Natural gas

A bridge or a gangplank?

A submission to the Independent Hydraulic Fracturing Review on the issue of climate change

Submitted by:

Yuill Herbert
11 Alex Cox Rd,
Tatmagouche, NS
B0K1V0

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"No one can predict the consequences of climate change with complete certainty; but we now know enough to understand the risks. Mitigation- taking strong action to reduce emissions - must be viewed as an investment, a cost incurred now and in the coming decades to avoid the risks of very severe consequences in the future. If these investments are made wisely, the costs will be manageable, and there will be a wide range of opportunities for growth and development along the way".

Stern Review: The Economics of Climate Change, pg. i (2006).

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"It was barely 11 months ago in Doha [UN Climate Change negotiations] when my delegation appealed to the world… to open our eyes to the stark reality that we face… as then we confronted a catastrophic storm that resulted in the costliest disaster in Philippine history. Less than a year hence, we cannot imagine that a disaster much bigger would come. With an apparent cruel twist of fate, my country is being tested by this hellstorm called Super Typhoon Haiyan, which has been described by experts as the strongest typhoon that has ever made landfall in the course of recorded human history".

Ye Sano, Lead negotiator for Philippines at UN Climate Summit in Warsaw, 2013

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"Let me highlight the one resource that is scarcest of all: time...we are running out of time. Time to tackle climate change. Time to ensure sustainable, climate-resilient green growth. Time to generate a clean energy revolution… We need you to step up. Spark innovation. Lead by action. Invest in energy efficiency and renewable energy for those who need them most — your future customers."

UN Secretary General Ban Ki Moon at the World Economic Forum, 2011

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"Global climate policy developments are currently buried in a trapped transition. The situation is one of drift, with only small advances taking place while the hard choices are postponed, often for years. This delay is enabled by the long timescales that underpin global ecological shifts. But the archetypal pathway suggests that the longer the period of drift, the greater the required reset and associated write-off of financial, political, and social capital will be".

Shell International[1]

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[1] Shell International (2013). New Lens Scenarios: A shift in perspective for a world in transition. Retrieved from: http://s01.static-shell.com/content/dam/shell-new/local/corporate/Scenarios/Downloads/Scenarios_newdoc.pd

Contents

Summary

The following is a summary of the evidence prepared in this submission.

>> Climate change is happening and human emissions are driving climate change.

>>Climate change is already irreversible.

>>Unabated climate change poses a grave risk to life as we know.

>>Climate change is already resulting in death and destruction around the globe.

>>Current efforts to reduce climate change are inadequate.

>>Nova Scotia has already reduced GHG emissions in excess of its legally-binding GHG target.

>>Natural gas was considered a bridge between dirtier fossil fuels such as coal and more expensive clean renewable energy.

>>New studies, as recent as this month, cast doubt on the climate benefit that natural gas from hydraulic fracking can provide.

>>The latest IPCC report increases the global warming impact of methane, the gas released during fracking.

>>An unconventional oil and gas industry represents a significant financial risk from the price of carbon and a growing divestment campaign.

>>An unconventional natural gas industry creates a lock-in effect limiting the ability of the Government of Nova Scotia to take necessary mitigative actions in the present and the future.

>>A modest onshore unconventional gas industry has the potential to double or more Nova Scotia's total 2012 GHG emissions.

>>Green completion, a technology to capture methane, while beneficial, only addresses leakage at one stage of the lifecycle in the production and distribution of natural gas.

For these reasons we recommend <u>a minimum of a ten year moratorium on hydraulic fracturing</u> in Nova Scotia.

The context of climate change

Climate change is happening and anthropogenic (human) emissions are driving climate change.

In May 2013, global carbon dioxide (CO_2) emissions reached 400 parts per million (ppm) likely for the first time in past 3 million years[2]. This milestone marks the beginning of *uncharted* territory, a period of uncertain and undesirable climatic and ecological change. Not only are global average temperatures increasing due to increased emissions from fossil fuel combustion, but positive feedback cycles threaten to compound those increases and/or hinder earth's ability to absorb these gases as the permafrost melts and forest fires increase, for example[3]. The Intergovernmental Panel on Climate Change has just published the Fifth Assessment Report (AR5) which consists of three reports, the Physical Science Basis (2013), Impacts, Adaptation and Vulnerability (2014) and Mitigation of Climate Change (2014)[4]. The first report, the Physical Science Basis, Impacts, Adaptation (2013) concluded that "*warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia*" (p.4) and "*Human influence on the climate system is clear"* (p.15), "*increasing carbon dioxide emissions by over 40% since pre-industrial times*" (pg.11).

Climate change is already irreversible.

One notable issue is the persistence of GHG emissions in the atmosphere which means that "*most aspects of climate change will persist for many centuries even if CO2 emissions are stopped… a substantial multi-century climate change commitment create by past, present and future emissions of CO2*" (p. 27). The delayed reaction of the climate will result in elevated temperatures for many centuries even if no more CO2 emissions are release and sea level will continue to increase.

Unabated climate change poses a grave risk

The report, Impacts, Adaptation and Vulnerability, assessed the risk that climate change poses for human and natural systems. The authors found impacts from climate change on natural and human systems on all continents and across the oceans in recent decades including:

- Altered hydrological systems, affecting water resources in terms of quantity and quality;
- Net negative impacts on crop yields;
- Significant vulnerability and exposure to climate vulnerability as highlighted by extreme weather events; and
- The impact of climate-related hazard on other stressors, particularly for people living in poverty.

Future risks include (pg.12):

- Risk of death, injury, ill-health, or disrupted livelihoods in low-lying coastal zones and small island developing states and other small islands, due to storm surges, coastal flooding, and sea-level rise.
- Risk of severe ill-health and disrupted livelihoods for large urban populations due to inland flooding in some regions.

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[2] Earth System Research Laboratory (2014).National Oceanic & Atmospheric Administration. Retrieved March, 2014 from: http://www.esrl.noaa.gov/gmd/ccgg/trends/weekly.html

[3] *Examples of these cycles include increased water vapour in the atmosphere, loss of sea, permafrost degradation and ocean acidification*

[4] IPCC reports are available at: http://www.ipcc.ch/. All page numbers refer to the Summary for Policy Makers.

- Systemic risks due to extreme weather events leading to breakdown of infrastructure networks and critical services such as electricity, water supply, and health and emergency services.
- Risk of mortality and morbidity during periods of extreme heat, particularly for vulnerable urban populations and those working outdoors in urban or rural areas.
- Risk of food insecurity and the breakdown of food systems linked to warming, drought, flooding, and precipitation variability and extremes, particularly for poorer populations in urban and rural settings.
- Risk of loss of rural livelihoods and income due to insufficient access to drinking and irrigation water and reduced agricultural productivity, particularly for farmers and pastoralists with minimal capital in semi-arid regions.
- Risk of loss of marine and coastal ecosystems, biodiversity, and the ecosystem goods, functions, and services they provide for coastal livelihoods, especially for fishing communities in the tropics and the Arctic.
- Risk of loss of terrestrial and inland water ecosystems, biodiversity, and the ecosystem goods, functions, and services they provide for livelihoods.

Climate change is already resulting in tragedy

The impacts of climate change are also uneven, doing the most damage to those who can least afford it. The Climate Vulnerability Monitor reports that climate change causes 400,000 deaths on average each year due to hunger and communicable diseases that are exacerbated by a warming climate and that in 2010 climate change caused economic losses equivalent to 1% of the global GDP or $700 billion. The report notes that it is the world's poorest communities within lower and middle-income countries that are the most exposed[5]. This analysis is reinforced by a recent report from the World Bank[6]:

> *Over the last 30 years, the world has lost more than 2.5 million people and almost $4 trillion to natural disasters. Economic losses are rising – from $50 billion each year in 1980, to just under $200 billion in 2012. And three quarters of those losses are a result of extreme weather.*

The impacts of climate change are also likely to be costly. In Canada, costs could start at $5 billion by 2020 and climb to between $21 and $43 billion a year by the 2050s depending on how much action is taken[7] with direct effects on timber supply, coastal areas and human health. In 2013, the cost of the flood in Calgary was $6 billion[8] and a flash flood in Toronto cost $850 million in insured damages[9].

