Notes_Fugitive-Gasses-from-Shale-Gas

Some notes compiled from some academic papers.

A bridge to nowhere: methane emissions and the greenhouse gas footprint of natural gas
Robert W. Howarth
Energy Science and Engineering 2014
(Howarth, 2014)

In response to public attention from our lectures, the EPA began to reanalyze their methane emissions [6], and in late 2010, EPA began to release updated and far higher estimates of methane emissions from the natural gas production segment (Howarth, 2014)

Because our conclusion ran counter to U.S. national energy policy and had large implications for climate change, and because the underlying data were limited and of poor quality, we stressed the urgent need for better data on methane emissions from natural gas systems. This need has since been amplified by the Inspector General of the EPA (Howarth, 2014)

While some of these offered support for our analysis, most did not and were either directly critical of our work, or without referring to our analysis reached conclusions more favorable to shale gas as a bridge fuel (Howarth, 2014)

(1) the amount of carbon dioxide that is directlyemitted
(2) the rate of methane emission from the natural gas system
(3) the global warming potential (GWP) of methane,
(4) the efficiency of use of natural gas in the energy system.
GHGfootprint
=CO2 emissions + (GWP * methane emissions)/efficiency (Howarth, 2014)

For conventional natural gas, we estimated a range of methane emissions from 1.7% to 6% (mean = 3.8%), and for shale gas a range of 3.6% to 7.9% (mean = 5.8%) [8]. We attributed the larger emissions from shale gas to venting of methane at the time that wells are completed, during the flowback period after high-volume hydraulic fracturing, (Howarth, 2014)

For upstream emissions, the revised EPA estimates gave emission factors of 1.6% (an increase from their earlier value of 0.2%) for conventional natural gas and 3.0% for shale gas (Howarth, 2014)

At least some of the differences among values in Table 1 are due more to different assumptions about the lifetime production of a shale gas well than to differences in emissions per well [18, 20]. Note that the upstream life cycle emissions are scaled to the lifetime production of a well (normalized to the methane content of the gas produced for the estimates given in Table 1), and this was very uncertain in 2011 since shale gas development is such a new phenomenon [21]. A subsequent detailed analysis by the U.S. Geological Survey has demonstrated that the mean lifetime production of unconventional gas wells is in fact lower than any of papers in Table 1 assumed [22], meaning that upstream shale gas emissions per production of the well from all of the studies should be higher, in some cases substantially so (Howarth, 2014)

relatively low estimate from Cathles et al. [17], which was based on the assumption that the gas industry would not vent gas for economic and safety issues (see critique of this in [18]), the mean of the other four studies is 1.7, or almost twice as high as the Cathles et al. [17] estimate and 20% higher than our estimate. (Howarth, 2014)

Since 2012, (….) upstream methane emission rates from unconventional gas fields (relative to gross methane production), 4% for a tight-sands field in Colorado [26] and 9% for a shale gas field in Utah (Howarth, 2014)

An important paper published late in 2013 [32] indicates the EPA made a mistake in reducing their emission estimates earlier in the year. In this analysis, the most comprehensive study to date of methane sources in the United States, Miller and colleagues used atmospheric methane monitoring data for 2007 and 2008 – 7710 observations from airplanes and 4984 from towers from across North America – together with an inverse model to assess total methane emissions nationally from all sources. They concluded that rather than reducing methane emission terms between their 2011 and 2013 inventories, EPA should have increased anthropogenic methane emission estimates, particularly for the oil and gas industry and for animal agriculture operations. They stated that methane emissions from the United States oil and gas industry are very likely two-fold greater or more than indicated by the factors EPA released in 2013 [32]. This suggests that total methane emissions from the natural gas industry were at least 3.6% in 2007 and 2008 (Fig. 2). (Howarth, 2014)

While methane is far more effective as a greenhouse gas than carbon dioxide, methane has an atmospheric lifetime of only 12 years or so, while carbon dioxide has an effective influence on atmospheric chemistry for a century or longer [34]. The time frame over which we compare the two gases is therefore critical, with methane becoming relatively less important than carbon dioxide as the timescale increases. (Howarth, 2014)

These more recent GWP values increased the relative warming of methane compared to carbon dioxide by 1.9-fold for the 20-year time period (GWP of 105 vs. 56) and by 1.6-fold for the 100-year time period (GWP of 33 vs. 21; Table 2). Our conclusion was that for the 20-year time period, shale gas had a larger GHG than coal or oil even at our low-end estimates for methane emission (Fig. 1); conventional gas also had a larger GHG than coal or oil at our mean or high-end methane emission estimates, but not at the very low-end range for methane emission (the best-case, low-emission scenario). At the 100-year timescale, the influence of methane was much diminished, yet at our high-end methane emissions, the GHG of both shale gas and conventional gas still exceeded that of coal and oil (Fig. 1). (Howarth, 2014)

