Briefing on the scientific evidence regarding the impacts of methane leaks from Hydraulic Fracturing (Shale Gas)

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1. Introduction

This briefing is based on research papers published in respected academic journals. Please refer to references at the bottom for exact sources cited. Most of the studies below relate to evidence in the USA, since it has a very high concentration of operational as well as abandoned shale gas (further referred to as fracking) sites.

Natural gas extracted by either conventional or hydraulic fracturing contains methane (CH_4), along with smaller amount of alkanes (e.g. ethane, propane), Nitrogen (N_2) and Carbon Dioxide (CO_2) (Peischl *et al.*, 2015).

2. What do studies say about Methane leaks to the atmosphere?

Studies show that unwanted methane leakage to the atmosphere occurs from both conventional gas extraction and from fracking methods. Methane emissions released to the atmosphere are problematic for a number of reasons. Firstly Methane (CH_4) is recognised to be 84 times more powerful as a greenhouse gas than Carbon Dioxide on a 20 time horizon (Myhre *et al.*, 2013, p. 714), as such **methane release makes a significant contribution to climate change**. Secondly Methane leakage from fracking sites **may pose a safety and air pollution hazard** (Karion *et al.*, 2013).

A number of USA studies have reported on atmospheric methane releases from fracking operations. The key findings were as follows:

Allen et al. (2013) found that:

- Methane emissions emanating from equipment leaks and pneumatic controllers were higher than emissions figures held by the regulator the EPA.

Brandt et al. (2014) found that:

- Official government figures have consistently underestimated methane emissions from leaks.
- A small number of gas well sites emit a disproportionately large amount of methane and have been termed 'super emitters'.
- Disused/abandoned wells are likely to be a significant source of methane emissions.
- There are significant benefits to preventing methane leakage.

Karion et al (2013) found that:

- Methane leakage from one fracking region was equivalent to between **6.2 - 11.7%**[1] (8.9% median value) of the hourly natural gas production of the region; methane leakage sources were: fractured wells, compressors and processing plant.
- Production figures suggest that above leakage rates are fairly typical and unlikely to varying much from one day to the next.
- Gas leakage is around 80% higher than US government figures show.

Howarth, Santoro and Ingraffea (2011) found that:

- **Methane leaks to the atmosphere from hydraulic fracturing operations are 30% - 100% higher (by volume) than methane leaks from conventional gas extraction**.
- The reason being that during fracking, methane is released from the flow back fluid and during 'drill out' after fracturing. Drill out is the process of drilling out plugs used to separate fracturing stages in order to release the gas. This process doesn't occur in conventional gas extraction.
- That between 3.6 – 7.9% of methane gas is lost via leakage for the shale gas process as a whole (i.e. from extraction to distribution) see Figure 1 below; of this 2.2 – 4.06% (of total production gas) leaks at well sites during various processes: well completion, routine gas venting, equipment leaks and emissions during liquid unloading.

Peischl et al (2015) investigated:

- Methane leaks in 3 major shale gas regions in the USA.
- Methane leaks (expressed as a percentage of production) were found to be 1.0% - 2.1% in Haynesville, 1.0 – 2.8% in Fayetteville region and 0.18 – 0.41% in the Marcellus region. The first two sites show similar results to those found by Howarth et al (2011).
- The quantities of methane equate to 80 tonnes/hour (Haynesville), 39 tonnes/hour (Fayetteville) and 15 tonnes/hour (Marcellus).
- They compared their results to four other studies, leakage rates of the studies ranged from 0.3% to 8.9%, (see Figure 2 below).

Process	**Conventional gas**	**Shale gas (fracking)**
Emissions during well completion	0.01%	**1.9%**
Routine venting and equipment leaks at well site	0.3 – 1.9%	0.3 – 1.9%
Emissions during liquid unloading	0 – 0.26%	0 – 0.26%
Emissions during gas processing	0 – 0.19%	0 – 0.19%
Emissions during transport, storage, and distribution	1.4 – 3.6%	1.4 – 3.6%
Total emissions	1.7 – 6%	3.6 – 7.9%

Figure 1: Methane emissions released into the atmosphere from conventional Vs shale gas processes (as the percentage of methane produced over well lifecycle) (Howarth, Santoro and Ingraffea, 2011, p. 683).

