AIR ADVISORY:
The Air Quality Impacts of Liquefied Natural Gas operations Proposed for Kitimat B.C.

SkeenaWild
CONSERVATION TRUST

Air Advisory:
The Air Quality Impacts of Liquefied Natural Gas operations Proposed for Kitimat B.C.

November 21, 2013

Prepared by Greg Knox

For SkeenaWild Conservation Trust

Cover photo: Current air emissions in Kitimat BC, August 2013. Lis Stanus.

SkeenaWild Conservation Trust is a regionally based organization. We are dedicated to bringing together governments, First Nations and members of the public in the Skeena Watershed to sustain the long-term health and resilience of the wild salmon ecosystem, while optimizing economic returns to First Nations and local communities

www.skeenawild.org

TABLE OF CONTENTS

EXECUTIVE SUMMARY

For the past two years, the Government of British Columbia has stated that the fuel produced by its proposed liquefied natural gas (LNG) industry will be "the cleanest in the world." A recent study (Glave/Moorhouse, 2013) investigated the carbon-pollution implications of this claim. That report concluded that without provincial policy leadership, an off-the-shelf British Columbia LNG plant would produce fuel with a carbon footprint three times greater than the world's current lowest-carbon LNG.

THE PLANTS WILL PLACE AN ENORMOUS BURDEN ON THE LOCAL AIRSHED AND ARE UNLIKELY TO LIKELY MEET A GLOBAL STANDARD FOR AIR QUALITY

Since that report's release in late September 2013, the BC government has signaled that it will allow future LNG plants—including the three proposed for the coastal city of Kitimat, B.C.—to burn natural gas to power the compressors at the heart of the LNG production process (called "direct drive"). The province has also since attempted to narrow the definition of "cleanest LNG in the world" to address only the operations of the LNG plants themselves and not the full carbon footprint of the fuel it produces, from wellhead to waterline, as previously promised.

However, even if the definition of "cleanest LNG" begins and ends at an LNG plant's fence line in Kitimat, as proposed, the plants will place an enormous burden on the region's airshed and are unlikely to meet any reasonable and objective global gold standard for air quality.

This report quantifies the air quality impacts of the three LNG facilities currently proposed for Kitimat, assuming the proponents proceed with their preferred direct-drive technology. Plants built with this direct-drive configuration burn natural gas to produce the energy necessary to compress, chill, and liquefy the incoming natural gas so it can be loaded aboard specialized tankers for export. Vast quantities of natural gas will be burned under these current proposals.

This paper also suggests strategies and solutions that would reduce the contaminants associated with direct-drive LNG production. Such strategies are already in use elsewhere in the world.

FINDINGS:

Assuming the three plants proposed for Kitimat use direct-drive technology as proposed—and as tacitly endorsed by the BC government—the volume of natural gas they would burn each year would be two and a half times greater than the volume burned annually in all of Metro Vancouver. Put another way, the three plants would collectively burn, in a confined airshed, the equivalent of 60 percent of all the natural gas currently burned in the entire province of B.C. every year (National Energy Board, 2004).

Though natural gas is often (correctly) described as the "cleanest-burning" petroleum fuel source, the sheer quantity of the fuel burned under the Kitimat proposals would drastically elevate air contaminants in the region.

Chief among these increased pollutants is nitrogen oxide (NOx) pollution. Nitrogen oxide emissions adversely affect human and animal respiratory systems and, when combined with water vapor, cause acid rain. As an organization that works to protect salmon habitat, the potential acidification of our waterways is cause for concern. These compounds also help contribute to ground level ozone (smog), and particulate matter, which also causes respiratory issues, particularly in vulnerable populations such as small children and the elderly. **If the three proposed plants were built, we estimate nitrogen oxide emissions would soar 500 percent above existing levels.**

If running on direct-drive compressors as proposed, the three plants would also emit a range of other contaminants. Volatile organic compounds (VOCs) would rise by 35 percent, particulate matter (PM) would increase 24 percent, carbon monoxide (CO) emissions would rise 10 percent, and sulphur dioxide (SOx) would increase seven percent above today's levels (Moorhouse, 2013).

FORTUNATELY, THE LNG INDUSTRY COULD ADOPT DIFFERENT DESIGNS AND TECHNOLOGIES TO KEEP AIR EMISSIONS LOW WHILE STILL PRODUCING LNG.