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[5] Fundacion DARA (2012). Climate vulnerability monitor: 2nd Edition. Retrieved from: http://www.daraint.org/wp-content/uploads/2012/09/CVM2ndEd-FrontMatter.pdf

[6] World Bank (2013). Damages from extreme weather mount as climate warms. World Bank Group. Retrieved from: http://www.worldbank.org/en/news/press-release/2013/11/18/damages-extreme-weather-mount-climate-warms

[7] National Round Table on the Environment and Economy (2012). Paying the price: The Economic impacts of climate change for Canada. Government of Canada.

[8] Wood, J. (2013). Province boosts cost of Alberta floods to $6 billion. Calgary Herald. Retrieved from: http://www.calgaryherald.com/news/Province+boosts+cost+Alberta+floods+billion/8952392/story.html

[9] Mills, C. (2013). Toronto's July flood listed as Ontario's most costly natural disaster. THe Toronto Star. Retrieved from: http://www.thestar.com/business/2013/08/14/july_flood_ontarios_most_costly_natural_disaster.html

Current policies are insufficient to prevent dangerous climate change

Climate change is a global issue, requiring a global response, but the current level of ambition in international negotiations is inadequate to prevent dangerous levels of climate change.[10] The United Nations Framework Convention on Climate Change (UNFCC) treaty was negotiated in Rio de Janeiro in 1992. 154 nations signed the treaty, pledging to reduce atmospheric GHGs with the goal of preventing dangerous anthropogenic interference with Earth's climate system. However, while the treaty included an objective to stabilise GHG emissions at safe levels the treaty, it contained no legally binding GHG emission limits and no enforcement mechanism.

In 1997 the Kyoto Protocol established legally binding emissions targets to be achieved by 2012 for 38 developed countries.[11] The Kyoto Protocol was ratified by over 150 countries, not including the United States. Canada was the first and only country to withdraw from the Protocol in 2011, thus avoiding the mandatory purchase of carbon credits to achieve its target.[12]

Countries have been negotiating intensely at annual meetings in Cancun, Copenhagen, Doha and Warsaw. In the final meeting prior to the end of the Kyoto Protocol's mandate period, the original parties minus Canada adopted new GHG targets by 2020 under the Protocol, thus extending the international framework for climate action. Currently countries are negotiating a new protocol that will apply to all countries, be legally binding, be completed by 2015 and be implemented by 2020.[13] However, these targets are insufficient to stabilise the climate at safe levels, accounting for between 3-7 GTCO2e of the 8-12 GTCO2e required.[14]

[10] Hare, B. et al (2012). Climate Action Tracker. Ecofys, Climate Analytics and PIK. Retrieved from: http://climateactiontracker.org/

[11] David Suzuki Foundation. (2009). History of climate change negotiations. Retrieved from: http://www.davidsuzuki.org/issues/History%20of%20climate%20negotiations.pdf

[12] CBC (2011). Canada pulls out of Kyoto Protocol. Retrieved from: http://www.cbc.ca/news/politics/canada-pulls-out-of-kyoto-protocol-1.999072

[13] UN Framework Convention on Climate Change. Retrieved from: http://unfccc.int/2860.php

[14] United Nations Environment Program (2013). The Emissions gas report 2013. Retrieved from: http://www.unep.org/pdf/UNEPEmissionsGapReport2013.pdf

Climate change policy in Nova Scotia

Nova Scotia has already achieved its GHG emissions target

The Province of Nova Scotia's Greenhouse Gas Emissions target, -10% below 1990 levels, is established in the Sustainable Prosperity Act.[15] The GHG target is supported by a legislated cap on emissions from Nova Scotia Power Inc., a renewable electricity plan, a waste diversion target, building code updates and other strategies. This GHG target, however, is less than the 25 to 40 percent that is required to stabilise GHG emissions at safe levels.[16]

In 2007, total GHG emissions from Nova Scotia were 23,300 kt CO2e[17]; the target for reductions by 2020 is 20,970 kt CO2e. In 2012, Nova Scotia's emissions were 19,000 ktCO2e, a 19% decline.[18] In other words, the Province had already signficantly exceeded its 2020 GHG target by 2011.

The majority of GHG emissions in Nova Scotia result from stationary combustion of fossil fuels, followed by mobile combustion for transportation. Of the 12,000 kt CO2e resulting from stationary combustion, approximately 64%, or 7,630 kt CO2e, result from the generation of electricity.

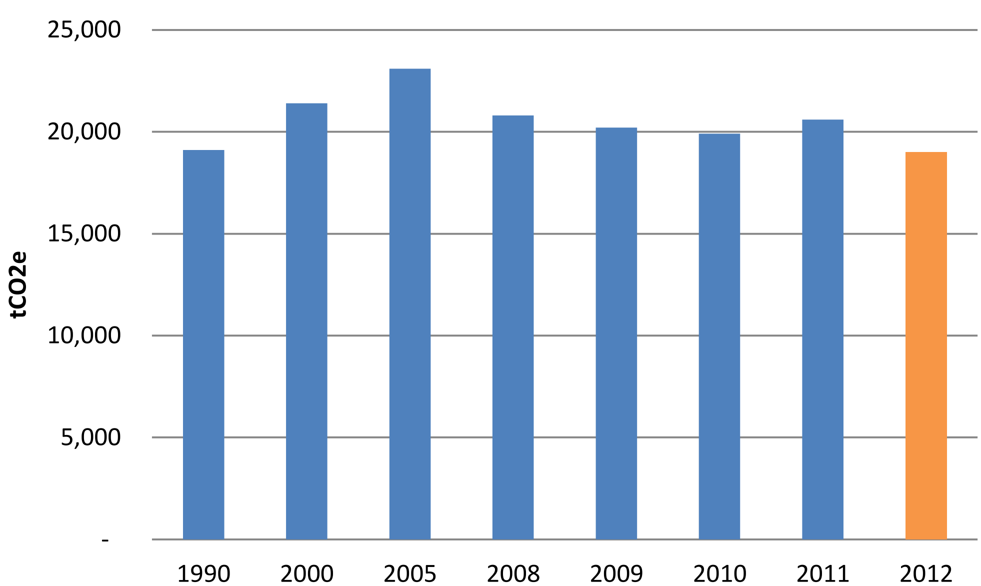

Figure 1: GHG emissions, Province of Nova Scotia

[15] Province of Nova Scotia (2013). Environmental Goals and Sustainable Prosperity Act. Chapter 7 of the Acts of 2007. Retrieved March, 2014 from: http://nslegislature.ca/legc/statutes/environmental%20goals%20and%20sustainable%20prosperity.pdf

[16] David Suzuki Foundation (2012). All Over the Map 2012: A comparison of provincial climate change plans. Retrieved March, 2014 from: http://www.davidsuzuki.org/publications/downloads/2012/All%20Over%20the%20Map%202012.pdf

[17] Government of Canada (2013). National Inventory Report 1990-2011: Greenhouse Gas Sources and Sinks in Canada. Retrieved March, 2014 from: http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/7383.php

[18] Government of Canada (2014). National Inventory Report 1990-2012: Greenhouse Gas Sources and Sinks in Canada.