[1] **Technical note:** where methane leakage is expressed as a percentage this always refers to emissions as a percentage of natural gas produced for distribution, unless otherwise stated.

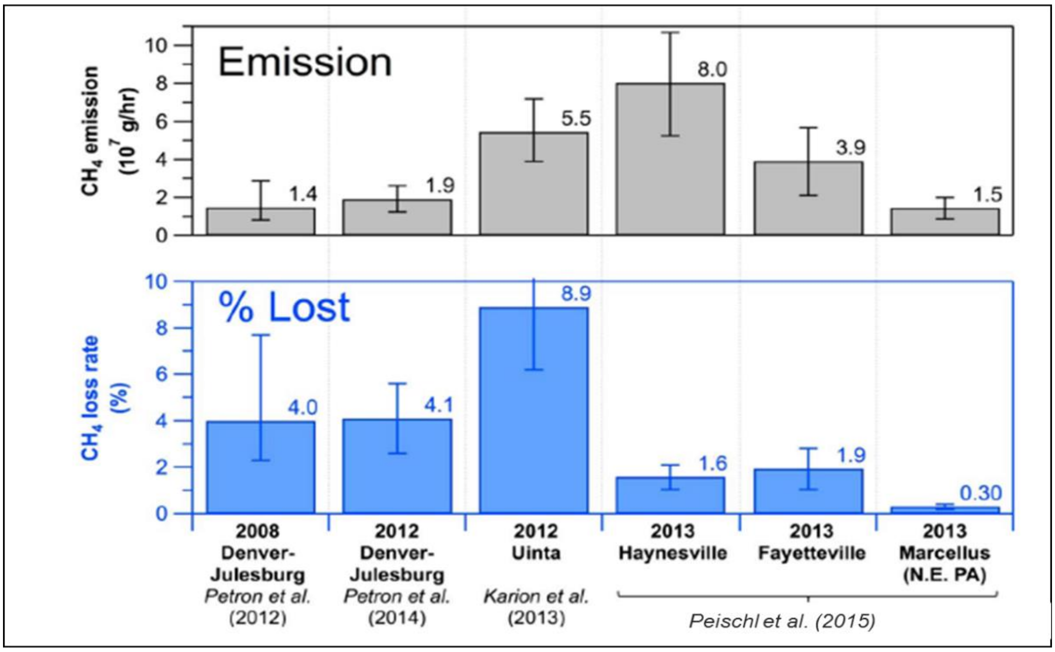

Figure 2: Methane emission quantities and % loss rate (expressed as % of overall production output) from oil and gas producing regions in the USA (Peischl et al., 2015, p. 2137).
Note: 10^7 g/hour is 10 tonnes per hour, so Haynesville emitted 80 tonnes of methane per hour.

Petron et al (2014) found that:

- Methane leakage was 19.3 tonnes per hour at their study site.
- Methane leakage was 3 times higher the Environmental Protection Agency (EPA) figures for the site.
- **Benzene a known carcinogenic compound was being released to the atmosphere by shale oil and gas extraction operations at a rate of 173 Kg/hour.**
- 75% of the methane measured in the study area was emanating from oil and gas extraction.

Caulton et al (2014) found that:

- The methane leakage from seven well pads which were in the drilling phase was between 100 and 1000 times higher than the EPA estimates from the extraction process.
- The leakage rate found was 3 – 17% (expressed as % of overall production output).
- **High methane leakage rates are likely to be an issue of national significance.**
- **There is an urgent need to identify and prevent methane leaks.**

3. What do these studies tell us?

1. Methane leakage is being significantly underestimated by EPA and US government figures.
2. Methane leaks from fracking are higher than from conventional gas extraction, due to the differing processes used in fracking.
3. Methane leakage is an inevitable side effect of fracking.
4. Across the studies leakage rates (as a percentage of production) range from 0.18% - 17%.
5. Disused/abandoned ‘fracked’ wells may leak significant amounts of methane.
6. Methane leakage could pose a safety and air pollution risk.
7. Methane leakage has significant consequences for climate change.

