PSE Healthy Energy
SCIENCE SUMMARY
MAR 2014

Methane Emissions from Modern Natural Gas Development

Methane is the second largest contributor to human-caused global warming after carbon dioxide. The past few years have seen major changes both in our understanding of the importance of methane as a driver of global warming and in the importance of natural gas systems as a source of atmospheric methane. Here, we summarize the current state of knowledge on modern natural gas development and its climate implications.

The importance of the decadal-scale and immediate methane mitigation

Recent climate models[1,2] show that global mean temperatures will likely increase by **1.5 to 2 degrees Celsius within the next 20-35 years**. Such an increase is expected to result in a 37%-81% loss in existing permafrost[2], a carbon store 2 times larger than that currently in the atmosphere.[3] A large-scale release of the carbon dioxide and methane stored in permafrost would bring about **accelerated warming and be irreversible on human time-scales**, i.e. a climate tipping point.[3,4] Because carbon dioxide remains in the atmosphere for centuries, significant reductions in carbon dioxide emissions - even if such emission reductions were enacted – will not be enough to constrain near-term temperature increases.[1] However, modeling shows that **immediate mitigation of short-lived climate forcing species such as methane** (and black carbon) may constrain temperature increases for the next 40 years. (UNEP).

Table 1. USEPA methane emission estimates 2011-2014 for the U.S. and natural gas sector. Methane emissions from the natural gas sector account for an estimated 25%-33% of national emissions in 2009. Based on 2009 U.S. natural gas withdrawals from natural gas wells, default U.S. Composition (78% methane), and EPA standard conditions (1 mol CH4 = 23.63 L) these emissions represent 2.4% to 3.5% of natural gas production.

	EPA 2011	EPA 2012	EPA 2013
Tg CO_2e $_{Total}$	686	672	604
Tg CO_2e $_{Nat\ Gas}$	221	221	151
% Tot Methane $_{Nat\ Gas}$	32.2	32.9	25
% US natural gas production	3.50%	3.40%	2.40%

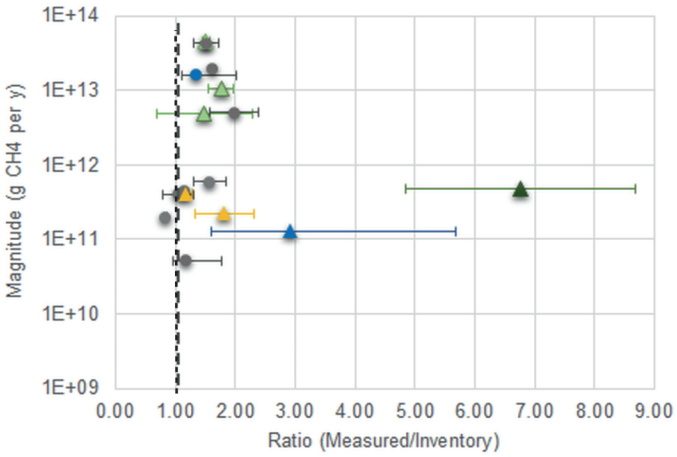

Figure 1. Measured atmospheric methane concentrations indicate that inventories are underestimating methane emissions from the natural gas sector and for the U.S. as a whole. Ratio > 1 (dotted line) represents measured emissions in excess of USEPA inventory estimates. The majority of measured fluxes indicate that **actual emissions are likely 1.5 times that reported in the inventory**. Triangle markers denote measurements taken from active oil and gas basins. (Source: Brandt et al. 2014)

Methane, Natural Gas, and the U.S. National Greenhouse Gas Inventory

The U.S. Environmental Protection Agency (USEPA) estimates national methane emissions from U.S. industry and energy sectors annually and tracks the trends in emissions over time. In 2011, USEPA[5] revised its estimate of methane emissions from natural gas production to reflect higher emissions resulting from unconventional natural gas development. After considerable political debate, emission estimates for the natural gas sector were revised downward in 2012[6] and again in 2013.[7] Despite these revisions, natural gas remained the **largest source of methane emissions in the national inventory** (25-33% of U.S. Methane emissions). Table 1 presents the estimated emissions for year 2009 as reported by USEPA across three reporting years and the percent of U.S. dry gas production (lifecycle leak rate) associated with each estimate.

A growing number of independent scientific studies indicate that USEPA's revisions are moving in the wrong direction. A recent review[8] of data from observed atmospheric methane concentrations indicates that **actual emissions are likely 1.5 times higher than inventory estimates** (Fig. 1).