Climate change and hydraulic fracturing

The premise: Natural gas as a bridge

Natural gas, when combusted, produces the least GHG emissions of the fossil fuels, but still more than renewable energy (Figure 2). As a result, many policy analysts have positioned natural gas as a transition fuel, a bridge between dirtier fuels, in particular coal, to the ultimate goal which is renewable energy and energy efficiency gains.[19]

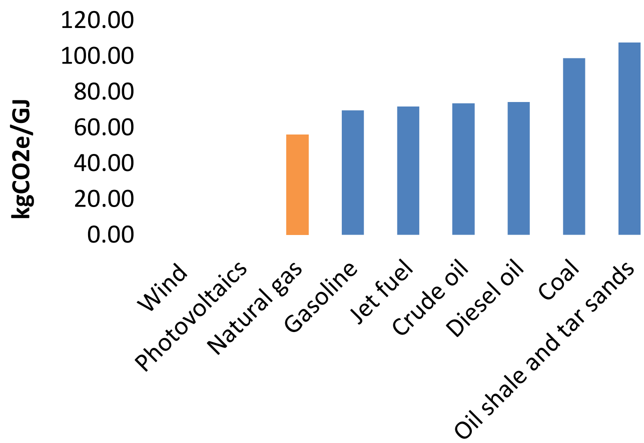

Figure 2: Emissions factor for combustion[20]

Many authors have countered the idea of natural gas as a bridge fuel, arguing it is a bridge to nowhere[21], a gangplank rather than a bridge[22] and a bridge fuel to faster climate change.[23] The four core arguments against natural gas as a bridge fuel are as follows:

1. Leakage: Leakage of methane throughout its lifecycle from production to distribution undermines or eliminates the GHG benefit of natural gas over other fossil fuels.
2. Potency: Methane is a more potent GHG than previously understood.
3. Lock-in: Investing resources in infrastructure with uncertain GHG benefits creates additional societal momentum behind a fossil fuel economy.
4. Scarcity: Resources are scarce and the economic case for a bridge fuel is no longer justified in the face of decreasing costs of renewable energy and an option society can ill afford.

[19] The idea of natural gas as a bridge fuel has many proponents, for example President Obama in his 2014 State of the Union address.

[20] IPCC (2006). 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Retrieved March, 2014 from: http://www.ipcc.ch/meetings/session25/doc4a4b/vol2.pdf

[21] Romm. J. (2012). Natural gas is a bridge to nowhere –Absent a serious price for global warming. ThinkProgress. Retrieved March, 2014 from: http://thinkprogress.org/climate/2012/01/24/407765/natural-gas-is-a-bridge-to-nowhere-price-for-global-warming-pollution/

[22] Ingraffea, A. (2013). Gangplank to a Warm Future. The Opinion Pages, New York Times. Retrieved March, 2014 from: http://www.nytimes.com/2013/07/29/opinion/gangplank-to-a-warm-future.html?_r=0

[23] Brun, M. (2014). Natural Gas – A bridge fuel to faster climate change. Ecology Graduate Student Association. Retrieved March, 2014 from: http://egsa.ucdavis.edu/blog/2014-02-18-natural-gas-a-bridge-fuel-to-faster-climate-change.

Leakage of methane is intrinsic to the natural gas lifecycle

There are two ways of measuring CH4 leakage; firstly by measuring CH4 leaks in the context of an actual project through to distribution and then summing up the number of such systems to identify overall leakage- the bottom-up approach; and secondly by measuring leakage from atmospheric CH4 emissions, a top-down approach. Measurement of CH4 emissions from shale gas is very recent, dating back to just 2010 and involves considerable uncertainty.[24]

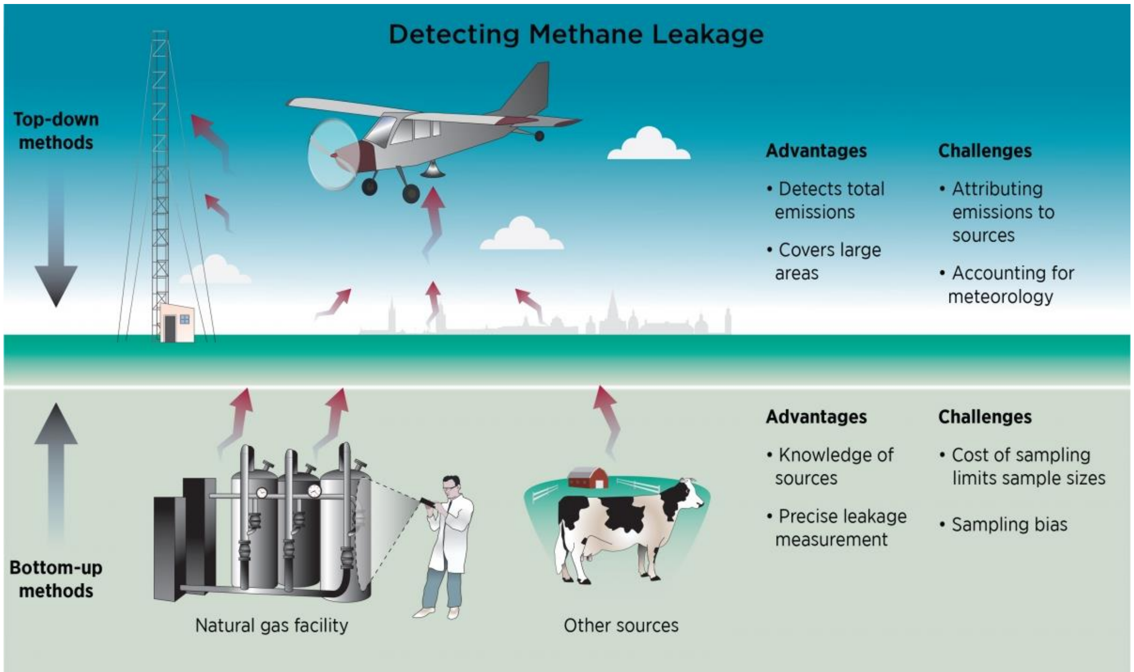

Figure 3: Methods for detecting natural gas emissions[25]

The amount of leakage determines the degree to which, or if at all, natural gas provide a net benefit to climate change mitigation efforts over dirtier fossil fuels such as coal, even though CH4 produces less CO2 in combustion. The most significant source of CH4 leakage for shale gas is during well completion including drilling, hydraulic fracturing and the flow-back of the fracturing fluid. The way in which the flowback fluid is handled can significantly impact the rate of leakage. Following production, contaminants are stripped from the gas in a process called production. At this stage, leakage is thought to occur primarily as a result of compressor seals and incomplete combustion in engines that drive compressors. The seals and engines are culprits as the gas moves through transmission and distribution.

[24] Caulton et al., (2014). Toward a better understanding and quantification of methane emissions from shale gas development. Proceedings of the National Academy of Science. Retrieved April, 2014 from: www.pnas.org/cgi/doi/10.1073/pnas.1316546111
[25] Graphic prepared by MIT Energy Initiative.

