with the transport of the LNG and the end use combustion are not included. As such, the numbers below are representative of the domestic GHGs emissions alone. These production scenarios are shown in the following figure.

[2] http://www.leg.bc.ca/38th3rd/1st_read/gov44-1.htm

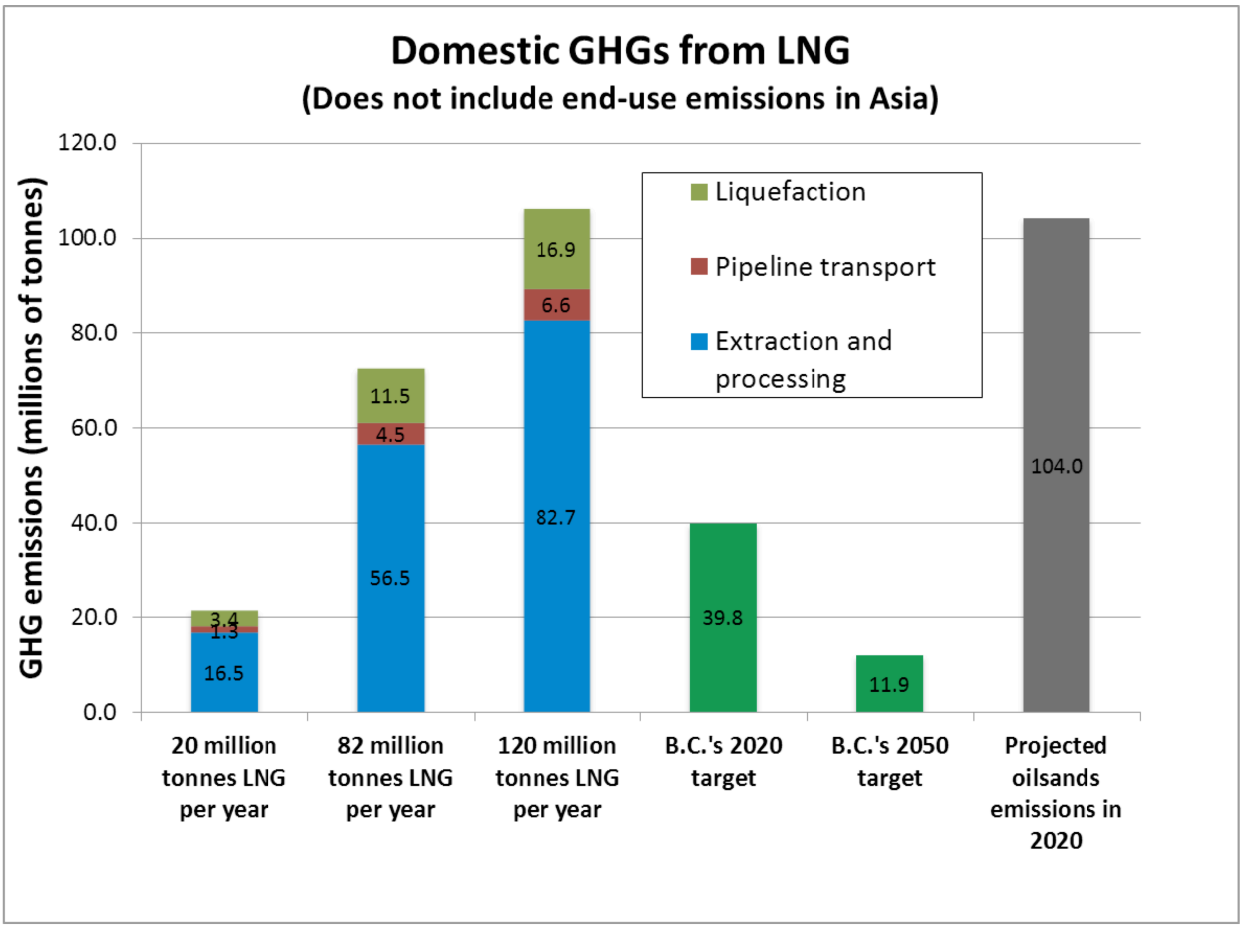
[3] http://www.gov.bc.ca/com/attachments/LNGreport_update2013_web130207.pdf

[4] While there is a scenario — featuring low levels of LNG production that draw from existing B.C. gas production with aggressive GHG mitigation — that could still allow B.C. to meet its target, this is well outside the scale of development and level of GHG control currently being contemplated.

[5] http://www.nature.com/news/methane-leaks-erode-green-credentials-of-natural-gas-1.12123#auth-1

[6] 12 million tonnes — http://pacificnorthwestlng.com/

[7] 12 million tonnes — http://lngcanada.ca/



The scenarios of 82 and 120 million tonnes of LNG production exceed all of B.C.'s climate reduction targets and a reference to the projected oilsands growth from Alberta is provided for comparison.

