The 8% vs 2% Debate: Comments on selected Papers (LM Cathles April 14, 2015)

Howarth et al. (2011) suggests that gas could be twice as bad as coal because methane leakage as the gas is produced and delivered to the customer is 8% or more of production. [link]

Cathles et al. (2012) in a commentary on Howarth contend that the leakage rate is presently less than 2% of production and could be made less. [link]

Howarth et al. (2012) respond and Cathles et al. (2012b) reply.

The leakage rate has been addressed in a number of papers. We summarize the papers that have had the most impact below, together with links to more extensive discussion.

The EPA(2010) originated the notion that leakage of natural gas during well completion and workover of unconventional wells could be much greater than for conventional gas wells in a Background Technical Support Document released in 2010 entitled “Greenhouse emissions reporting from the petroleum natural gas industry”. They estimated, based on averaging 4 data points taken from industry power point presentations to the Natural Gas STAR program, that 9175 Mcf is produced during the completion of a typical unconventional gas wells. Assuming that none of this gas production is captured and 50% is flared, the EPA estimated that on average 4587 Mcf of natural gas is vented into the atmosphere during the completion of every unconventional gas well, and they assumed the same amount of gas is vented for each unconventional gas workover. In light of Harrison(2012) below, the EPA production-during-completion and venting numbers are way too high. Gas leakage during unconventional well completion and workover is probably similar to the leakage for conventional wells, and a negligible part of total leakage. The EPA makes a distinction between a Background Technical Support Document and a Report, and has stated that they have not reviewed the subject analysis in detail and continue to believe switching to natural gas would have carbon and health benefits. What was seemingly intended by the EPA to be a helpful suggestion that needed further verification (that unconventional wells leak a lot more methane during workover and well completion) has unfortunately become a fact for many workers, and this is making effective scientific discussion of the greenhouse impact of natural gas more difficult. More detailed discussion and references can be found [here](http://www.epa.gov/climatechange/emissions/downloads10/Subpart-W_TSD.pdf).

Harrison (2012) prepared a report for the Devon Energy Corporation documenting gas leakage during completion of 1578 unconventional (shale gas or tight sand) gas wells by 8 different companies with a reasonable representation across the major unconventional gas development regions of the U.S. Industry green completed 93.5% of these wells and flared 54% of the 6.5% that was not captured for sales in the green completions. Thus only 3% of the wells vented to the atmosphere during completion. The maximum average production of the wells during well completion was 765 Mscf, which is far less than the EPA's assumed 9175 Mscf/completion. The bottom line is that the Devon study indicates that the average shale gas
well vents 23 Mscf during completion, which is less than the 36.65 Mscf the EPA says is vented during the completion of a conventional well. A more detailed discussion is provided here.


Hughes (2011) corrected leakage rates in DOE study by Skone (2011) upward so that they were in better agreement with Howarth et al.’s estimates by lowering the expected ultimate recovery (EUR) of Skone's wells. All analyses (including EPA, 2010; Howarth, 2011) estimate the ratio of leakage to EUR under the (reasonable) assumption that leakage and EUR are related. A productive well should leak more gas than an unproductive well, for example. Because the numerator and denominator are related, it is not valid to lower the denominator (the EUR) to increase the percentage of leakage. More discussion is offered here.


Petron et al. (2012) analyzed air samples taken from a 300 m high tower SW of the Denver-Julesburg Basin (DJB) and inferred that the leakage of methane from gas and oil wells in the DJB was ~4% of the total methane production there. This estimate is double the 2% that industry had estimated. However, using the same data Levi (2012) pointed out that if mixing end members are selected which better distinguished wet and dry gas sources, the tower-inferred leakage rates no longer differ from the bottoms-up estimates. There is thus no indication that methane is leaking at greater rates than expected from established EPA estimation methods from this basin. Elaboration is provided here.