4. Methane implications for energy policy & climate change

A 2009 study found that we have already exceeded a safe planetary boundary in terms of climate change (Rockström *et al.*, 2009). A safe concentration of carbon dioxide in the atmosphere is 350ppm (parts per million) (Rockström *et al.*, 2009), current concentrations of carbon dioxide are 402ppm (NOAA, 2016), so significantly above safe levels. The authors warn that going beyond the safe 350ppm levels:

Risk irreversible climate change, such as the loss of major ice sheets, accelerated sea level rise and abrupt shifts in forest and agricultural systems.(Rockström *et al.*, 2009, p. 473)

As such mitigation of greenhouse gas emissions is an urgent priority.

Given that methane is a very powerful greenhouse gas, particularly over a 20 year time horizon (Myhre *et al.*, 2013) leaks from fracking operations are a significant cause for concern. One well referenced study states that methane leakage from extraction, production and distribution can offset the climate benefit of using natural gas for power generation (Alvarez *et al.*, 2012)

If methane leakage from extraction, production and distribution exceeds 3.2%, then it is worse than coal in terms of climate impact, when used for power generation *(Alvarez et al., 2012).*

Howarth, Santoro and Ingraffea (2011) conclude that climate change impact of shale gas is >20% than coal, and on a 100 year horizon it is at equivalent to coal in terms of climate impact.

In carbon emission terms the case has also been made against utilising more gas in the UK. The government's gas strategy which proposed an expansion of gas was described by the Committee on Climate Change (the government's official advisers in climate change) as follows:

This would not be economically sensible, and would entail unnecessary costs and price increases. Neither would it be compatible with meeting carbon budgets and the 2050 target…Early decarbonisation of the power sector should be plan A – and the dash for gas Plan Z. (Committee on Climate Change, 2012).

Given that a number of studies above have found leakage rates at well sites to be in excess of the 3.2% critical benchmark, it is extremely questionable whether natural gas from fracking can be justified as a 'low carbon bridge fuel'.

5. Implications of the research

- Given the scale of methane leakage found at sites in the USA and its potential to exacerbate climate change, why does the Department of Energy and Climate Change (DECC) believe gas from hydraulic fracturing is a 'low carbon bridging fuel'?
- Will the government and/or companies undertaking hydraulic fracturing fund independent scientists to monitor their sites for methane leakage into the air and ground water? And will they allow public access to this data?
- How will hydraulic fracturing companies prevent safety and air pollution hazards from methane emissions?
- For how long are hydraulic fracturing companies responsible for the maintenance of 'abandoned' wells in order to ensure they are not leaking methane?

Terms

Term	Explanation
Drill out	A technique used in hydraulic fracturing where plugs which are used to separate fracturing stages are drilled out to release the natural gas (Howarth, Santoro and Ingraffea, 2011)
EPA	Environmental Protection Agency, the US equivalent of the environment agency
Flow back fluids	Chemicals and water which flow back to the surface after it has been hydraulically fractured (Howarth, Santoro and Ingraffea, 2011).
Routine gas venting	High pressure release of natural gas (including methane) directly to the atmosphere (OGP, 2000)

References

Allen, D. T., Torres, V. M., Thomas, J., Sullivan, D. W., Harrison, M., Hendler, A., Herndon, S. C., Kolb, C. E., Fraser, M. P., Hill, A. D. and others (2013) 'Measurements of methane emissions at natural gas production sites in the United States', *Proceedings of the National Academy of Sciences*, 110(44), pp. 17768–17773. Available at: http://www.pnas.org/content/110/44/17768.short (Accessed: 19 January 2016).

Alvarez, R. A., Pacala, S. W., Winebrake, J. J., Chameides, W. L. and Hamburg, S. P. (2012) 'Greater focus needed on methane leakage from natural gas infrastructure', *Proceedings of the National Academy of Sciences*, 109(17), pp. 6435–6440. Available at: http://www.pnas.org/content/early/2012/04/02/1202407109.short (Accessed: 20 January 2016).

Brandt, A. R., Heath, G. A., Kort, E. A., O'Sullivan, F., Pétron, G., Jordaan, S. M., Tans, P., Wilcox, J., Gopstein, A. M., Arent, D. and others (2014) 'Methane leaks from North American natural gas systems', *Science*, 343(6172), pp. 733–735. Available at: http://psb.vermont.gov/sites/psb/files/CLF-SC-2%20Science-Methane%20Leaks.pdf (Accessed: 20 January 2016).