Improvements can be made in several areas to reduce the overall domestic GHG emissions from B.C. operations. For example, formation CO_2 that is currently vented to the atmosphere during processing in the Horn River could be captured and sequestered. The Spectra Energy Fort Nelson Gas Plant has conducted a feasibility assessment of a carbon capture project which could reduce GHG emissions by 2.2 million tonnes per year.[8] Eliminating venting and flaring during fracking, also known as 'green completions,' is estimated in the U.S. to reduce methane emissions by 26%[9] when fully implemented under EPA regulations. No jurisdiction in Canada is planning on requiring green completions.

Another option is using renewable energy to power the LNG refrigeration and compression requirements. This was originally planned for the first two LNG facilities, but is no longer the likely option because of concerns about higher costs and the challenge of ensuring adequate supplies of electricity by the end of the decade. The LNG facilities will now be permitted to use natural gas to power operations[10]. The feasibility of a grid-connected LNG terminal is remote as the capacity currently does not exist to support the terminal's substantial power demands.

[8] http://www.cslforum.org/publications/documents/Edmonton2011/Laundry-TG-FortNerlsonProjectOverview-Edmonton0511.pdf

[9] http://www.epa.gov/airquality/oilandgas/pdfs/20110728factsheet.pdf

While technology option exist to eliminate or capture the vast majority of sources, these all have costs associated with them, and only a portion could be implemented without having a material impact on the competiveness of B.C. LNG. As a result, any significant LNG development in B.C. will be accompanied by a significant increase in GHGs that will make achieving B.C.'s targets impossible.

How does B.C. LNG compare with the energy sources it would displace from a life cycle perspective?

Natural gas and LNG are often trumpeted as the cleanest of the fossil fuels, and a climate benefit when compared to coal. There are also claims that, when the full life cycle of GHGs is accounted for, natural gas is not as 'clean' as proponents argue and it may be more greenhouse gas intensive than coal. If LNG is significantly cleaner than coal, there is a potentially valid argument that exporting it from B.C. is in the climate's interests. If LNG is not significantly cleaner than coal, that potential argument disappears.

Greenhouse gases from LNG and the associated shale gas development must be compared against other energy sources for similar end use to determine if they will help to reduce greenhouse gas emissions, both in the present and for future development. Combustion and formation emissions from shale gas development are well understood and monitored in B.C. Based on the reported emissions from combustion and formation emissions, natural gas is less GHG-intensive than coal on a life cycle basis.

On a life cycle basis, fugitive and methane venting sources associated with shale gas development are not well understood and there is uncertainty over the actual volume of methane releases. Another area of uncertainty in the analysis is the disagreement over the appropriate time frame to analyze the GHGs. For example, the 20 year global warming potential of methane is 72, which means that if the same mass of methane and carbon dioxide were introduced into the atmosphere, that methane will trap 72 times more heat than the carbon dioxide over the next 20 years. If the same comparison is done over a 100 year time frame, methane has a GWP of 25.[11]

A controversial study published in April 2011 led by Cornell University Professor Robert Howarth concluded that emissions from shale gas were 30–100% higher than conventional gas, and 20–100% higher than coal over a 20-year time frame, but comparable to coal on a 100-year frame, based on analysis per unit of energy.[12] There have been many other studies conducted that offer differing perspectives. NETL scientist Timothy Skone presented a lecture at Cornell that suggested that natural gas has 48% lower GHG emissions than coal on a 20-year time frame

[10] http://www.theglobeandmail.com/news/british-columbia/bc-liberals-declare-natural-gas-a-clean-energy-source/article4362331/

See last page: http://www.gov.bc.ca/com/attachments/LNGreport_update2013_web130207.pdf

[11] http://www.ipcc.ch/publications_and_data/ar4/wg1/en/tssts-2-5.html

[12] R. Howarth, R. Santoro and A. Ingraffea, "Methane and the greenhouse-gas footprint of natural gas from shale formations." Letter, *Climatic Change* 106 (2011). http://www.springerlink.com/content/e384226wr4160653/

basis.[13] Discrepancies surrounding the methane leakage rates of natural gas operations are a main point of contention in these reports and are still actively being studied in the U.S.[14]

There are currently no peer reviewed life cycle assessments published on the B.C.-specific situation that combines shale gas extraction and LNG production; however, there are studies looking at other case studies around the world. Jiang et al. found that life cycle emissions from Marcellus shale are comparable to those of imported liquefied natural gas and 20–50% lower than coal for production of electricity in the U.S. using a 100-year time frame.[15] The Australia Pacific LNG Project claims that the life cycle GHG emissions from their activities are 43% less than coal per GJ of energy delivered.[16]

While many observers are uncomfortable declaring the issue closed, many are now skeptical of the estimates at the higher end of the spectrum and seem to be expecting that the numbers for B.C. operations will settle towards the lower end of spectrum relative to other jurisdictions.