Karion et al. (2013) used the difference between airplane-measured upwind and downwind methane air concentrations to assess methane leakage from Uintah County, Utah, where 4800 gas and ~1000 oil wells produce ~1% or U.S. natural gas. The conditions for measurement were good and the production area isolated and well cleaned out by high winds prior to the flight. The methane venting they determined was 8.9±2.7% of production. The Uintah production has an unusually high fraction of its gas vented or flared (5% of production compared to 2.1% in the Denver-Julesburg, 2.5% in the Piceance, 0.34% in the N. San Juan, and 1.3% in the S. Can Juan). This could be a high leakage basin. The fraction of detected gas that is new and associated with production, and the fraction that is natural leakage from the basin in undetermined, however.


Allen et al. (2013). The life cycle bottoms-up estimates of mentane leakage rates associated with natural gas production and delivery by the EPA and others have been decreasing in recent years. In their 2013 analysis EPA reduced their production leakage numbers significantly (see graph and
Discussion by Hausfather and Muller here) with the result that total leakage in 2011 from production through delivery of natural gas was ~1.8% of production. To test whether leakage could be greater at production sites than EPA estimates would indicate, the Environmental Defense fund and Industry funded Allen et al. to survey 489 hydrofractured gas wells at 150 production sites representing about 2/3 of the onshore and offshore source types of U.S. gas production. The survey found much less leakage associated with completion and flowback (2.7% of what EPA estimated for wells that were hydraulically fractured). But they also found that leakage associated with chemical pumps, pneumatic controllers, and equipment leaks was greater than EPA estimated, and this largely offset the reduction in well completion and flowback leakage. On net, the U.S. leakage is reduced only very slightly (1.79 to 1.69% of production) by the revisions in emission factors suggested by the Allen et al. study. Production leakages for both Howarth’s low and high estimates (1.2 and 4.06% of production) are much higher than indicated by the latest bottom–up surveys of ~0.6%. Links to the data that indicates this and a graphical indication of it is provided here.


Caulton et al. (2014) used an instrumented aircraft to survey and measure local and regional methane emissions in a ~50 x ~50 km area of southwestern Pennsylvania and northern West Virginia. They estimated methane fluxes from current coal mining and animal husbandry (negligible) in the area as well as oil (negligible) and gas production that suggested leakages associated with natural gas production could be 22 to 62% of the total methane flux. Based on two flights with similar estimate ranges, the total methane flux measured from the 2844 km² area was between 5.7 and 42.3 kg CH₄ s⁻¹. Methane fluxes were found that were associated with 7 pads cumulatively containing ~40 wells (about 1% of the ~4000 wells in the area). The average methane flux per pad was 0.23 ± 0.04 kg CH₄ s⁻¹. All the wells that were leaking were in the initial stages of drilling (had not reached the source shale and had not been hydrofractured), and the leaking gas is believed to be coal bed methane (very pure CH₄). The rate of leakage is small compared to that which would be of global warming concern (~4% of a Howarth “Haynesville well leakage”—see discussion in Brandt et al. article just below). The combined emissions from all the leaking pads was 1.7 kg CH₄ s⁻¹, or 4 to 30% of the leakage from the 2844 km² survey area. The biggest methane emission site by far was a coal mine shaft (Caulton et al.’s Fig. 3). The regional leakage measured ranges from 2.8 to 17.3% of the known gas production from the area, and is not statistically different from the bottom–up estimates of leakage. However, the high range of emissions, the coal bed methane composition of the gas, and the surprising leakage during initial (shallow) drilling suggests that in some areas there could be more leakage during the very initial stages of drilling than expected from EPA emissions factors (no emissions are expected at this stage). More discussion is provided by Lou Derry in a Dot.earth blog posting here.