The most recent synthesis report from the IPCC in 2013 on the physical science basis of global warming highlights the role of methane in global warming at multiple timescales, using GWP values for 10 years in addition to 20 and 100 years (Howarth, 2014)

At the 20-year timescale, total global emissions of methane are equivalent to over 80% of global carbon dioxide emissions. And at the 100-year timescale, current global methane emissions are equivalent to slightly less than 30% of carbon dioxide emissions [34] (Fig. 3). This difference in the time sensitivity of the climate system to methane and carbon dioxide is critical, and not widely appreciated by the policy community and even some climate scientists. (Howarth, 2014)

switching from coal to natural gas, which does reduce carbon dioxide but also increases methane emissions). One of many mechanisms for such catastrophic change is the melting of methane clathrates in the oceans or melting of permafrost in the Arctic (Howarth, 2014)

An increasing body of science is developing rapidly that emphasizes the need to consider methane's influence over the decadal timescale, and the need to reduce methane emissions (Howarth, 2014)

the production of electricity from coal versus shale gas as an example; electric-generating plants on average use heat energy from burning natural gas more efficiently than they do that from coal, and this is important although not usually dominant in comparing the GHGs of these fuels (Howarth, 2014)

Alvarez and colleagues [40] concluded that for electricity generation, the GHG of using natural gas was less than for coal for all time frames only if the rate of methane leakage was less than 3.2%.

This analysis uses the average efficiency for electric power plants currently operating in the United States, 41.8% for gas and 32.8% for coal [20]. The emissions per unit of energy produced as electricity are higher than for the heat generation alone, due to these corrections for efficiency. Although the difference in the footprintsfor using the two fuels is less for the electricity comparison than for the comparison for heat generation, at this 20-year timescale the GHG of natural gas remains greater than that of coal, even at the low-end methane emission estimate (Howarth, 2014)

American Gas Foundation (....) The report argues that an in-home natural gas appliance will have a higher efficiency in using the fuel (up to 92%) compared to the overall efficiency of producing and using electricity ("only about 40%," according to this study). However, they did not include methane emissions in their analysis, nor did they consider the extremely high efficiencies available for some electrical appliances, such as in-home air-sourced heat pumps for domestic hot water. For a given input of electricity, such heat pumps can produce 2.2-times more heat energy, since they are harvesting and concentrating heat from the local environment (Howarth, 2014)

20-year GWP, the in-home natural gas heater had a GHG that was twice as large as that of the heat pump. (Howarth, 2014)

However, in contrast to a possible advantage in replacing coal with natural gas for electricity generation (if methane emissions can be kept low enough), using natural gas to replace diesel fuel as a long-distance transportation fuel would greatly increase greenhouse emissions [29, 40]. In part, this is because the energy of natural gas is used with less efficiency than diesel in truck engines. (Howarth, 2014)

Society needs to wean itself from the addiction to fossil fuels as quickly as possible. But to replace some fossil fuels (coal, oil) with another (natural gas) will not suffice as an approach to take on global warming. Rather, we should embrace the technologies of the 21st Century, (Howarth, 2014)

Implications of Shale Gas Development for Climate Change

Richard G. Newell & Daniel Raimi
Environ. Sci. Technol. 2014
(Newell & Raimi, 2014)

amount of methane that escapes from natural gas and petroleum systems, that is from systems upstream of enduse combustion, including production, processing, and transportation of natural gas. (Newell & Raimi, 2014)

According to the 2013 EPA GHG Inventory, methane emissions from natural gas systems accounted for roughly 146 million tons of CO2e in 2011, equal to roughly 10% of all natural-gas related GHG emissions and 1.3% of gross U.S. natural gas withdrawals in 2011. (Newell & Raimi, 2014)

One study by Howarth et al.21 estimates that up to 7.9% of methane produced during the lifetime of a well escapes, negating the GHG benefits of natural gas relative to coal for electricity production. (Newell & Raimi, 2014)

Atmospheric measurements taken near oil and gas fields have suggested high methane emissions in some locations (Newell & Raimi, 2014)

But natural gas has also displaced some investment in renewables and nuclear (Newell & Raimi, 2014)

Natural gas is competing with renewables for investment dollars, as 77% of new generating capacity in 2012 came from natural gas (32%) and wind (45%). (Newell & Raimi, 2014)

One such international issue is the recent increase in U.S. coal exports. These new exports raise an important question: are GHG reductions in the United States from substituting natural gas for coal being offset by the GHG emissions arising from exported coal combusted outside the United States? (Newell & Raimi, 2014)

Allocating Methane Emissions to Natural Gas and Oil Production from Shale Formations