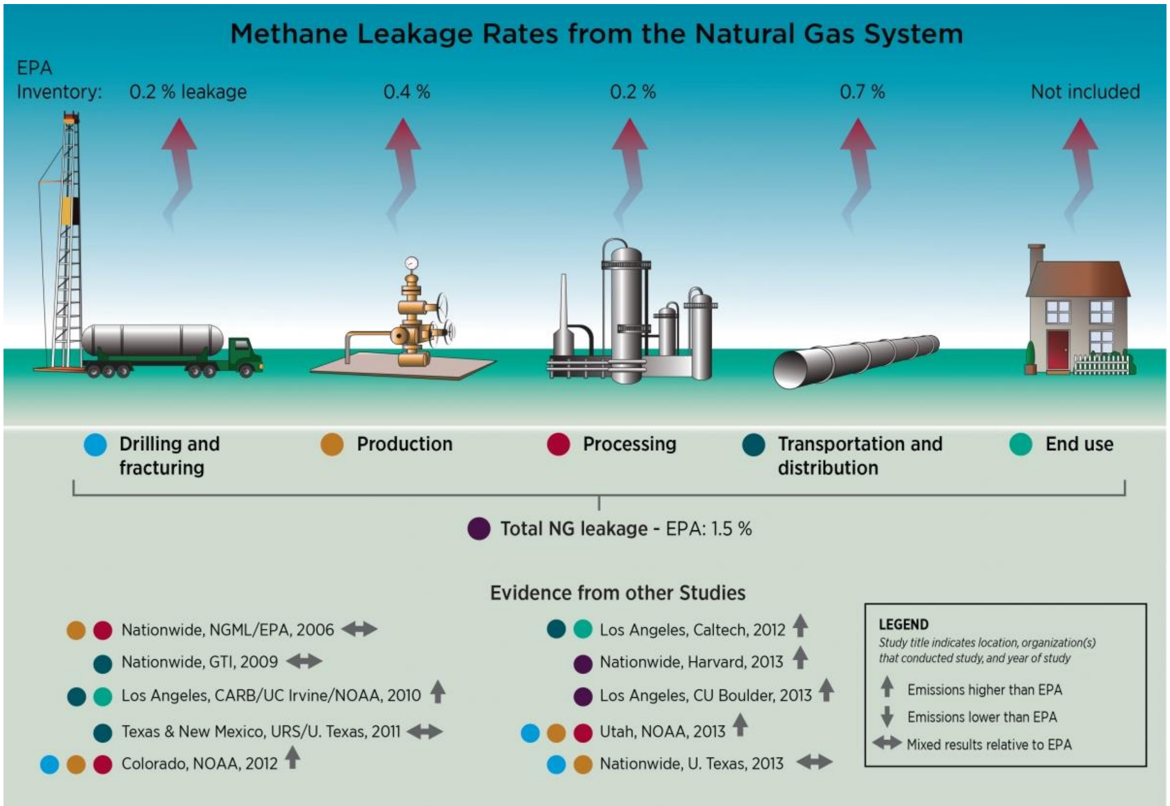

Figure 4: Natural gas emissions by industry segment[26]

The most sophisticated method to compare GHG emissions is lifecycle accounting in which emissions from each stage of the lifetime of the emissions are tabulated, which for natural gas includes 'upstream' and 'midstream' (drilling and the well pad) and 'downstream' (distribution and combustion). Another way to classify the emissions for natural gas is the emissions resulting from direct combustion and indirect emissions resulting from leakage, transportation, diesel engines for compression, land-use changes and resource consumption (steel, cement, organic chemicals). Direct combustion and fugitive emissions (leakage) are the major contributors to GHG emissions, accounting for 10-15 times indirect sources.[27] However, the contribution from fugitive emissions varies according to the rate of leakage and assumptions around the global warming impact of CH4.

The leakage threshold at which natural gas provides positive climate benefit in relation to coal varies from study to study, from 6 percent leakage per year or less[28] to as low as 3.2% when switching from coal-fired generators to natural gas.[29]

Fugitive methane emissions are underestimated

There is considerable uncertainty about the extent of CH4 leakage. EPA estimated in 2010 between 1.5% and 2.2% of methane extracted from the ground leaked into the atmosphere, drawing on studies that range from less than

[26] Graphic prepared by MIT Energy Initiative.
[27] Santoro, R., Howarth, R., Ingraffea, R. (2011). Indirect Emissions of Carbon Dioxide from Marcellus Shale Gas Development. A Technical Report from the Agriculture, Energy, & Environment Program at Cornell University. June 30, 2011
[28] Larson, E. (2013). Natural gas & climate change. Climate Central. Princeton, NJ.
[29] Tollefson, J. (2013). Methane leaks erode green credentials of natural gas. Nature, 9. Retrieved from http://www.globalwarming-sowhat.com/carbon-sinks--sources-/methane-leaks-erode-green.rtf

1% to as high as 7.7%. A study by Howarth and al. that estimated leakage at 7.9% for shale gas (Table 1)[30] was considered high and an outlier[31], however Howarth at al. have responded with a systematic defense of their analysis.[32] Other estimates range significantly from 0.6% to 7.7% for upstream and midstream emissions and 0.07% to 10% for downstream emissions.[33]

Table 1: Fugitive emissions associated with development of natural gas as a percentage of methane produced over the lifecycle of a well.[34]

	Conventional gas	Shale gas
Emissions during well completion	0.01%	1.9%
Routine venting and equipment leaks at well site	0.3-1.9%	0.3 to 1.9%
Emissions during liquid unloading	0 to 0.26%	0 to 0.26%
Emissions during gas processing	0 to 0.19%	0 to 0.19%
Emissions during transport, storage and distribution	1.4 to 3.6%	1.4 to 3.6%
Total emissions	1.7 to 6.0%	3.6 to 7.9%

Recent studies using a top-down field-scale actual field scale measurements are tipping the balance in favour of higher estimates finding total upstream and mid-stream emissions of 2.3% to 11.7%,[35,36], in contrast to another study which used data from well sites which found lower CH4 emissions than EPA estimates.[37] A 2013 study published in the Proceedings of the National Academy of Sciences (PNAS) used measurements of CH4 including 4,984 samples from tall towers and 7,710 samples from airplanes to correlate CH4 concentrations with particular activities. The study's research team — based at Harvard, Stanford, the University of Colorado, NCAR, Lawrence Berkeley National Laboratory and the E.U.'s Institute for Environment and Sustainability found that oil and gas emissions were 4.9+/-2.6 times higher than EPA estimates.[38]

A 2014 review of 20 years of technical literature on natural gas emissions in the US and Canada found that official inventories consistently underestimate actual CH4 emissions, for example EPA estimates may understate

[30] Howarth, R., Santoro, R., & Ingraffea, A. (2011). Methane and the greenhouse-gas footprint of natural gas from shale formations. Climatic Change, 679–690.
[31] MacKay, D. and Stone, T. (2013). Potential greenhouse gas emissions associated with shale gas extraction and use. Department of Energy & Climate Change. Government of UK.
[32] Howarth, R., Santoro, R., & Ingraffea, A. (2012). Venting and leaking of methane from shale gas development: response to Cathles et al. Climatic Change. doi:10.1007/s10584-012-0401-0
[33] Howarth, R., Shindell, D., Santoro, R., Ingraffea, A., Phillips, N., & Townsend-Small, A. (2012). Methane emissions from natural gas systems. Background Paper Prepared for the National Climate Assessment, 1–6. Retrieved from http://www.eeb.cornell.edu/howarth/publications/Howarth_et_al_2012_National_Climate_Assessment.pdf
[34] Howarth, R., Santoro, R., & Ingraffea, A. (2011). Methane and the greenhouse-gas footprint of natural gas from shale formations. Climatic Change, 679–690.
[35] Karion, A., Sweeney, C., & Pétron, G. (2013). Methane emissions estimate from airborne measurements over a western United States natural gas field. Geophysical Research Letters.
[36] Montzka, A., Sweeney, C., Andrews, A., & Dlugokencky, M. (n.d.). Estimation of Emissions from Oil and Natural Gas Operations in Northeastern Colorado. Epa.gov, 2010–2013. Retrieved from http://www.epa.gov/ttnchie1/conference/ei20/session6/gpetron.pdf
[37] Allen, D., et al. (2013) Measurements of methane emissions at natural gas production sites in the United States. Proc Natl Acad Sci USA 110(44):17768–17773.
[38] Miller, S. M., Wofsy, S. C., Michalak, A. M., Kort, E. a, Andrews, A. E., Biraud, S. C., … Sweeney, C. (2013). Anthropogenic emissions of methane in the United States. Proceedings of the National Academy of Sciences of the United States of America, 110(50), 20018–22.

emissions by between 25 and 75%.[39] This study found that system-wide leakage is unlikely to be sufficient to undermine the climate benefits of coal to natural gas substitution using a 100-yr time frame. The same study noted that climate benefits from vehicle fuel substitution from gasoline to natural gas are, however, uncertain for gasoline and light-duty vehicles and improbable for diesel and heavy duty vehicles. The study concludes that natural gas is a bridge that must be traversed carefully.