Brandt et al (2014) note the striking difference between top town (air flux surveys) and bottom up (emission factor-based) estimates of methane leakage and compile existing U.S. data as a ratio of measured natural gas production-related emissions to those expected from EPA bottoms up estimates. They find that the leakage rates estimated from top-down methods are about 50% greater than bottoms up estimates, and the pose a “fat tail” thought experiment to probe whether this extra leakage could be coming from a few bad leaky wells or pipelines. They conclude that the heavy tail “represents an opportunity for large mitigation benefits” but caution “hydraulic fracturing for NG is unlikely to be a dominant contributor to total emissions.” Their message is important but stated in such a muted fashion that many have missed their intended point. In fact, if associated with gas production processes, the fat tail leakages are so preposterous (the fat tail would require 700 gas wells leaking at a rate so dangerous that they would certainly have been noticed and complete emptying of a 4 ft diameter 100 psi gas pipeline 9,000 miles long every year) that the strong message of the fat tail thought experiment can only be that, if the top down venting is real, it must be coming essentially entirely from sources not associated with gas production. Discussion is provided here which includes an email from the lead authors that they agree with the summary just given.


Howarth (2014) reviews recent data and his arguments that methane leakage could be so great that it provides no suitable bridge to a desirable energy future. He concluded that CO₂ controls future climate “unless the emissions of methane lead to tipping points and a fundamental change in the climate system”, and asks “Given the sensitivity of the global climate system to methane, why take any risk with continuing to use natural gas at all?” The counter-answer is, of course, that the world should take advantage of methane if it reduces the intensity and risk of climate change.

The scientific crux of the paper is whether or not methane use will increase or decrease tipping point risk. Howarth comments at length on a figure in the IPCC (2013) report that shows CO₂-equivalent emissions of methane are slightly higher than CO₂ on a 10 year timescale, stating “the current global release of methane from all sources exceeds (slightly) all carbon dioxide emissions as agents of global warming; that is, methane emissions are more important (slightly) than carbon dioxide emissions for driving the current rate of global warming.” This statement is not correct and represents a fundamental misunderstanding of what controls methane concentrations in the atmosphere. The sources and sinks of methane are presently nearly in balance. This means that nearly as much methane is removed from the atmosphere each year as enters it. The yearly CO₂-equivalent emissions are nearly balanced by almost equal CO2-equivalent sinks. It is yearly increases in methane emissions, not the level of the emissions, that could cause methane concentrations in the atmosphere to increase, and this greenhouse forcing is much smaller. This issue is discussed at length here.

Howarth reports that models by Shindell et al. (2012) predict that “unless emissions of methane are reduced immediately, the Earth’s average surface temperature will warm by 1.5°C by about 2030 and by 2.0°C by 2045 to 2050 whether or not carbon dioxide emissions are reduced.” This suggests methane is a risk in itself, but the point of Shindell’s paper is that, because the concentration of methane in the
atmosphere responds so quickly to changes in methane emission rates, controlling methane presents an opportunity to reduce greenhouse forcing. Shindell calculates that reducing methane emissions by 140 Tg yr\(^{-1}\) could reduce warming by ~0.5°C and I have verified his suggestion here.

Howarth’s tipping point argument is flawed. The important thing is how much human actions can change the peak anthropogenic forcing. Below this reduced peak human actions will simply delay of accelerate when the world reached some degree of warming. Any tipping point will arrive slightly sooner or later, but not be avoided. Reducing the peak warming is the sole benefit to be had, and there is consensus that the peak warming will be reduced by substituting gas for the other fossil fuels if the leakage is less than ~9% of consumption (see discussion here).

Despite Howarth’s arguments, methane presents the biggest and best opportunity we have to reduce greenhouse warming. The question is not “Why take the risk?” but “Why not take the opportunity?”

http://onlinelibrary.wiley.com/doi/10.1002/ese3.35/abstract;jsessionid=D9EA215506FD37FF01FEF2E04CD8E3B8.f04t01

http://www.sciencemag.org/content/335/6065/183.abstract

Ingraffea et al. (2014) use compliance reports to the Department of Environmental Protection in Pennsylvania to examine more than 41,000 conventional and unconventional oil and gas wells to statistically assess casing and cement impairment. They find that the records indicate 0.7 to 9.1% of the wells show compromised cement and/or casing integrity. They state further that “Hazard modeling suggests that the cumulative loss of structural integrity in wells across the state may actually be slightly higher than this, and upward of 12% for unconventional wells drilled since January 2009”. They suggest leaking wells are one possible primary mechanism of methane emissions, but indicate more studies are needed to quantify well leakage.