The specific human health and ecological impacts of such increases in contaminants are unknown. The BC government is currently undertaking an airshed study to fully understand the links between air emissions from proposed LNG projects and human and environmental health in Kitimat (Ministry of the Environment, 2013). This research is expected to shed more light on how much more pollution the Kitimat airshed can safely withstand. Unfortunately, this research is being carried out under tight timelines and with a limited budget. This has raised concerns about whether current research can provide a comprehensive understanding of potential impacts on which to base sound decisions.

However, as stated above, we do know that NOx, SOx, PM, VOC and CO emissions cause health and ecological issues. Several of these pollutants adversely affect human and animal respiratory systems and are linked to asthma, bronchitis and emphysema. NOx and SOx also cause acid rain, acidifying lakes, streams and soils. NOx, PM, and VOCs contribute to smog and reduced visibility (Environment Canada, 2013a). (For a full list of impacts, see Appendix 3.)

At the time of this report's publication, industry and government are still finalizing decisions on how proponents will be allowed to power their proposed LNG plants. These proponents have access to cleaner options that would produce much less air pollution.

The LNG industry could adopt alternative designs and technologies to keep air emissions low while still producing fuel. The proposed Kitimat LNG facilities could use electrically driven compression (in a configuration known in the industry as "e-drive"), combined with grid, wind, hydroelectric energy and combined-cycle natural gas to reduce both carbon pollution and air emissions (Glave/Moorhouse, 2013).

From an air quality perspective, it would be difficult to objectively claim a given plant is the "cleanest in the world" unless it used these technologies.

Using electrical grid (hydroelectric) and wind power would reduce the amount of natural gas that would be burned to power the plants' LNG compressors. So would more efficient combined-cycle natural gas generation technology. Less natural gas combustion would mean less pollution in the airshed. Proponents also have the option to locate a combined-cycle natural gas facility outside the airshed, delivering the electricity to the LNG facilities over transmission lines. This would in turn reduce air quality impacts in the

Kitimat airshed. It should be noted that both sourcing power from the electric grid and locating combined-cycle natural gas facilities in other locations would have impacts elsewhere, which must be carefully considered.

Whatever decision is made today by government and industry will likely lock us into a path of either clean or dirty LNG for the next 30-plus years. Retrofitting cleaner technology at a later date would be costly and difficult.

WHATEVER DECISION IS MADE TODAY BY GOVERNMENT AND INDUSTRY WILL LIKELY LOCK US INTO A PATH OF EITHER CLEAN OR DIRTY LNG FOR THE NEXT 30 PLUS YEARS.

REDUCING THE RISK

The Government of British Columbia establishes air-quality targets based on concentrations of pollutants in the air (Ministry Environment – British Columbia, 2013). Through the Ministry of the Environment, the government sets targets for many pollutants including: Nitrogen Oxides (NOx), Sulphur Dioxides (SOx), Particulate Matter (PM), Carbon Monoxide (CO) and Volatile Organic Compounds (VOCs). (See Health & Environmental Impacts 101, page 8.)

The targets are intended to protect the health of British Columbians, and are enforced by controlling the amount of pollution industry creates. Each of the targeted pollutants impact either people—through respiratory issues, such as asthma—or ecosystems, through, for example, acid rain. Burning fossil fuels such as natural gas, gasoline and diesel emits many of these pollutants, but there are other sources as well, such as road dust and VOCs from forests.

Tonnes / yr	**NOx**	**SOx**	**PM**	**VOC**	**CO**
Current Emissions					
	1,378.00	6,592.00	2,032.00	453.00	44,818.00
Future Emissions					
LNG Facilities	7,467.95	172.86	492.37	156.39	4,546.14
LNG Tanker	353.22	275.95	5.02		114.40
LNG Total	7,821.17	2,792.70	497.39	156.39	4,660.53
LNG & Current	9,199.17	9,384.70	2,529.39	609.39	49,478.53
Rio Tinto Alcan	288.00	15,330.00	420	80.00	44,329
Enbridge	283.26	900.04	35.51	77.17	76.51
All Future Emissions	*9,482.43*	*16,949.86*	*1,779.90*	*686.56*	*49,555.04*
% Increase All	*588%*	*157%*	*12%*	*52%*	*11%*
% Increase LNG	*568%*	*7%*	*24%*	*35%*	*10%*

Table 1: Existing and potential future air emissions (LNG direct drive scenario) in the Kitimat airshed (Moorhouse, 2013).