Finally another study using aircraft to measure fugitive emissions estimated total emissions ranging from 2.8%-17.3%. The researchers found readings over wells which were being drilled and that had not yet been fractured 100 to 1000 times EPA's estimate for that stage. Notably, bottom-up inventories usually assume no emissions during the pre-hydraulic fracturing period.[40]

EPA is currently exploring strategies to significantly reduce CH_4 emissions from the oil and gas sector, upstream and midstream.[41] However, it may be extremely expensive to reduce leakage associated with aging downstream natural gas infrastructure and our understanding of leakage at this stage is also evolving, with one recent study of gas service in Manhattan identifying fugitive emissions at 2.68%.[42]

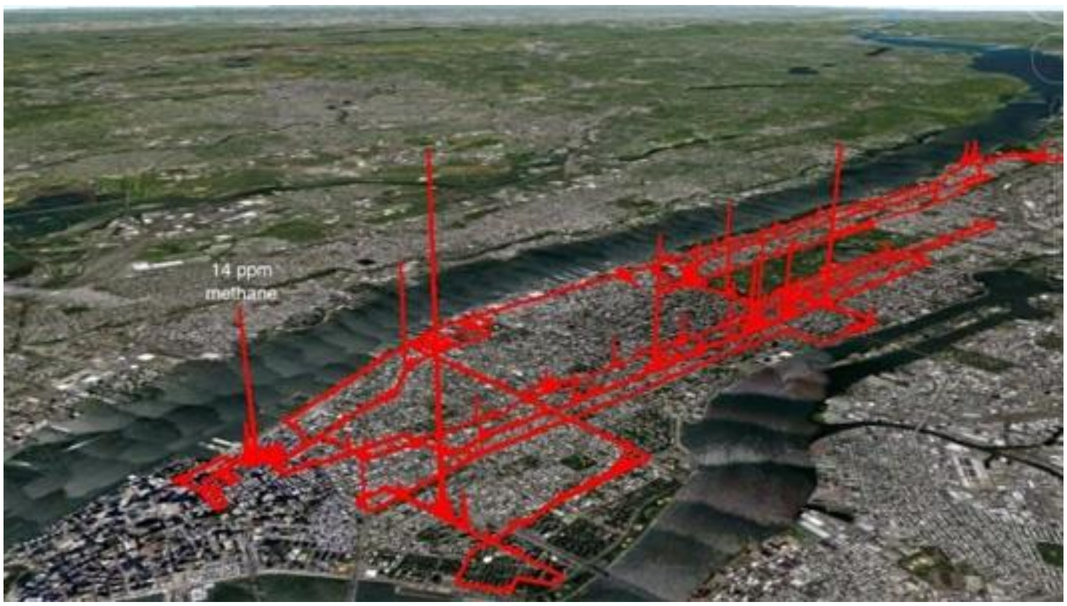

Figure 5: Visualisation of CH_4 concentrations resulting from leakage in Manhattan's natural gas distribution system[43]

[39] Brandt, A., Heath, G., Kort, E., & O'Sullivan, F. (2014). Methane leaks from North American natural gas systems. Science, 7–9. Retrieved from ftp://aftp.cmdl.noaa.gov/pub/schnell/Science-2014-Brandt-733-5.pdf

[40] Caulton et al., (2014). Toward a better understanding and quantification of methane emissions from shale gas development. Proceedings of the National Academy of Science. Retrieved April, 2014 from: www.pnas.org/cgi/doi/10.1073/pnas.1316546111

[41] EPA (2014). White Papers on Methane and VOC Emissions. Retrieved April, 2014 from: http://epa.gov/airquality/oilandgas/whitepapers.html

[42] Ackley, R. and Payne, B. (2013). Extended Report on Preliminary Investigation of Ground-Level Ambient Methane Levels in Manhattan, New York City, New York. Gas Safety, Inc., Southborough, MA (www.GasSafetyusa.com)
Commissioned by Damascus Citizens for Sustainability. Retrieved April, 2014 from: http://www.damascuscitizensforsustainability.org/2013/03/manhattan-natural-gas-pipeline-emissions-press-release/

[43] Visualisation generated as part of the project: Emissions: Images from the Mixing Layer. Retrieved April, 2014 from: http://cooper.edu/events-and-exhibitions/exhibitions/emissions-images-mixing-layer

Short term impacts of methane release have not been considered

Natural gas is predominantly composed of methane (CH4), a potent greenhouse gas. The impact of greenhouse gases is determined by their Global Warming Potential (GWP). GWP is measured relative to the impact of a molecule of CO2. For example, a molecule of CH4 was previously estimated to have a GWP of 21 times that of a molecule of CO2. Molecules of CH4 and another common greenhouse gas, N2O, degrade over time; they are a more potent greenhouse gas immediately when they are emitted and their potency degrades over time. Most studies assessing the GHG impact of shale gas have employed the 100-year GWP but the 2013 IPCC Report states *"there is no scientific argument for selecting 100 years compared with other choices. The choice of time horizon is a value judgement because it depends on relative weights assigned to effects at different times*" (pg. 712).[44] The use of a GHG emissions factor for a 20-yr horizon is significantly more potent, likely eliminating the advantage of using natural gas over dirtier fuels such as coal.

Methane is more potent

The Fifth Assessment Report increased the GWP for CH4 was from 21 to 28-34 (Table 2), an increase of 33% to 64% over the 100-yr timescale, indicating that CH4 is a more damaging GHG than previously understood, with significant implications for any activity that releases CH4, including hydraulic fracturing. The implications are even more significant even the 20-yr GWP is used.

Table 2: Global Warming Potentials for three common GHGs[45]

Common name	Chemical formula	Lifetime	Global warming potentials		
				20-yr	100-yr
Carbon dioxide	CO2	variable		1	1
Methane	CH4	12.4	No cc fb	84	28
			With cc fb	86	34
Nitrous oxide	N2O	121	No cc fb	264	265
			With cc fb	298	284

Cc fb refers to climate-carbon feedback and uncertainties are large.

The case for using a 20-yr GWP is based on the immediate need to control CH4 to avoid tipping points in the climate system, particularly since CH4 release from the permafrost is more likely as global temperature exceeds 1.8^{o}C above the baseline temperature between 1890 and 1910, which would result in rapidly accelerating positive feedback of further climate change.[46] Global atmospheric CH4 concentrations were stagnant or decreasing until the late 1990s to ~2007, generating increased concern about both CH4 and its contribution to climate change and the source of CH4 emissions.[47]

An onshore industry inhibits GHG mitigation through the lock-in effect

Lock-in, or path dependence, is the idea that current decisions can limit possibilities for future decision making. . The combination of an expensive transition and the fear of forfeited investments compels one to maintain the

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[44] IPCC (2013). Anthropogenic and Natural Radiative Forcing (Chapter 8). The Physical Science Basis. Retrieved March, 2014 from: http://www.climatechange2013.org/images/report/WG1AR5_Chapter08_FINAL.pdf
[45] Ibid.
[46] Howarth, R., Santoro, R., & Ingraffea, A. (2012). Venting and leaking of methane from shale gas development: response to Cathles et al. Climatic Change. doi:10.1007/s10584-012-0401-0
[47] Frankenberg C, et al. (2011) Global column-averaged met
ane mixing ratios from 2003 to 2009 as derived from SCIAMACHY: Trends and variability. J Geophys Res 116(D4):D04302.

path of least resistance despite ongoing disadvantages.[48] For example, the long distances and distributed destinations associated with suburban landscape patterns create a dependence on personal automobiles. Alternative systems such as public transit cannot efficiently service dwellings constructed in a suburban pattern, even if there are compelling social, environmental and economic reasons for doing so.