Daniel Zavala-Araiza, David T. Allen, Matthew Harrison, Fiji C. George and Gilbert R. Jersey
ACS Sustainable Chem. Eng. 2015
(Zavala-Araiza etal, 2015)

A key factor in assessing the greenhouse gas footprint of natural gas systems is the quantification of methane emissions. (Zavala-Araiza etal, 2015)

Methane and the greenhouse-gas footprint of natural gas from shale formations

Robert W. Howarth, Renee Santoro & Anthony Ingraffea;
Climatic Change 2011

(Howarth, Santoro & Ingraffea, 2011)

Although natural gas is promoted as a bridge fuel over the coming few decades, in part because of its presumed benefit for global warming compared to other fossil fuels, very little is known about the GHG footprint of unconventional gas. Here, we define the GHG footprint as the total GHG emissions from developing and using the gas, expressed as equivalents of carbon dioxide, per unit of energy obtained during combustion. (Howarth, Santoro & Ingraffea, 2011)

in late 2010, theU.S. Environmental Protection Agency issued a report concluding that fugitive emissions of methane from unconventional gas may be far greater than for conventional gas (EPA 2010). (Howarth, Santoro & Ingraffea, 2011)

Recent modeling indicates methane has an even greater global warming potential than previously believed, when the indirect effects of methane on atmospheric aerosols are considered. (Howarth, Santoro & Ingraffea, 2011)

The GHG footprint of shale gas consists of the direct emissions of CO2 from end use CO2 from fossil fuels used to extract, develop, and transport the gas, and methane fugitive emissions and venting. (Howarth, Santoro & Ingraffea, 2011)

new EPA (2010) report notes that the 1996 “study was conducted at a time when methane emissions were not a significant concern in the discussion about GHG emissions” and that emission factors from the 1996 report “are outdated and potentially understated for some emissions sources.” Indeed, emission factors presented in EPA (2010) are much higher, by orders of magnitude for some sources. (Howarth, Santoro & Ingraffea, 2011)

A significant amount of this water returns to the surface as flow back quantities of methane (EPA 2010). The amount of methane is far more than could be dissolved in the flow-back fluids, eflecting a mixture of fracture-return fluids and methane gas. (Howarth, Santoro & Ingraffea, 2011)

Between 0.6% and 3.2% of the life-time production of gas from wells is emitted as methane during the flow-back period. (Howarth, Santoro & Ingraffea, 2011)

More methane is emitted during “drill-out,” the stage in developing unconventional gas for production in which the plugs set to separate fracturing stages are drilled out to release gas for production. (Howarth, Santoro & Ingraffea, 2011)

Combining losses associated with flow-back fluids (1.6%) and drill out (0.33%), we estimate that 1.9%of the total production of gas from an unconventional shale-gas well is emitted as methane during well completion. (Howarth, Santoro & Ingraffea, 2011)

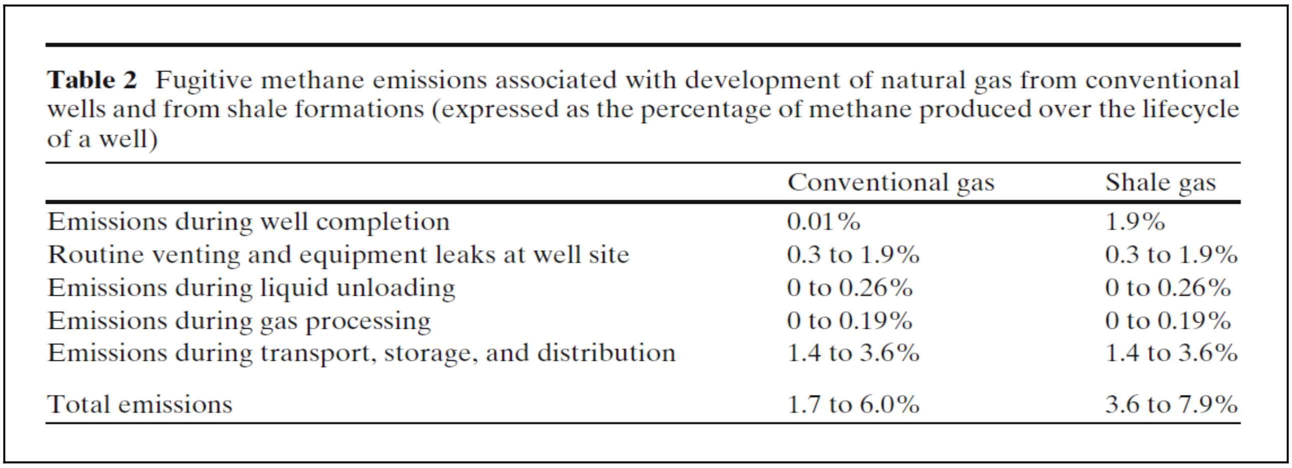


Table 2 Fugitive methane emissions associated with development of natural gas from conventional wells and from shale formations (expressed as the percentage of methane produced over the lifecycle of a well)