To reiterate, an LNG facility can use electrically driven compression technology, combined with grid, wind energy and combined cycle natural gas to reduce its carbon emissions. This configuration can offer air-quality improvements in two ways.

First, using the grid and clean energy like wind and hydroelectric reduces the amount of natural gas required for the liquefaction process, as does using more efficient combined-cycle natural gas technology. Less natural gas combustion means fewer emissions.

Second, the combined cycle natural gas facilities can be moved outside the airshed and use transmission lines to deliver the electricity to the LNG facilities.

If the combined-cycle natural gas facilities were to remain in the airshed, emissions of NOx, SOx, PM, VOC and CO in the airshed would increase by 300 percent, 7 percent, 13 percent, 17 percent, and 5 percent, respectively.

If the facility were moved outside of the region, emissions of NOx, SOx, PM, VOC and CO in the airshed would increase by 26 percent, four percent, 0 percent, 0 percent, and 0 percent, respectively.

That's a significant improvement, but may still lead to air quality issues. We recommend the BC government determine thresholds for NOx, SOx, PM, VOC and CO that protect human and environmental health in the region and, prior to approving any new project, ensure the project's emissions will not cause these thresholds to be exceeded.

DETAILED DISCUSSION OF RESULTS

To determine the change in emissions, we developed three scenarios. Each scenario includes an estimate of existing emissions as well as emissions estimates for the three LNG facilities and the proposed Enbridge Northern Gateway terminal (the latter of which primarily comprises emissions from marine traffic).

The first scenario assumes the three proposed LNG facilities are built in Kitimat using direct-drive natural gas turbines to cool the natural gas and natural gas turbines for electricity generation (BC Standard).

The second scenario also assumes the three proposed LNG facilities are built in Kitimat, but that they incorporate e-drives and obtain electricity from a mix of grid, wind and combined-cycle natural gas electricity generation (BC CC and RE – CC Kitimat).

In the last scenario, the combined-cycle natural gas facility is moved outside the Kitimat airshed (BC CC and RE – CC outside Kitimat). Figure 1 summarizes these results.

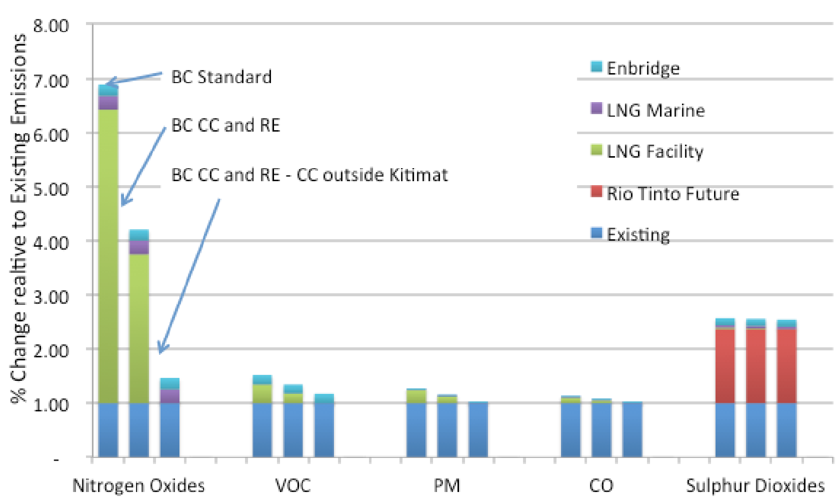

Figure 1: Change in air emissions for the B.C. standard, Kitimat and outside Kitimat scenarios (Moorhouse, 2013). Only emissions from Rio Tinto Alcan's existing aluminum smelter are included under "existing." The company's modernization project will increase SO_2 and reduce PM emissions relative to the existing levels shown here.

As Figure 1 shows, locating the combined-cycle natural gas facility outside the Kitimat airshed would reduce reduce NOx, PM, VOC and CO emissions in the airshed to near existing levels (the BC CC and RE – CC outside Kitimat scenario). It is worth noting that as emissions near maximum thresholds, even small increases can lead to health impacts.