In the case of Nova Scotia, the development of an onshore unconventional natural gas industry will result in:

- Infrastructure and technological lock-in results from large investments in pipelines, gas turbines or other infrastructure as well as smaller investments such as natural gas furnaces at the household level. These investments are made with the expectation of a certain lifetime over which to generate a return on investment.
- Financial lock-in results from investment strategies that are created, people who are dependent on the industry for work and governments that receive tax and other revenues.
- Regulatory lock-in occurs when scarce provincial and municipal government resources are invested in the development of regulatory and tax regimes to support the industry as well as the provision of subsidies.
- Political lock-in results from the combination of the other factors, as governments seek to protect their citizens from economic insecurity.

These examples and other create a momentum which means that governments, communities and politicians are less aggressive, less proactive and less responsive to policies which may undermine the industry even if it is clearly in the broader public interest to do so.

The insight of the lock-in effect is that industries such as oil and gas create a momentum that is difficult to restrict even when they cause public harm. Many jurisdictions are already engaged in the resulting and prolonged struggle, but because Nova Scotia does not have a mature industry, it is a position to avoid this struggle, a position which is strengthened by the clear indications of the risk that hydraulic fracturing poses to the climate and otherwise and that renewable energy can provide the same benefits as a natural gas industry in the near to medium future.

Climate change is a financial risk to hydraulic fracturing

In addition to the risks that climate change impacts pose for unconventional gas operations, the fossil fuel sector is increasingly vulnerable to financial risks associated with regulations and divestment campaigns. To mitigate the risk of regulations, the larger fossil fuel companies are internalising a cost of carbon in their operations in the anticipation that this cost will ultimately be imposed as society seeks to address climate change. A study from Carbon Disclosure Project found that many major companies have internalised the price of carbon as a core element in their ongoing business strategies using prices ranging from US $6-60 per tonne of CO_2e. These companies include Exxon Mobil, BP and Shell,[49] however it is unlikely that many of the shale gas companies in Nova Scotia are factoring this potential cost in their economic valuations.

The risk of climate change has not been publically reported by companies but new regulations are shifting this dynamic. On April 14th, the European Parliament voted in favour of a new law requiring corporate reporting of

[48] Liebowitz, S., & Margolis, S. (2009). Path Dependence, Lock-in and History. Journal of Law, Economics and Organisation, 11(1), 205–226.
[49] Carbon Disclosure Project (2013). Use of internal carbon price by companies as incentive and strategic planning tool. Retrieved April 2014 from: https://www.cdp.net/CDPResults/companies-carbon-pricing-2013.pdf

environmental and social impacts, recognising they will influence a company's profitability[50], and a similar standard was recently adopted by the Australian Securities Exchange. [51]

The US EPA and other federal agencies already apply an escalating cost to every tonne of CO_2 to represent the economic damages resulting from government policies and regulations. Called the Social Cost of Carbon, the incorporation of this value favours options that result in reduced or no GHG emissions and attempts to internalise the increasing cost of damage caused by climate change.[52]

Figure 6: Divestment action at University of Wisconsin

Of greater financial risk is a growing fossil fuel divestment campaign, most recently given prominence when Nobel Prize winner Archbishop Desmond Tutu came out in support comparing it directly with the apartheid boycott. [53] Another unlikely support, the President of the World Bank early in 2014 said governments and businesses should consider withdrawing funding from oil, gas and coal companies.[54] While divestment is unlikely to directly influence the financial status of shale gas companies, a report by researchers at the University of Oxford found that divestment campaigns can shift market norms and close off channels of financing for fossil fuels, result in the

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[50] European Union (2014). Non-financial reporting. Retrieved March 2014 from: http://ec.europa.eu/internal_market/accounting/non-financial_reporting/index_en.htm

[51] Carbon Disclosure Project (2014). Climate Disclosure Standard Board and CDP welcome new environmental reporting requirement from Australian Securities Exchange. Retrieved April, 2014 from: https://www.cdp.net/en-US/News/CDP%20News%20Article%20Pages/CDSB-CDP-welcome-reporting-requirement-from-ASX.aspx

[52] US EPA (2013). The Social Cost of Carbon. Retrieved April 2014 from: http://www.epa.gov/climatechange/EPAactivities/economics/scc.html

[53] Tutu, D. (2014). We need an apartheid-style boycott to save the planet. Comment article in the Guardian. Retrieved April, 2014: http://www.theguardian.com/commentisfree/2014/apr/10/divest-fossil-fuels-climate-change-keystone-xl

[54] King, E. (2014). World Bank chief backs fossil fuel divestment drive - See more at: http://www.rtcc.org/2014/01/27/world-bank-chief-backs-fossil-fuel-divestment-drive/#sthash.oZGEWkp4.dpuf

withdrawal of debt finance and create a stigma against fossil fuel companies. The stigma can then generate restrictive legislation and a compression in trading multiples.[55]

The fossil fuel industry is beginning to feel the pressure. For the first time in 2014, in response to a call from shareholders, Exxon Mobile issued a report on the risks that climate change poses to its future business[56], a sea change in approach for a company that has been actively funding disinformation campaigns on climate change for years. [57]

The financial risks of hydraulic fracturing include a variety of factors beyond climate change, the focus on this paper. A 2013 report by four different investors of 24 companies involved in shale gas found that they are providing insufficient disclosure on potential health and environment risks to enable investors to assess the risk, spurring on a number of shareholder votes relating to management of risk.[58]

As the impacts of and response to climate change increase, the financial viability of fossil fuels in general and natural gas will be at risk creating stranded assets, or assets that have suffered from premature write-downs, devaluations or conversion to liabilities. Prudent public policy is to discourage industries which are more vulnerable to becoming a stranded asset.

The final financial risk to fossil fuels in general is the decreasing cost of renewable energy (Figure 6); this is also the opportunity to address the climate risk and avoid the risk of stranded assets. Costs of crystalline silicon photovoltaic systems have fallen 57% between the second quarter of 2009 and the first quarter of 2013, onshore wind has fallen by 15%, land-fill gas by 16% and biomass gasification by 26%. As a result in an increasing number of countries large-scale hydropower, large geothermal, onshore wind and off-grid PV are the economical solution.[59]

In other words, the primary justification for natural gas as a bridge from coal to renewable energy while the costs of renewables decrease is no longer valid in many places in the world. If this is not already the case in Nova Scotia, it soon will be as the cost of renewables continues to fall.

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[55] Ansar, A., Caldecott, B. and Tilbury, J. (2014) Stranded assets and the fossil fuel divestment campaign: what does divestment mean for the valuation of fossil fuel assets? Retrieved April, 2014 from: http://www.smithschool.ox.ac.uk/research/stranded-assets/SAP-divestment-report-final.pdf

[56] ExxonMobil (2014). Climate change: Managing climate change risks. Retrieved April 2014 from: http://corporate.exxonmobil.com/en/environment/climate-change/managing-climate-change-risks

[57] Union of Concerned Scientists (2007). Smoke, mirrors and hot air: How ExxonMobil uses Big Tobacco's tactics to manufacture uncertainty on climate science. Retrieved April,2014 from: http://www.ucsusa.org/assets/documents/global_warming/exxon_report.pdf

[58] Liroff et al. (2013) Disclosing the facts: Transparency and risk in hydraulic fracturing operations. Retrieved April, 2014 from: http://disclosingthefacts.org/

[59] Intergovernmental Panel on Climate Change. 5th Assessment Report- Climate Change 2014: Mitigation of Climate Change. Chapter 7: Energy. Retrieved April, 2014 from: http://report.mitigation2014.org/drafts/final-draft-postplenary/ipcc_wg3_ar5_final-draft_postplenary_chapter7.pdf