While there are no peer-reviewed studies[17] of B.C. emissions from the natural gas sector, B.C. facilities are required to report emissions annually. The emissions from the oil and gas sector are presented in a table in the Appendix.

The fugitive emissions category includes the methane leakage that occurs throughout natural gas processes; it makes up 9.6% of the total emissions for this sector. From what we have heard this is most likely at the lower end of the range compared to other jurisdictions. This data is primarily based on modeling and generally does not include field-based measurement to verify the accuracy of these numbers and confirm which rates should be used in the analysis. Efforts are currently underway in the U.S. to further study this issue.[18]

The argument that the exported LNG will displace a more GHG-intensive fuel source such as coal hinges on the outcome of such a study as well as the assumption that the LNG will truly displace other fuel sources and not be used to generate additional capacity.

How much warming is expected for the planet if there is a significant increase in the global LNG market?

Even if the evidence finds that B.C. LNG is significantly cleaner than coal, the evidence we were able to find concludes that B.C. export of LNG should not be characterized as a climate solution.

First, it is not clear that LNG would displace more carbon-intensive fossil fuels. Korea, Japan and China are the most likely export destinations and the role that LNG will play in those countries is not yet clear. Exports to China could certainly reduce coal use, but the situation is different in Korea and Japan. The David Suzuki Foundation (DSF) conducted a scenario

[13] T. Skone, NETL, “Life Cycle Greenhouse Gas Analysis of Natural Gas Extraction & Delivery in the United States,” presented to the Cornell University lecture series on unconventional natural gas development, May 12, 2012. http://www.netl.doe.gov/energy-analyses/refshelf/PubDetails.aspx?Action=View&PubId=386

[14] http://fuelfix.com/blog/2013/04/28/epa-lowered-estimates-of-methane-leaks-during-natural-gas-production/

[15] M. Jiang, et al., “Life cycle greenhouse gas emissions of Marcellus shale gas,” *Environmental Research Letters* 6 (2011). doi:10.1088/1748-9326/6/3/034014

[16] http://www.aplng.com.au/eis

[17] Pembina released a study that was informally reviewed by industry and government: http://www.pembina.org/pub/2264

[18] http://www.engr.utexas.edu/news/7416-allenemissionsstudy

analysis exploring B.C.'s LNG exports on Japanese emissions. Each scenario considers Japan either completely or partially using LNG for its energy. For Japan to reduce net emissions it would need to displace all existing coal electrical capacity.[19] The DSF analysis found that under all three scenarios, GHG emissions increase from the 2010 baseline. For the second scenario (all nuclear replaced with LNG), emissions go up 123 million tonnes from the baseline. The third scenario (50% restored nuclear, oil and coal generating facilities replaced with B.C. LNG) leads to a 5 million tonne increase from baseline.

Second, while natural gas may be cleaner than coal, it is still a significant source of GHGs that will contribute to climate change. The IEA's recent report *Golden Rules for a Golden Age of Gas*[20] found that a major shift to gas will lead to a 3.5°C increase in global temperature in the long-term. The 3.5°C was less warming than would have occurred absent low-cost gas reserves, but it is much higher than the 2°C global target.

Blok et al. have looked at the gap between current emission trends and what is necessary to put the world on a path that would limit a global temperature increase to 2°C above pre-industrial levels by 2020 (a gap of approximately 12 Gt CO_2e between business-as-usual development and sustainable pathways). They propose 21 major initiatives that can "wedge the gap" to trigger GHG emission reductions of around 10 Gt CO_2e by 2020.[21] None of their 21 initiatives include expansion of liquefied natural gas (LNG) as a viable option.

Finally, the potential for LNG to have a beneficial impact on the global climate can only be realized if there are climate policies in place to guide the extraction, processing, liquefaction and end use of the gas. Stronger climate change policies will mean an incentive for renewables to be more of the energy mix (rather than just a coal-to-gas shift) and an incentive for gas to be used more efficiently. Without climate policies on both the production and end use side of the supply chain, it is difficult to ensure that the LNG would be beneficial from a climate perspective. At this point all evidence suggests that we are on track for 3.5°C warming and that LNG will not play a meaningful role in mitigating GHG emissions.

Consequences of climate change for B.C.