CAUTIONS

The estimates discussed above assume the following:

- **Number of Facilities:** Existing emissions include the Rio Tinto Alcan smelter, and existing road and marine emissions. These emissions may change over time but we've assumed they remain constant, except for the known changes in SO2 and PM from the Rio Tinto Alcan Modernization. We further assume three LNG facilities are built, Shell – LNG Canada (24 million tonnes per annum [mta]), Chevron – Kitimat LNG (10 mta) and the Douglas Channel LNG project (0.9 mta) with a combined production of 34.9 mta. The actual number of facilities that will be built remains uncertain (Macquarie, 2012). We also include Enbridge to show the contribution of this project.
- **Pollution Control Technology:** Companies can incorporate pollution control technologies to reduce emissions. Our estimates are based on the pollution control technologies adopted by the planned Sabine Pass LNG facility (Sabine Pass LNG, 2011). This facility design is similar to what could be built in B.C. Sabine pass also plans to use steam injection to reduce NOx emissions by 60% and good combustion practices (i.e. running the equipment to its design specifications) to reduce other air emissions. Pollution control technologies can significantly reduce emissions, but can't eliminate them and tend to increase costs. Sabine Pass considered other pollution control technologies infeasible for cost and technical reasons, so we assume the LNG industry will make similar pollution control decisions here.
- **Cold Climate Advantage:** We assume a 25% energy efficiency cold climate advantage for B.C. operations (Morgan, 2012).
- **Air Quality and Air Emissions:** Linking air emissions to air quality changes and then human health impacts is complex and depends on local air temperature, pressure, humidity, sunlight, topography, and the exact mix of air pollutants in the atmosphere among other factors. Higher emissions do not necessarily mean human health impacts and small increases do not necessarily mean low impacts. Consider a bathtub that's being filled up, but all you know if how much water you're putting in, not how much it can hold. You can't tell if a little bit of water will make it overflow, or a lot. It's similar with air quality; we don't know the size of the bathtub. However, we suspect that the bathtub is getting full because air quality experts think so and because some existing estimates of SO2 emissions show that small increases in emissions lead to air quality that doesn't achieves targets (Fowlie, 2013; Kitimat LNG, 2005).
- **Sulphur Emissions:** Sulphur emissions are primarily associated with acid gas removal, a process to clean natural gas by removing carbon dioxide and hydrogen sulphide, and marine vessels. SO2 emissions from this process occur regardless of the location of the power generation facility.

FURTHER RESEARCH

This report shows the likely air emissions in Kitimat if LNG facilities are built using our understanding of standard technologies and approaches. It also shows how the LNG industry could change its practices to significantly reduce air emissions and Kitimat. However, only a rigorous air quality study can demonstrate what quantity of air emissions could be safely emitted in Kitimat without adverse health and environmental effects. The Government of British Columbia has committed to undertaking such a study, and will complete it by March 31, 2014.

SOURCES

Cheniere. (2011). Resource Report 9 – Air and Noise Quality.

Environment Canada. (2013a). Criteria Air Contaminants and Related Pollutants. Retrieved from http://www.ec.gc.ca/air/default.asp?lang=En&n=7C43740B-1

Environment Canada. (2013b). National Pollutant Release Inventory 2012. Retrieved from http://www.ec.gc.ca/inrp-npri/

Fowlie, J. (2013, July 1). Air pollution a concern as Kitimat considers list of industrial projects. Vancouver Sun. Vancouver. Retrieved from http://www.vancouversun.com/business/energy/pollution+concern+Kitimat+considers+list+industrial/8600213/story.html?__lsa=d6b2-3e64

Glave, J., & Moorhouse, J. (2013). The Cleanest LNG in the World? How to Slash Carbon Pollution from Wellhead to Waterline. Vancouver. Retrieved from http://cleanenergycanada.org/wp-content/uploads/2013/09/CEC_Cleanest_LNG_World.pdf

Jacques Whitford/AxysReport. (2010). Enbridge: Atmospheric Environment: Technical Data Report (pp. 3–15).

Kitimat LNG. (2005). 7.1 Assessment of Project Effects, Mitigations Requirements and Residual Effects.