	Conventional gas	Shale gas
Emissions during well completion	0.01%	1.9%
Routine venting and equipment leaks at well site	0.3 to 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%

Emissions are far lower for conventional natural gas wells during completion, since conventional wells have no flow-back and no drill out. (Howarth, Santoro & Ingraffea, 2011)

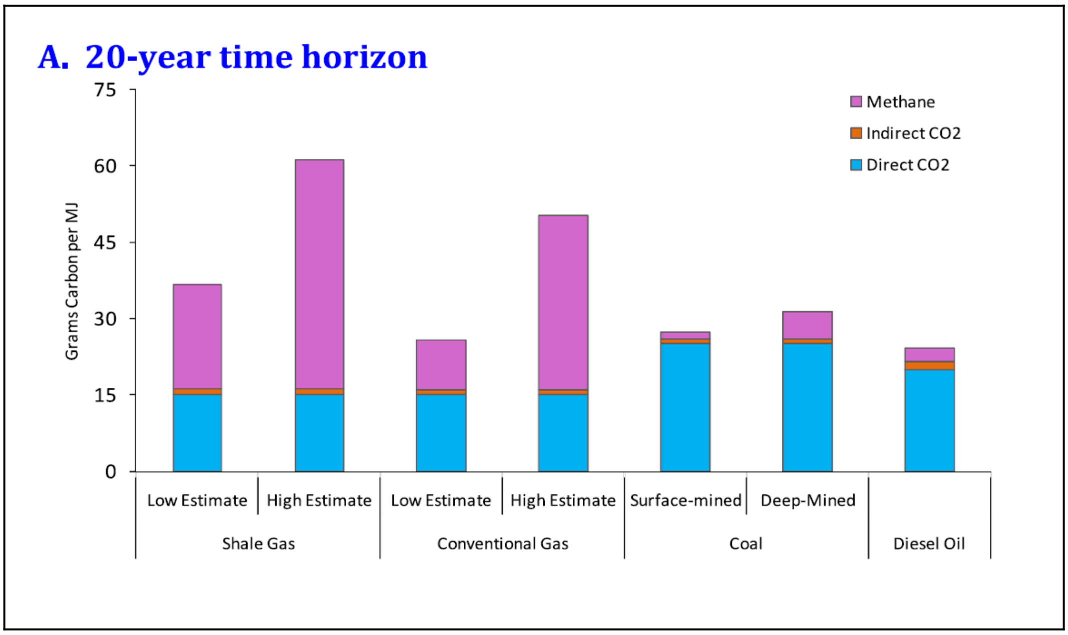
We therefore give a range of 0% (i.e. no processing, for wells that produce “pipeline ready” gas) to 0.19% of gas produced as our estimate of processing losses (Table 2). (Howarth, Santoro & Ingraffea, 2011)

Another way to estimate pipeline leakage is to examine “lost and unaccounted for gas,” e.g. the difference between themeasured volume of gas at the wellhead and that actually purchased and used by consumers. At the global scale, this method has estimated (Howarth, Santoro & Ingraffea, 2011)