The consequences of 3.5°C warming could be catastrophic. Over the past 30 years alone there have been more extreme weather events including temperature extremes, wildfires, droughts, floods and storms — the overall loss trend is beginning to exceed $150 billion per year.[22] According to the B.C. Ministry of Environment, the impacts of a 2-5°C increase in average annual temperature this century would result in reduced water supply due to glacial retreat in the south, reduced winter snow pack and earlier snowmelt; increased stress on species at risk; and increased river temperatures and stress on salmon. Climate change has already had a severe impact on the province's forestry sector as the mountain pine beetle has attacked 18.1 million hectares of B.C.'s forests and killed an estimated 710 million cubic metres of

[19] T. Bryant and R Kadowaki, "Would exporting B.C. LNG reduce global greenhouse gas emissions?" *David Suzuki Foundation*, blog July 17, 2012. http://davidsuzuki.org/blogs/panther-lounge/2012/07/would-exporting-bc-lng-reduce-global-greenhouse-gas-emissions/

[20] International Energy Agency. (2012). Golden Rules for a Golden Age of Gas. Available online: http://www.worldenergyoutlook.org/media/weowebsite/2012/goldenrules/WEO2012_GoldenRulesReport.pdf

[21] Blok et al. (2012). Bridging the greenhouse‐gas emissions gap. Nature Climate Change, 2, 471‐474.

[22] S. Chu and A. Majumdar, "Opportunities and challenges for a sustainable energy future," *Nature* 488 (2012) .

commercially valuable pine.[23] Climate change has been the major driver of this outbreak because winters have not seen the sustained cold temperatures needed to kill the beetles.

[23] https://www.for.gov.bc.ca/hfp/mountain_pine_beetle/Pine%20Beetle%20Response%20Brief%20History%20May%2023%202012.pdf

Appendix

Proposed LNG Projects

Project	Initial production (MT of LNG/year)	Potential capacity (MT of LNG /year)
Douglas Channel[a]	0.7	0.9
LNG Canada (Shell)[b]	12	24
Kitimat LNG[c]	5	10
Petronas[d]	12	18
BG Group PLC[e]	14	18
Total	**43.3**	**70.9**

[a] http://www.douglaschannelenergy.com/project-description.htm
[b] http://lngcanada.ca/our-business/project-overview/ and http://www.reuters.com/article/2012/07/27/shell-canada-lng-idUSL2E8IRCC720120727
[c] http://www.kitimatlngfacility.com/
[d] http://www.theglobeandmail.com/report-on-business/industry-news/energy-and-resources/petronas-to-sweeten-payoff-if-ottawa-okays-progress-deal/article5954680/
[e] http://www.theglobeandmail.com/report-on-business/industry-news/energy-and-resources/bc-lng-plans-at-crossroads-after-petronas-progress-deal-blocked/article4627080/

Emission sources from the oil and gas sector in B.C.

Emission Source	Category	Total	Percent
Stationary Combustion: Natural Gas	Stationary Combustion	5,060,500	49.0
Stationary Combustion: Other Fuels	Stationary Combustion	276,100	2.7
Electricity Generation	Electricity generation	150,600	1.5
Well Testing Flares	Flaring	139,500	1.4
Associated Gas Flares	Flaring	35,200	0.3
Flare Stacks	Flaring	362,700	3.5
Continuous High Bleed Device Vents	Venting	311,100	3.0
Pneumatic Pump Vents	Venting	173,700	1.7
Continuous Low Bleed and Intermittent Device Vents	Venting	68,900	0.7
Acid Gas Removal	Venting	2,408,000	23.3
Dehydrator Vents	Venting	97,100	0.9
Well Venting for Liquids Unloading	Venting	6,200	0.1
Well Venting, with or Without Hydraulic Fracturing	Venting	4,100	0.0
Blowdown Vent Stacks	Venting	58,900	0.6
Well Testing Venting	Venting	1,100	0.0
Associated Gas Venting	Venting	730	0.0
Centrifugal Compressor Vents	Venting	102,000	1.0

Reciprocating Compressor Vents	Venting	52,400	0.5
EOR Injection Pump Blowdowns	Venting	-	-
Other Venting Sources	Venting	40,900	0.4
Storage Tanks	Fugitive	16,900	0.2
Gathering Pipeline Equipment Leaks	Fugitive	156,500	1.5
Equipment Leaks from Valves, Connectors, etc.	Fugitive	784,300	7.6
Above-Ground Meters/Regulators at Gate Stations	Fugitive	5,900	0.1
Below-Ground Meters/Regulators/Valves	Fugitive	8,500	0.1
Other Fugitive Sources	Fugitive	9,400	0.1
Wastewater processing	Wastewater	17	0.0
TOTAL		**10,331,500**	**100**

Source: B.C. Ministry of Environment[24]

[24] http://www.env.gov.bc.ca/cas/mitigation/ggrcta/reporting-regulation/emissions-reports.html