Caulton, D. R., Shepson, P. B., Santoro, R. L., Sparks, J. P., Howarth, R. W., Ingraffea, A. R., Cambaliza, M. O. L., Sweeney, C., Karion, A., Davis, K. J., Stirm, B. H., Montzka, S. A. and Miller, B. R. (2014) 'Toward a better understanding and quantification of methane emissions from shale gas development', *Proceedings of the National Academy of Sciences*, 111(17), pp. 6237–6242. doi: 10.1073/pnas.1316546111.

Committee on Climate Change (2012) *CCC says early decarbonisation of the power sector should be plan A – and the dash for gas Plan Z – 5 December 2012*. Available at: https://www.theccc.org.uk/2012/12/05/ccc-says-early-decarbonisation-of-the-power-sector-should-be-plan-a-and-the-dash-for-gas-plan-z/ (Accessed: 21 January 2016).

Howarth, R. W., Santoro, R. and Ingraffea, A. (2011) 'Methane and the greenhouse-gas footprint of natural gas from shale formations', *Climatic Change*, 106(4), pp. 679–690. doi: 10.1007/s10584-011-0061-5.

Karion, A., Sweeney, C., Pétron, G., Frost, G., Michael Hardesty, R., Kofler, J., Miller, B. R., Newberger, T., Wolter, S., Banta, R., Brewer, A., Dlugokencky, E., Lang, P., Montzka, S. A., Schnell, R., Tans, P., Trainer, M., Zamora, R. and Conley, S. (2013) 'Methane emissions estimate from airborne measurements over a western United States natural gas field', *Geophysical Research Letters*, 40(16), pp. 4393–4397. doi: 10.1002/grl.50811.

Myhre, G., Shindell, D., Bréon, F. M., Collins, W., Fuglestvedt, J., Huang, J., Koch, D., Lamarque, J. F., Lee, D., Mendoza, B. and others (2013) 'Anthropogenic and Natural Radiative Forcing', in Stocker, T. F., Qin, D., Plattner, G.-K., Tignor, M., Allen, S. K., Boschung, J., Nauels, A., Xia, Y., Bex, V., and

Midgley, P. M. (eds) *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge and New York: Cambridge University Press.

NOAA (2016) *ESRL Global Monitoring Division - Global Greenhouse Gas Reference Network*. Available at: http://www.esrl.noaa.gov/gmd/ccgg/trends/ (Accessed: 21 January 2016).

OGP (2000) *Flaring & venting in the oil & gas exploration & production industry. An overview of purpose, quantities, issues, practices and trends*. London and Brussells: International Association of Oil and Gas Producers Publications. Available at: http://www.ogp.org.uk/pubs/288.pdf (Accessed: 21 January 2016).

Peischl, J., Ryerson, T. B., Aikin, K. C., de Gouw, J. A., Gilman, J. B., Holloway, J. S., Lerner, B. M., Nadkarni, R., Neuman, J. A., Nowak, J. B., Trainer, M., Warneke, C. and Parrish, D. D. (2015) ‘Quantifying atmospheric methane emissions from the Haynesville, Fayetteville, and northeastern Marcellus shale gas production regions’, *Journal of Geophysical Research: Atmospheres*, 120(5), p. 2014JD022697. doi: 10.1002/2014JD022697.

Pétron, G., Karion, A., Sweeney, C., Miller, B. R., Montzka, S. A., Frost, G. J., Trainer, M., Tans, P., Andrews, A., Kofler, J., Helmig, D., Guenther, D., Dlugokencky, E., Lang, P., Newberger, T., Wolter, S., Hall, B., Novelli, P., Brewer, A., Conley, S., Hardesty, M., Banta, R., White, A., Noone, D., Wolfe, D. and Schnell, R. (2014) ‘A new look at methane and nonmethane hydrocarbon emissions from oil and natural gas operations in the Colorado Denver-Julesburg Basin’, *Journal of Geophysical Research: Atmospheres*, 119(11), p. 2013JD021272. doi: 10.1002/2013JD021272.

Rockström, J., Steffen, W., Noone, K., Persson, \AAsa, Chapin, F. S., Lambin, E. F., Lenton, T. M., Scheffer, M., Folke, C., Schellnhuber, H. J. and others (2009) ‘A safe operating space for humanity’, *Nature*, 461(7263), pp. 472–475. Available at: http://www.nature.com/nature/journal/v461/n7263/full/461472a.html (Accessed: 21 January 2016).