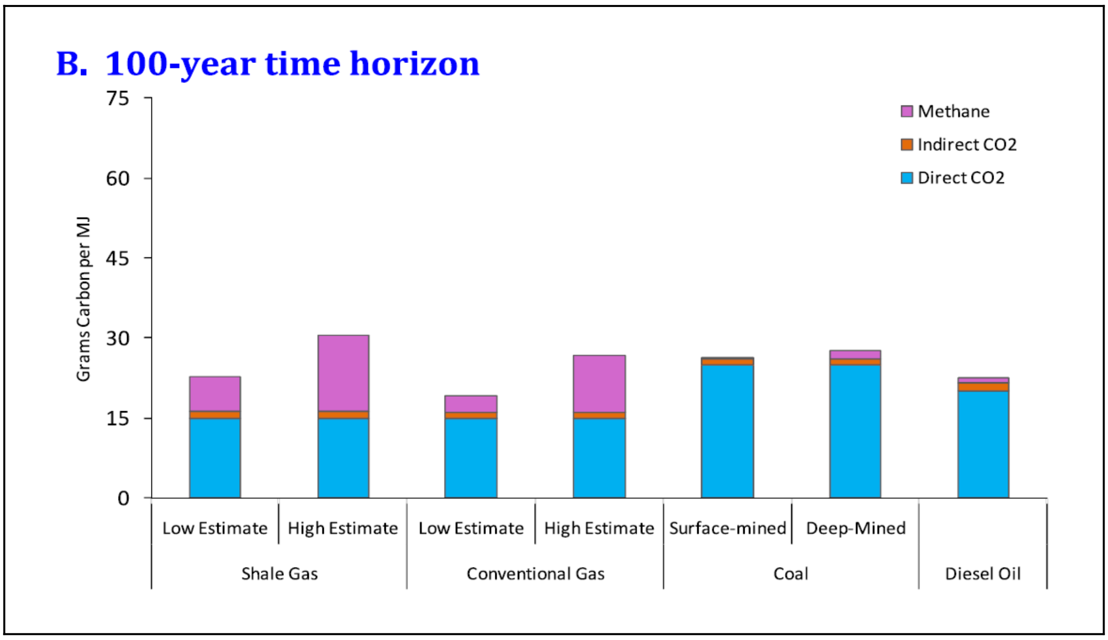
Summing all estimated losses, we calculate that during the life cycle of an average shale-gas well, 3.6 to 7.9% of the total production of the well is emitted to the atmosphere as methane (Table 2). This is at least 30% more and perhaps more than twice as great as the life-cycle methane emissions we estimate for conventional gas, 1.7% to 6%. Methane is a far more potent GHG than is CO2, but methane also has a tenfold shorter residence time in the atmosphere, so its effect on global warming attenuates more rapidly (IPCC 2007). Consequently, to compare the global warming potential of methane and CO2 requires a specific time horizon. (Howarth, Santoro & Ingraffea, 2011)

Methane dominates the GHG footprint for shale gas on the 20-year time horizon, contributing 1.4- to 3-times more than does direct CO2 emission (Fig. 1a). At this time scale, the GHG footprint for shale gas is 22% to 43% greater than that for conventional gas. When viewed at a time 100 years after the emissions (Howarth, Santoro & Ingraffea, 2011)

GHG footprint for shale gas is 14% to 19% greater than that for conventional gas   (Howarth, Santoro & Ingraffea, 2011)



A. 20-year time horizon



B. 100-year time horizon

The large GHG footprint of shale gas undercuts the logic of its use as a bridging fuel over coming decades, if the goal is to reduce global warming. We do not intend that our study be used to justify the continued use of either oil or coal, but rather to demonstrate that substituting shale gas for these other fossil fuels may not have the desired effect of mitigating climate warming. (Howarth, Santoro & Ingraffea, 2011)

Remote sensing of fugitive methane emissions from oil and gas production in North American tight geologic formations

Oliver Schneising, John P. Burrows, Russell R. Dickerson, Michael Buchwitz, Maximilian Reuter, and Heinrich Bovensmann

Earth’sFuture, Earth Future 2014

(Schneising etal, 2014)

....because the combustion of natural gas or oil produces less CO2 per unit of energy than that of coal (about 56% for gas and 79% for oil). However, the climate benefit from shifting away from coal is offset by fugitive methane release during the fracturing, production, and distribution process. (Schneising etal, 2014)

In contrast to conventiomnal gas and oil production, a sigificant amout of methane is already emeitted during the well completion. (Schneising etal, 2014)

In this manuscript, we present an analysis of column-averaged dry air mole fractions of atmospheric methane (denoted XCH4). (Schneising etal, 2014)

Figure 2 gives an overview of the long-term global XCH4 data set showing column-averaged dry air mole fractions as a function of latitude and time. The interhemispheric gradient and the seasonal cycle, as well as the renewed methane growth since about 2007 [Rigby et al., 2008; Dlugokencky et al., 2009], are all clearly detected. (Schneising etal, 2014)

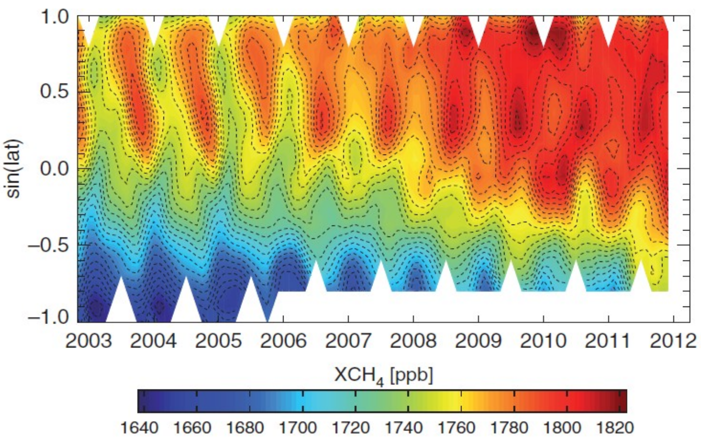


Figure 2. Overview of the long-term global satellite XCH4 data set derived from SCIAMACHY; shown are column-averaged dry air mole fractions of methane as a function of latitude and time. (Schneising etal, 2014)