http://www.pnas.org/cgi/ijlink?linkType=ABST&journalCode=pnas&resid=111/30/10955

http://www.pnas.org/content/111/30/10902.full. (2 page review of Ingraffea paper).
**King and King (2013)** present a detailed analysis of the environmental risks in well construction, distinguishing from the start between barrier and well failure. Reviewing data sets from over 600,000 wells worldwide they find that single barrier failures can occur in several percent of wells and sometimes more, but integrity failures occur 100 to 1000 times less frequently because wells are engineered with multiple barriers and many single barrier failures are fixed when breach is detected. Gas bubbling around newly drilled wells is not uncommonly observed, but is the temporary venting of shallow gas liberated by the ground disturbance associated with drilling as occurs also when water wells are drilled. Natural seepage is common in hydrocarbon producing areas and needs also to be taken into account. They conclude that the percentage of wells that are in service that leak is between 0.03 and 0.005%.

**Comment:** Only new leakage counts for greenhouse forcing. The leakage from old wells will have already been factored into the industrial era rise in atmospheric methane concentration, and their leakage, if significant, is presumably decreasing. New methane leakage associated with new drilling is what will count, and it appears from the above that multiple barriers can more than adequately contain potential future leakage. To prevent leakage permanently wells could be filled with sand. Capillary barriers would then prevent any leakage.

**Schneising et al (2014)**

Determined the difference in the rate of methane leakage over the entire U.S. for the period between 2002 to 2008 and the period between 2009 and 2011. The leakage rate increased in the Bakken and Eagle Ford, two areas where the production rate had increased markedly. The ratio of the increased leakage to the increased production in these areas was 10.1±7.3% and 9.1±6.2% respectively. Areas where production had not increased showed no increase in methane leakage.

**Comment:** The one-sigma error bars are large on the new leakage as a percent of new production estimates. The high marginal leakage is probably a transient associated with disturbance related to drilling. If so it should decay rapidly, reducing its suggested the top-down versus bottom-up discrepancy. But even if the additional leakage is associated with additional production, the ratio these two quantities is terribly misleading. Gas production in any well decays very quickly in the first few years of production. Unless a field has constant new drilling and production its output will decline. Suppose that the drilling is just such that the field production is kept constant. The new field production is then zero and if there is extra leakage associated with the new drilling, the ratio of the change in leakage to the change in production will be infinite (something divided by zero is infinity). Schneising et al.’s leakage of 10% of new production is a meaningless ratio for estimating methane
leakage. Analysis that takes into account the decline in production of old wells is needed for sensible inferences to be made.

My Summary as of November 3, 2014
1. Top down estimates of methane leakage are about 50% greater than bottom’s up estimates (Brandt et al., 2014; see summary above).
2. This difference cannot be emissions directly related to gas recovery because the required leakages are unreasonably large (Brandt et al., 2014; see summary above).
3. The discrepancy, if real, most likely is due to natural leakage in areas where gas is being recovered. If this leakage is either stimulated by past drilling, or is natural (not stimulated by human activities), it is already accounted for by the rise in methane levels since 1750 AD. Discussion here.
4. Only if methane leakage is stimulated by new human activities (such as new drilling) could it produce additional greenhouse warming. (See Coulton et al., 2014 review above).
5. Decreasing fossil fuel or agricultural methane emissions is an opportunity to decrease greenhouse forcing (Schindell et al. in Howarth 2014 discussion above and discussion here).
6. Substituting natural gas for coal and some oil will reduce greenhouse forcing and will reduce tipping point risks unless the leakage associated with natural gas production is greater than 14% of consumption. (See very brief discussion and links here).

Papers post November 3, 2014

Schwietzke et al. (2014)
Three decades of global methane and ethane measurements are used to estimate the fraction of produced natural gas that is released to the atmosphere (FER). It finds an upper bound on FER from 2006-2011 of 5% of natural gas production, and a likely FER since 2000 of 2 to 4% of production and trending downward. Natural hydrocarbon seepage would lower these estimates.