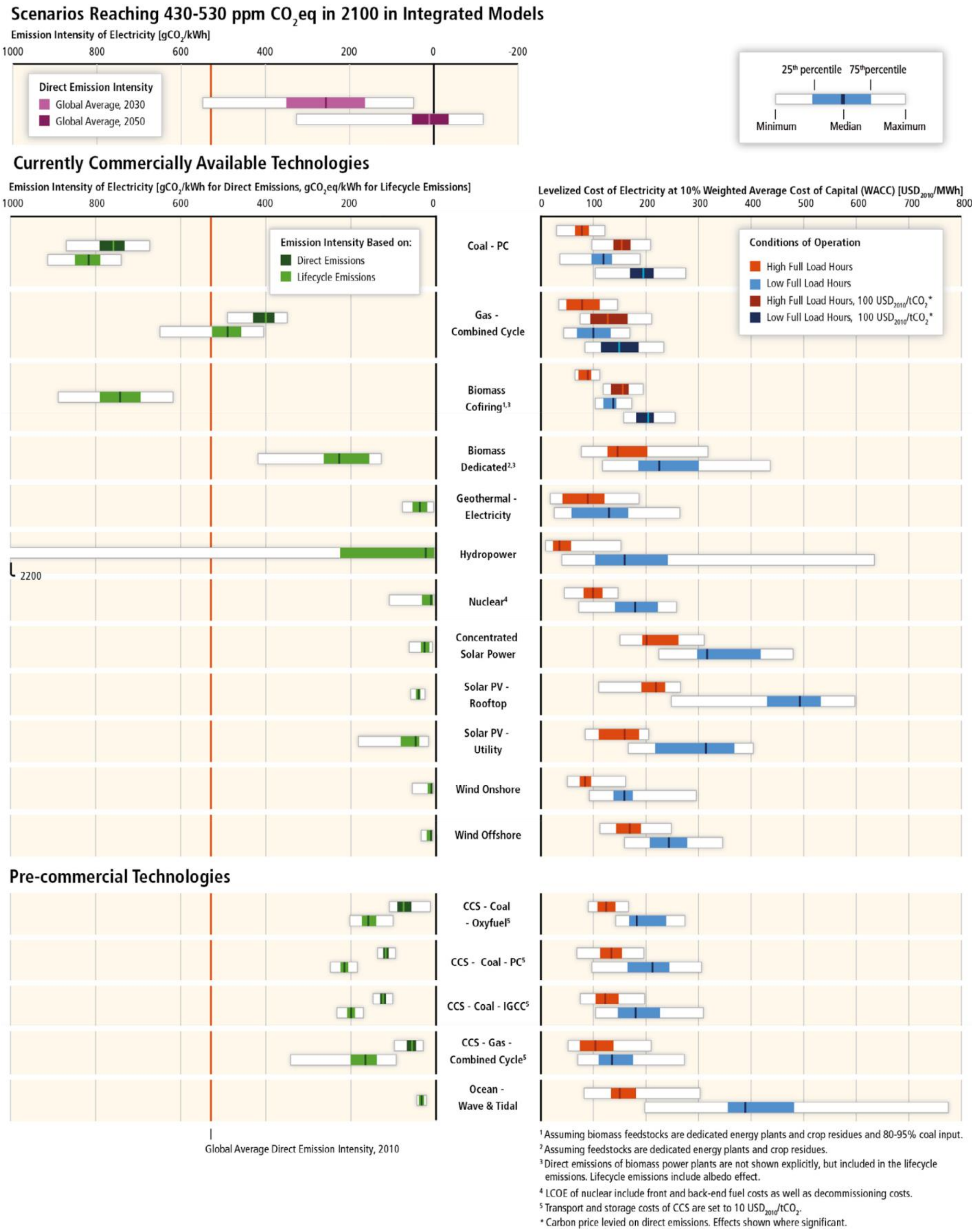

Figure 7: Private costs of power supply technologies[60]

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[60] Ibid.

The impact on Nova Scotia's climate policy

Fugitive emissions

The implications for Nova Scotia's GHG emissions are game-changing. The National Inventory Report indicated that in 2012 fugitive emissions accounted for 100 kt CO2e of a total of 19,000 kt CO2e. This number in itself seems problematic based on fugitive emissions alone that escape from pipelines and natural gas infrastructure. The following calculations will illustrate the challenge:

The US Geological Survey indicates that wells can range in production from 1-74 million m3.[61] Assuming that the Nova Scotia regulatory regime is more extensive than that in US states and the associated costs will favour more productive wells, we will explore a well of 74 million m3 (2.60 bcf). Shale gas includes additional gases such as ethane, propane, CO2 and N2, so we will assume that the unprocessed shale gas is 86% CH4.

1. 74 million m3 * 86% = 63.6 million m3 of CH4

The leakage rate varies considerably in the literature. At the lowest end, we will assume that all of the CH4 is captured during the upstream and midstream processes (green completions), but that losses occur in distribution at a rate of 1.4%[62], a rate less than the 2.68% found in Manhattan. At the highest end is a recent finding of 17.3% with significant losses occurring pre-fracking during the drilling phase.[63] In between we use estimates of 3.60% and 7.85%.[64]

2. 63.6 million m3 * 1.4%= 0.89 million m3 of CH4[65]

3. 63.6 million m3 * 3.6%= 2.29 million m3 of CH4

4. 63.6 million m3 *7.85%= 5.00 million m3 of CH4

5. 63.6 million m3 *17.3%= 11.01 million m3 of CH4

The volume of gas is converted to a mass assuming 0.76 kg/m3 and to tonnes by multiplying by a 1,000.

6. 0.89 million m3*0.76*1,000= 677 tCH4

7. 2.29 million m3*0.76*1,000= 1,741 tCH4

8. 5.00 million m3*0.76*1,000= 3,797 tCH4

9. 11.01 million m3*0.76*1,000= 8,367 tCH4

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[61] USGS (2012) - Variability of Distributions of Well-Scale Estimated Ultimate Recovery for Continuous (Unconventional) Oil and Gas Resources in the United States.

[62] Howarth, R., Santoro, R., & Ingraffea, A. (2011). Methane and the greenhouse-gas footprint of natural gas from shale formations. Climatic Change, 679–690. doi:10.1007/s10584-011-0061-5

[63] Caulton et al., (2014). Toward a better understanding and quantification of methane emissions from shale gas development. Proceedings of the National Academy of Science. Retrieved April, 2014 from: www.pnas.org/cgi/doi/10.1073/pnas.1316546111

[64] Opp. Cit.

[65] This assumes that the natural gas is consumed in Nova Scotia. If it is shipped elsewhere, the emissions associated with leakage from distribution will be divided up according to the proportion of distribution in each jurisdiction.

The tCh4 is then converted into global warming potential (GWP). As discussed above the Fifth Assessment Report recommends emissions factors of 28 and 34 for the 100 yr time span and 84 and 86 for the 20 yr timespan.

Table 3: Variation in estimate for tCO2e for a single fracked well.

		GWP			
Leakage rate	**CH4 Emissions**	**28**	**34**	**84**	**86**
	tCH4	tCO2e			
1.4%	677	18,960	23,022	56,879	58,233
3.6%	1,741	48,753	59,200	146,260	149,742
7.85%	3,797	106,309	129,090	318,928	326,522
17.3%	8,637	234,287	284,491	702,861	719,595

Table 3 indicates the order of magnitude difference resulting from different leakage rates for different wells in the natural gas system and the global warming impact of different time periods by methane. These results, which are based on real conditions, illustrate the significance of the risk from hydraulic fracking for Nova Scotia's climate policy.