Our leakage estimates are similar to the earlier results (Figure 7): 4.0% (2.3%–7.7%) for the Denver-Julesburg [Pétron et al., 2012], 8.9% (6.2%–11.7%) for the Uintah basin [Karion et al., 2013], and a possible range of 2.8%–17.3% for the Marcellus shale formation. (Schneising etal, 2014)

Venting and Leaking Methane from Shale-Gas-Development: Response to Cathles etal

Howarth & Santoro & Ingraffea
Climatic-Change 2012
(Howarth & Santoro & Ingraffea. 2012)

Promoters view shale gas as a bridge fuel that allows continued reliance on fossil fuels while reducing greenhouse gas (GHG) emissions. (Howarth & Santoro & Ingraffea. 2012)

The new estimate for methane emissions from conventional gas in the EPA (2011a) inventory, 0.38 g C MJ-1,is within the range of our estimates: 0.26 to 0.96 g C MJ-1 (Table 1). As discussed below, we believe the new EPA estimate may still be too low, due to a low estimate for emissions during gas transmission, storage, and distribution. (Howarth & Santoro & Ingraffea. 2012)

For shale gas, the estimate derived from EPA (2011a) of 0.60 g C MJ-1 is within our.estimated range of 0.55 to 1.2 g C MJ -1 (Table 1); as with conventional gas, we feel the EPA estimate may not adequately reflect methane emissions from transmission, storage, and distribution. (Howarth & Santoro & Ingraffea. 2012)

During the weeks following hydraulic fracturing, frac-return liquids flow back to the surface, accompanied by large volumes of natural gas. We estimated substantial methane venting to the atmosphere at this time, leading to a higher GHG footprint for shale gas than for conventional gas (Howarth et al. 2011). (Howarth & Santoro & Ingraffea. 2012)

According to EPA (2011d), during well cleanup following hydraulic fracturing “backflow emissions are a result of free gas being produced by the well during well cleanup event, when the well also happens to be producing liquids (mostly water) and sand. The high rate backflow, with intermittent slugs of water and sand along with free gas, is typically directed to an impoundment or vessels until the well is fully cleaned up, where the free gas vents to the atmosphere while the water and sand remain in the impoundment or vessels.” (Howarth & Santoro & Ingraffea. 2012)

The gas produced is not in solution, but rather is free-flowing with the liquid in this frothy mix. The gas cannot be put into production and sent to sales until flowback rates are sufficiently decreased to impose pipeline pressure (Howarth & Santoro & Ingraffea. 2012)

Is it unsafe for industry to vent gas during flowback, as Cathles et al. assert? Perhaps, but venting appears to be common industry practice, and the latest estimates from EPA (2011b, page 3–12) are that 85% of flowback gas from unconventional wells is vented and less than 15% flared or captured. (Howarth & Santoro & Ingraffea. 2012)

Under sufficiently high wind conditions, vented gas may be mixed and advected laterally rather than rising buoyantly, but we can envision no atmospheric conditions under which methane would sink into a layer over the ground. Buoyantly rising methane is clearly seen in Forward Looking Infra Red (FLIR) video of a Pennsylvania well during flowback (Fig. 1). (Howarth & Santoro & Ingraffea. 2012)

We estimated emissions for the Haynesville basin as the median of data given in Eckhardt et al. (2009), who reported daily rates ranging from 400,000 m3 (14 MMcf) to 960,000m3 (38 MMcf). We assumed a 10-day period for the latter part of the flowback in which gases freely flow, the mean for the other basin studies we used. (Howarth & Santoro & Ingraffea. 2012)

According to EPA (2011b), the break-even price at which the cost of capturing flowback gas equals the market value of the captured gas is slightly under $4 per thousand cubic feet. This is roughly the well head price of gas over the past two years, suggesting that indeed industry would turn a profit by capturing the gas, albeit a small one. Nonetheless, EPA (2011b) states that industry is not commonly capturing the gas, probably because the rate of economic return on investment for doing so is much lower than the normal expectation for the industry. That is, industry is more likely to use their funds for more profitable ventures than capturing and selling vented gas (EPA 2011b). There also is substantial uncertainty in the cost of capturing the gas. At least for low energy wells, a BP presentation put the cost of “green” cleanouts as 30% higher than for normal well completions (Smith 2008). The value of the captured gas would roughly pay for the process, according to BP, at the price of gas as of 2008, or approximately $6.50 per thousand cubic feet (EIA2011a). (Howarth & Santoro & Ingraffea. 2012)