Peischl et al. (2015)
Using airplane surveying methods, these authors measured atmospheric methane emission rates from 3 regions (the Haynesville shale play in Tx and La, the Fayetteville shale play in central Ark, and the Marcellus shale play in northeastern Pa) that account for over half of the unconventional U.S. natural gas production and ~20% of the total U.S. natural gas production. The found weighted average methane emission rate of these areas was 1.1% of production, which is compatible with 2013 EPA bottom-up estimates as shown in the table below. The 1.1% of production site emissions correspond to the EPA bottom up emissions during field production and processing and the near site transmission losses, assumed to be half the total. These site emissions represent ~65% of the total. The remaining 35% of
the EPA total emissions of 1.79% of production occur during transmission and distribution further from the production site.

Table 1. Summary of leakage rates from Pieschl et al (2015)

<table>
<thead>
<tr>
<th>Basin</th>
<th>Leakage Rate [% of area production]</th>
<th>Production [% of U.S total]</th>
<th>Author</th>
</tr>
</thead>
<tbody>
<tr>
<td>Denver-Julesberg</td>
<td>3.1-5.3</td>
<td>0.9</td>
<td>Petron et al (2012)</td>
</tr>
<tr>
<td>&quot;</td>
<td>4.1±1.5</td>
<td>0.9</td>
<td>Petron et al (2014)</td>
</tr>
<tr>
<td>Unita</td>
<td>6.2-11.7</td>
<td>1.0</td>
<td>Karion et al (2013)</td>
</tr>
<tr>
<td>Los Angeles</td>
<td>17±5</td>
<td>0.05</td>
<td>Pieschl et al (2013)</td>
</tr>
<tr>
<td>Marcellus SW Pa</td>
<td>2.8-17.3</td>
<td>2.7</td>
<td>Caulton et al (2014)</td>
</tr>
<tr>
<td>Haynesville (Tx and La)</td>
<td>1.0-2.1</td>
<td>6.9</td>
<td>Peischl et al (2015)</td>
</tr>
<tr>
<td>Fayetteville (Ark)</td>
<td>1.0-2.8</td>
<td>3.4</td>
<td>&quot;</td>
</tr>
<tr>
<td>Marcellus NE Pa</td>
<td>0.18-0.41</td>
<td>8.0</td>
<td>&quot;</td>
</tr>
<tr>
<td>Production-weighted average of Haynesville, Fayetteville and Marcellus</td>
<td>1.1</td>
<td>20</td>
<td>&quot;</td>
</tr>
</tbody>
</table>

Table 2. Bottom-up EPA(2013) estimates of natural gas methane leakage in 2011 compared to Peischl top down

<table>
<thead>
<tr>
<th>Leakage</th>
<th>Percent of production</th>
<th>Combining for comparison to Peischl et al.</th>
<th>% of total leakage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field production</td>
<td>0.66%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Processing</td>
<td>0.24%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transmission and Storage</td>
<td>0.54%</td>
<td>Fld+Proc+50%T&amp;S = 1.17%</td>
<td>65%</td>
</tr>
<tr>
<td>Distribution</td>
<td>0.34%</td>
<td>50% T&amp;S+Distrib = 0.61%</td>
<td>35%</td>
</tr>
<tr>
<td>Total</td>
<td>1.79%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Conclusions as of April 14, 2015

These last two papers show that there may be very little difference between the top-down and bottom-up estimates of methane leakage as a fraction of total natural gas production. Schweitzke et al. (2014) show trends in methane and ethane in the atmosphere suggest the natural gas leakage since 2000 AD was ~3% of natural gas production and trending down, which is precisely what the EPA has been estimating. Peischl et al (2015) show that the top down weighted average of fields representing 20% of the total (and >50% of the unconventional) U.S. natural gas production is nearly exactly what EPA would estimate for basin-scale leakage (1.1% of production or ~65% of the EPA estimated total leakage of 1.79%). The 8% vs 2% debate seems to be resolved in favor of the 2%.