Macquarie. (2012). Canadian LNG : The race to the coast. Retrieved from http://www.investorvillage.com/uploads/8056/files/Cdn_LNG_100912.pdf

Ministry of the Environment (2013) Airshed Study to Assess Effects of LNG in Kitimat. Victoria. Retrieved from http://www2.news.gov.bc.ca/news_releases_2013-2017/2013env0077-001506.htm

Ministry Environment – British Columbia. (2013). Provincial Air Quality Objective Information Sheet (pp. 1–4). Victoria. Retrieved from http://www.bcairquality.ca/reports/pdfs/aqotable.pdf

Ministry of Energy and Mines. (2013). Liquefied Natural Gas A Strategy for B.C.'s Newest Industry (p. 12). Victoria. Retrieved from http://www.gov.bc.ca/ener/popt/down/liquefied_natural_gas_strategy.pdf

Moorhouse, J. (2013). Calculations of air emissions from proposed LNG facilities Kitimat BC.

Morgan, J. (2012). Rules of Thumb for Screening LNG Developments. Perth. Retrieved from http://www.engineersaustralia.org.au/sites/default/files/shado/Divisions/Western Australia Division/Groups/Oil_Gas/lng_technical_presentation_ieaustralia_oil_and_gas_division_perth_october_2012.pdf

National Energy Board. (2004). The British Columbia Natural Gas Market: An Overview and Assessment. Ottawa. Retrieved from http://www.neb-one.gc.ca/clf-nsi/rnrgynfmtn/nrgyrprt/ntrlgs/bcgsvvwssssmntprl2004-eng.pdf

Sabine Pass LNG. (2011). Environmental Assessment for the Sabine Pass Liquefaction Project. Retrieved from http://www.circleofblue.org/waternews/wp-content/uploads/2012/01/FERC_Sabine-Pass.pdf

APPENDIX 1: DATA SOURCES

This section contains the primary data sources used to develop the emission estimates in the report. The primary assumptions have been discussed earlier in the report and additional detail is available in The Cleanest LNG in the World? (Glave & Moorhouse, 2013).

Estimate	Source	Justification
Existing Emissions		
Rio Tinto Alcan	(Environment Canada, 2013b)	Facility is in Kitimat and 2012 NPRI is the most recent public data. Largest single source of CAC emissions.
Existing Marine Emissions	(Kitimat LNG, 2005)	Most recent emission estimates are from 2000 and available in the original Kitimat LNG application.
Road Dust	(Kitimat LNG, 2005)	IBID
Motor Vehicles	(Kitimat LNG, 2005)	IBID
Kitimat Marine Terminal – Shell	(Environment Canada, 2013b)	Facility is in Kitimat and 2012 NPRI is the most recent public data. Only emissions are VOCs.
LNG Facilities – All Scenarios		
Natural gas turbines	(Cheniere, 2011)	Based on Sabine Pass LNG facility because it includes both direct drive and single cycle turbines for electricity generation.
Marine Emissions	(Kitimat LNG, 2005)	Kitimat LNG provides estimates of marine emissions for its proposed facility. These estimates are for B.C.
Enbridge Northern Gateway Terminal		
All emissions	(Jacques Whitford / AxysReport, 2010)	Most recent estimate of potential Enbridge emissions in Kitimat, primarily from Marine emissions.
Rio Tinto Alcan Modernization		
(RTA's Kitimat Modernization Project 2013 Update)	Rio Tinto Alcan provides estimates of its emissions after the modernized aluminum smelter is in operation	