To summarize, most studies conclude that methane emissions from shale gas are far higher than from conventional gas: approximately 40% higher, according to Skone et al. (2011) and using the mean values from Howarth et al. (2011), and approximately 60% higher using the estimates from EPA (2011a) and Hultman et al. (2011). (Howarth & Santoro & Ingraffea. 2012)

Emission Factors for Hydraulically Fractured Gas Wells Derived Using Well- and Battery-level Reported Data for Alberta, Canada
David R. Tyner and Matthew R. Johnson
Environ. Sci. Technol. 2014
(Tyner & Johnson, 2014)

In 2011 in the province of Alberta, there were 12 800 well legs drilled (i.e., licensed drilling events), each defined by a unique 19 well identifier (UWI) within the AER well database. A further analysis of fluid codes identified 2989 (23%) as natural gas well legs, of which 2735 were subsequently hydraulically fractured. (Tyner & Johnson, 2014)

In Alberta, well-completion flaring and venting is regulated 060,23 under AER’s Directive which specifies that all monthly flared, incinerated or vented gas volumes (i.e., raw natural gas volume at 15 °C and 101.325 kPa) of 100m3 / month or greater must be reported to the PRA. (Tyner & Johnson, 2014)

just over one-third (544 of 1579, or 34.5%) of well structures reported some degree of attributable flaring and venting during well-completion. (Tyner & Johnson, 2014)

Well-completion flaring and venting emission factors were calculated from the available nonconfidential volumetric data from the PRA representing 1208 unique well structures. Flared and vented volumes for each well structure were normalized by the number of contributing fractured UWI within that well structure, and these data were subsequently averaged by natural gas well type. (Tyner & Johnson, 2014)

Total greenhouse gas emissions from flaring and venting during well-completions in Alberta in 2011 can be estimated assuming that nonconfidential fractured UWIs are representa tive proportions of green-completions and flaring and venting rates .20 are consistent Considering IPCC AR5 greenhouse gas emission factors derived for Alberta in Table 2, this yields an estimated total GHG emission from flaring and venting during tight gas well-completions in 2011 of 147.2 ktCO2e. (Tyner & Johnson, 2014)

Capturing fugitive methane emissions from natural gas compressor buildings
R. Litto, R.E. Hayes, B. Liu
J Envir Manag 2007
(Litto & Hayes & Liu, 2007)
Methane has a shorter atmospheric lifetime than other GHGs: methane lasts around 12 years in the atmosphere, whereas carbon dioxide lasts about 120 years (IPCC , 1992). Owing to methane's high effectiveness and short atmospheric life time, stabilization of methane emissions will have an immediate impact on mitigating potential climate change. A key challenge in the reduction of GHG is the mitigation of adverse economic impacts. Because methane is a source of energy as well as GHG, its emissions reduction strategies have the potential to be low cost, or even profitable. Fugitive methane reduction has the potential to produce immediate results with minimal adverse economic effects. (Litto & Hayes & Liu, 2007)

Keeping this fact in mind, it is estimated that the main contributors to global methane emissions are agriculture (44%), landfills and biomass burning (22%), coal (12%) and the oil and gas industry (15%) (Moore et al., 1998). The 15% of emissions from the oil and gas industry equals about 47 Mt/yr (1081 Mt/yr of CO2 equivalent), using 1990/92 data (Moore et al., 1998). Overall, it has been estimated that fugitive methane emissions account for about 50% of the GHG emissions of the Canadian conventional oil and gas sector. (Litto & Hayes & Liu, 2007)

In the oil and gas sector, methane emission occurs through leakage and venting of gases during normal operations, maintenance and system upset. Here, we use the term venting to describe streams that can be isolated as concentrated streams, whereas the term leakage refers to streams that, although initially concentrated, quickly become diluted with air and are thus at very low methane concentration. Frequently, the term ''fugitive emissions'' is used to refer to low concentration or lean streams. (Litto & Hayes & Liu, 2007)

Because natural gas compressor stations are a major source of fugitive methane emission, they can provide a convenient starting point for reduction efforts. Further, because the leak sources are enclosed, there is a better chance of implementing low-cost capture methods. (Litto & Hayes & Liu, 2007)

Flares can be used for concentrated streams and for large volumes. The drawback of flares is that they are unpopular with the general public, and require the use of a support fuel if the heat content of the emission stream is not sufficiently high. (Litto & Hayes & Liu, 2007)

Methane emissions (especially fugitives) often consist of a low concentration mixture of methane and air that cannot be destroyed by conventional combustion, because their composition is outside the flammabilit limits (about 5–16% by volume for methane in air). (Litto & Hayes & Liu, 2007)