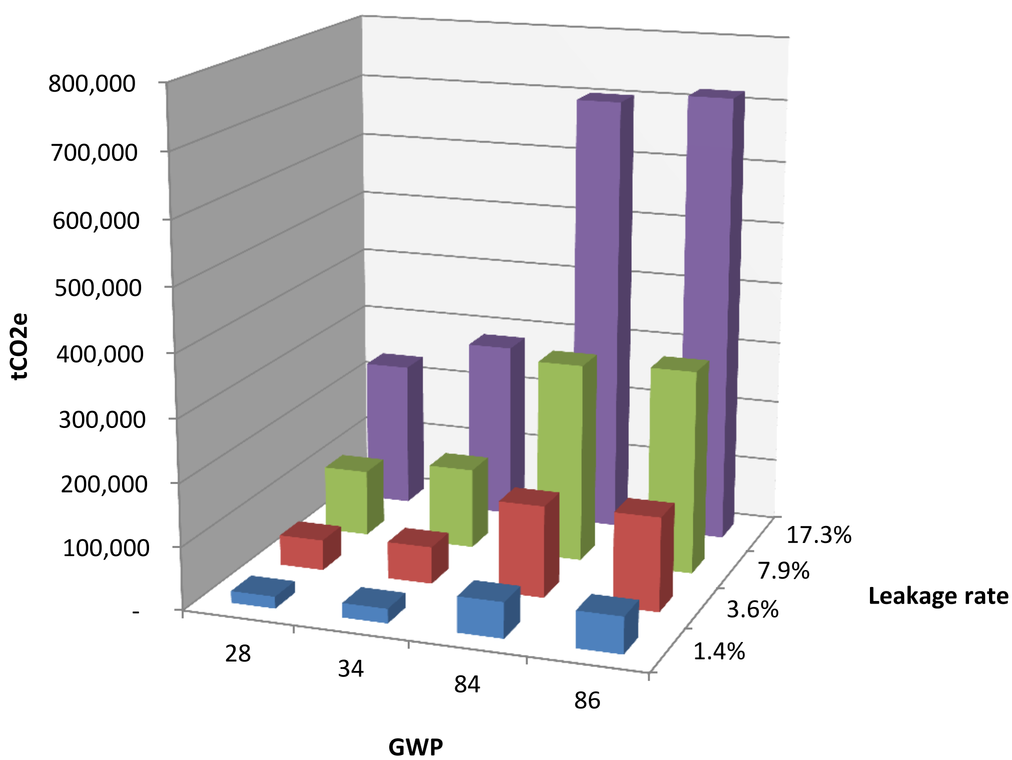

Figure 8: Illustration of GHG emissions from a single fracked well

For example, in 2012, total GHG emissions in the province were 1.97 million tCO2e below the 202 target of 20.97 million tCO2e. If a well emits 18,960 tCO2e, the province could permit 100 wells and total emissions would still be less than the 2020 target, all else being equal. If the 20 year GWP is used and leakage turns out to be higher than 1.4%, approximately 7,85% across the system, just 6 wells can be permitted without exceeding the GHG target. Or if the wells produce substantially more than 74 million m3 of gas, the CH4 emissions climb.

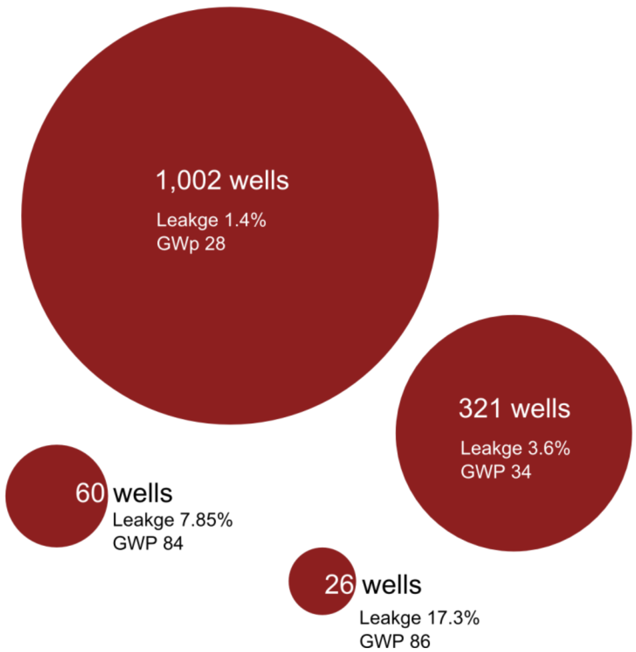

Figure 9: Number of fracked wells equivalent to 2012 total GHG emissions, Nova Scotia.

Conclusion

The Government of Nova Scotia has initiated a meaningful transition away from fossil fuels, highlighted by efforts such as the COMFIT, renewable energy targets, the Marine Renewable Energy Strategy and Efficiency Nova Scotia. These efforts are generating new employment, reducing energy consumption, reducing GHG emissions, stimulating innovation and attracting positive attention for Nova Scotia. These efforts would be negated by an onshore natural gas industry based on hydraulic fracturing,

While the Fifth Assessment Report from the IPCC discusses a potential role for natural gas, it is unequivocal that near term emissions can by reduced by switching from coal "when fugitive emissions associated with its extraction and supply are low".[66] As I have demonstrated in this paper, there is considerable uncertainty about the fugitive emissions associated with hydraulic fracturing and the natural gas system in general, with one papers released post-Fifth Assessment finding leakage 100 to 1,000 times EPA estimates.

In summary:

[66] Intergovernmental Panel on Climate Change. 5th Assessment Report- Climate Change 2014: Mitigation of Climate Change. Chapter 7, pg.6

1. The rates of methane emissions associated with natural gas systems are highly uncertain and several recent studies indicate they are significantly higher than previously assumed, meaning that there may be no GHG benefit of natural gas over other fossil fuels;
2. The development of an onshore natural gas industry will significantly increase the difficulty of a transition to a low carbon economy as a result of the lock-in effect; and
3. Renewables are already more cost effective in many parts of the world than fossil fuels and have significantly less financial and security risks associated.

The IPCC's Fifth Assessment Report states[67]:

> Bringing energy system CO2 emissions down toward zero, as is ultimately required for meeting any concentration goal, requires a switch from carbon-intensive (e.g., direct use of coal, oil, and natural gas) to low-carbon energy carriers (most prominently electricity, but also heat and hydrogen) in the end-use sectors in the long run.

Nova Scotia is on this path towards zero emissions, but the as has been demonstrated with the simple modelling, between 26 and 1,000 fracked wells would double the Province's total GHG emissions.

Two years ago UN Secretary General Ban Ki Moon gave a speech on redefining sustainable development. Ban Ki Moon talked about how economic growth has been fuelled by the abundance of natural resources. He stated "*we have mined our way to growth. We burned our prosperity. We believed in consumption without consequences. Those days are gone… Climate change is showing us that the old model is more than obsolete. It has rendered it extremely dangerous*".[68]

In September 2014, UN Secretary General Ban Ki Moon will host a summit for the world's leaders on climate change at the UN Headquarters in New York, the first of its kind, in recognition of the urgency. The Secretary General has invited leaders to bring bold pledges to kick start international negotiations that will conclude in Paris in 2015, launching a new global climate agreement under the United Nations Framework Convention on Climate Change.

The paper demonstrates that hydraulic fracturing will hinder our efforts to stop climate change, that the alternatives of renewable energy are too compelling and that the Government of Nova Scotia needs to place a moratorium on hydraulic fracturing so that we can attend those meetings in New York as a climate leader, contributing unequivocally to address the gravest challenge of our time.

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[67] Intergovernmental Panel on Climate Change. 5th Assessment Report- Climate Change 2014: Mitigation of Climate Change. Chapter 6, pg. 38.

[68] Secretary-General (2011). Twentieth-century model 'A global suicide pact', Secretary-General tells World Economic Forum session on Redefining Sustainable Development. Retrieved March, 2014 at: http://www.un.org/News/Press/docs/2011/sgsm13372.doc.htm