Table 2: Data for Existing and Proposed Air emission sources

APPENDIX 2: BRITISH COLUMBIA AIR QUALITY TARGETS

Contaminant	Avg. Period	Level	Air Quality Objective		Date Adopted	Date Last Reviewed	Source
			$\mu g/m^3$	ppb			
Carbon Monoxide (CO)	1 hour	A B C	14,300 28,000 35,000	13,000 25,000 30,000	1975	-	PCOs for Food-processing, Agriculturally Orientated, and Other Misc. Industries
	8 hour	A B C	5,500 11,000 14,300	5,000 10,000 13,000	1975	-	PCOs for Food-processing, Agriculturally Orientated, and Other Misc. Industries
Formaldehyde[h]	1 hour	Action Episode	60 370	50 308	2005	-	Provincial AQO
Nitrogen Dioxide (NO_2)	1 hour	MAL MTL	400 1000	213 532	1975 1978	1989	NAAQO
	24 hour	MAL MTL	200 300	106 160	1975 1978		
	annual	MDL MAL	60 100	32 53	1975		
Ozone (O_3)	1 hour	MDL MAL MTL	100 160 300	51 82 153	1974 1974 1978	1989	NAAQO
	8 hour	CAAQS	123	63[l]	2013	-	CAAQS
	24 hour	MDL MAL	30 50	15 26	1974 1974	1989	NAAQO
	Annual	MAL	30	15	1974		
Particulate Matter <2.5 microns ($PM_{2.5}$)	24 hour	AQO	25[j]	-	2008	-	Provincial AQO
		CAAQS	28[k]	-	2013	-	CAAQS
	Annual	AQO Goal	8[j] 6[j]	- -	2005 2005	-	Provincial AQO
		CAAQS	10[l]	-	2013	-	CAAQS
Particulate Matter <10 microns (PM_{10})	24 hour	AQO	50	-	2005	-	Provincial AQO
Sulphur Dioxide (SO_2)	1-hour	A or Lower B or Upper C	450 900 900	170 340 340	1974-79	-	PCOs for various sectors
	3-hour	Lower Upper	375 665	140 250	1979	-	
	24-hour	A or Lower B or Upper C	160 260 360	60 100 140	1974-79	-	
	annual	A or Lower B C[m]	25 50 80	10 20 30	1974-79	-	
Total Reduced Sulphur (TRS) compounds measured as H_2S	1 hour	A B	7 28	5 20	1977	-	PCOs for the Forest Products Industry
	24 hour	A B	3 6	2 4	1977	-	

Table 3: British Columbia Air Quality Guidelines (Ministry Environment – British Columbia, 2013)

APPENDIX 3: HEALTH & ENVIRONMENTAL IMPACTS 101

The air emissions discussed in this report, along with ammonia, ozone and secondary particulate matter are collectively known as criteria air contaminants (CACs). Each of these pollutants has environmental and health impacts. However, the degree of impact depends on the concentration. The following describes how the pollutants are produced and their known impacts on human health and the environment (Environment Canada, 2013a).

- Nitrogen Oxides (NOx): Combustion processes like burning natural gas, diesel or gasoline form nitrogen oxides. Most atmospheric NO_2 is emitted as NO, which is rapidly oxidized by ozone to NO_2. Nitrogen dioxide, in the presence of hydrocarbons and ultraviolet light, is the main source of tropospheric ozone and of nitrate aerosols, which form an important fraction of the ambient air PM 2.5 mass. NOx emissions adversely affect human and animal respiratory systems. Epidemiological studies have shown that bronchitic symptoms of asthmatic children increase in association with annual NO_2 concentration, and that reduced lung function growth in children is linked to elevated NO_2 concentrations within communities already at current North American and European urban ambient air levels. NOx also helps create smog (ground level ozone) and particulate matter, which also causes respiratory issues. When combined with water vapor, NOx contributes to acid rain. Acid rain is then deposited into lakes, streams, and soils, increasing the acidity in the environment. This in turn impacts fish, amphibians, aquatic insects, and plants. Steelhead and rainbow trout are particularly susceptible.

- Sulphur Dioxides SOx: SOx is released when materials containing sulphur are burned or processed, like natural gas, coal and oil. Like NOx it adversely affects human and animal respiratory systems while also contributing to acid rain.

- Particulate Matter (PM): Particulate matter is generally produced in three ways: 1. Through combustion (like burning wood, natural gas or diesel). 2. By dust from road traffic or wind and 3. Secondary formation from SO¬x, NOx and ammonia. It is linked asthma, bronchitis and emphysema and also degrades visibility.

- Carbon Monoxide (CO): Carbon monoxide is also produced through combustion and in high concentrations is deadly. At lower concentrations it can "impair exercise capacity, visual perception, manual dexterity, learning functions, and ability to perform complex tasks".

- Volatile Organic Compounds (VOCs): VOCs can come from both fumes from paints and gasoline tanks as well as natural sources like trees. VOCs have human health and environmental impacts on their own and also contribute to smog and secondary PM.