For many streams catalytic combustion is a viable option, in which a suitable catalytic reactor is used to destroy the hydrocarbons. Catalytic combustion is a flameless combus tion process that can be used to oxidize emissions that cannot sustain a conventional flame. Furthermore, catalytic combustion occurs at temperatures lower than conven tional combustion processes and thus produces fewer harmful by-products. (Litto & Hayes & Liu, 2007)

When the gas flows through the pipelines, it loses pressure owing to friction, and the gas is periodically recompressed in compressor stations, located at distances of 100–150km apart. (Litto & Hayes & Liu, 2007)

Fugitive methane emissions in the oil and gas sector are a major contributor to GHG emissions. At the same time, they are potentially much easier to reduce or eliminate than gases such as carbon dioxide, which is very expensive to capture and sequester using current technology. Fugitive emissions in natural gas compressor stations can poten tially be collected using the building itself. (Litto & Hayes & Liu, 2007)

Environmental Impacts Gas Flaring, Venting Add Up
Kris Christen
Am Chem Soc 2004
(Christen, 2004)

However, the World Bank estimates show that more than 100 billion cubic meters of gas is still flared or vented worldwide annually. (Christen, 2004)

“That’s enough fuel to cover the combined annual gas consumption of Germany and France,” (Christen, 2004)

this amount is equivalent to roughly 12% of the emissions reductions that developed countries committed to under the Kyoto Protocol (Christen, 2004)

because reporting data, when they exist, don’t distinguish between flaring, where the gas is burned and emitted as CO2, and venting, where the gas is simply released to the atmosphere as methane, (Christen, 2004)

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In general people are prepared to sacrifice four their children

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Climate change on track to make world 'uninsurable': IAG

https://www.afr.com/business/insurance/climate-change-on-track-to-make-world-uninsurable-iag-20181115-h17xu5?fbclid=IwAR228E5vr2aLplWIRtlaBAVwiwScmsKEIQ2WxAq2tiqYnAmWjGML_n-99D0
15 Nov 2018 at 11:00 PM
by **James Fernyhough**

Insurance giant IAG has warned a failure to reduce greenhouse gas emissions could result in a world that is "pretty much uninsurable", with poorer communities likely to bear the brunt of the effects.

In Australia, IAG said temperature increases of more than 3 degrees would expose greater swaths of Queensland to cyclones and flooding, while a rise of more than 4 degrees could make the risks to insurers prohibitive.

"It's a big question because it depends on reinsurance capital, but if you take some of the models that are being done on cyclone risk, for example, there could be more of Queensland exposed to cyclone and flooding in a 3-degree world," Jacki Johnson, IAG's group executive people, performance and reputation, told *The Australian Financial Review.*

*"*There is some commentary globally that in a 4-degree world, the world becomes pretty much uninsurable."

This week 16 of the world's biggest insurers, including IAG and QBE, launched an initiative with the United Nations to develop new risk assessment tools in an effort to make insurance accessible and affordable.

Participating insurers, which also include AXA, Allianz and Swiss Re, will work with climate scientists to develop a better understanding of the new and unpredictable weather events resulting from climate change.
The focus of the initiative is on responding to climate change, rather than preventing it. However, Ms Johnson said the future of insurance depended upon limiting global temperature rises, which could only be achieved by a reduction in greenhouse gas emissions.

"We have been very vocal [on the fact that] something will have to change because you cannot continue to have the carbon emissions and think that the world will be insurable," she said.

While the Paris agreement officially aims to keep global temperature rises below 1.5 degrees above pre-industrial levels, current policies would result in far higher temperature rises.

Emissions increasing
According to Climate Action Tracker, a German-government backed initiative, under current policies global temperatures are on track to rise by 3.4 degrees by the end of the century.

Will Steffen, professor emeritus at Australian National University and member of the Climate Council, predicted rises would be even higher.

"I suspect on current trajectories it will be more like 4 degrees. So we're not on a good track at all," he told *The Australian Financial Review.*

Australia's own emissions are increasing, putting it on track to fall significantly short of its own target of a 26-28 per cent reduction below 2005 levels by 2030.

The Department of the Environment and Energy projects by 2030 Australia's greenhouse gas emissions will be just 5 per cent below 2005 levels by 2030.

The United States, meanwhile, the world's second biggest greenhouse gas emitter after China, last year withdrew from the Paris agreement, and Brazil's president-elect Jair Bolsonaro has threatened to do the same, increasing the risk that temperatures will soar past 3 degrees.

The business community has increasingly got behind efforts to curb temperature rises, with even oil and gas giant Woodside's chief executive Peter Coleman this week calling for a price on carbon.

Ms Johnson said IAG did not have a view on how greenhouse gas emissions should be reduced.

"We're willing to lend our voice to the impact of climate and what has to be modelled, and what needs to be mitigated, but the actual policy settings for energy would be outside of our expertise," she said.