Field-Level Methane Measurements

Pétron et al. (2012)[9] provided the first measured fluxes from an unconventional gas field at the landscape scale, and reported a "best estimate" of 4% (range of 2.3% to 7.7%) from production and processing streams. Similar atmospheric sampling studies for other modern gas and oil basins[10-13] indicate **fugitive losses from local production and natural gas processing ranging from 3.7% to 17%** of natural gas production (Fig. 2). Additional studies focusing on transmission and distribution streams of the natural gas lifecycle are ongoing.

Relative Climate Impact

Several studies[14-16] have used detailed climate modeling to assess the climate impact of modern natural gas systems and infer a limit of fugitive losses within which gas may offer

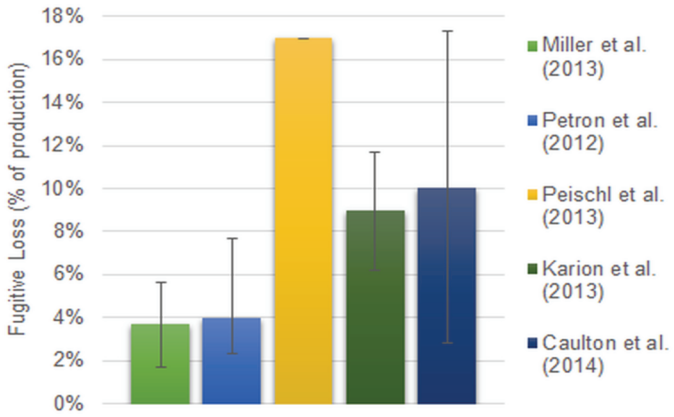

Figure 2. Range of methane losses from modern natural gas and oil production across regions as calculated from atmospheric measurements. Regions measured are TX-OK-KS (Miller et al. 2013); Weld County, CO (Pétron et al. 2012); Los Angeles Basin, CA (Peischl et al. 2013); Uintah Basin, UT (Karion et al. 2013); Marcellus Shale, PA-WV-OH (Caulton et al. 2014).

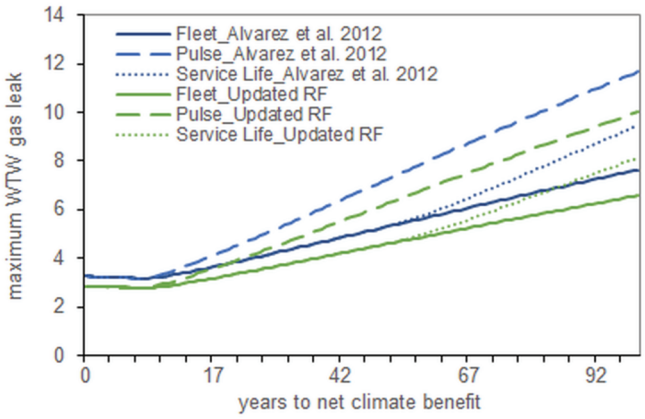

Figure 3. Maximum life-cycle losses from the natural gas sector as a function of time until net climate benefit after substitution of natural gas for coal in a single emission pulse (dashed), emissions for the service life (50 years) of a power plant (dotted), and permanent power plant fleet conversion (solid). Accounting for IPCC 2013 revised radiative forcing of methane drops the maximum loss rate to 2.8% - a value far exceeded in all atmospheric sampling studies.

climate benefit relative to other fossil fuels. Wigley (2011) found a switch from coal to natural gas across all emission scenarios (lifecycle losses of 0%-10% of production) resulted in warming over the next 20+ years. Myrvold and Caldiera (2012) found that a transition to gas would require 100 y or more to achieve just 25% reduction in warming. Alvarez et al. (2012) report a maximum lifecycle methane emissions of 3.2%, above which conversion to natural gas will exacerbate climate change. Alvarez et al., however, use old IPCC values for the forcing enhancements of methane. Adjusting their calculations to match the most recent IPCC consensus **indicates an emissions limit of just 2.8% (Fig. 3) - a value already far exceeded in all 5 of the field sampling studies from Fig 2**.

References

1. UNEP/WMO (2011). Integrated Assessment of Black Carbon and Tropospheric Ozone: Summary for Decision Makers. United Nations Environmental Program (UNEP), UNON/Publishing Services Section/Nairobi, ISO 14001:2004-certified
2. IPCC (2013). 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 University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp
3. Schuur E. A. G., et al. (2008) Vulnerability of Permafrost Carbon to Climate Change: Implications for the Global Carbon Cycle, *BioSci*. **58**(8):701-714
4. Schaefer, K., et al. (2011). Amount and timing of permafrost carbon release in response to climate warming. *Tellus, Series B*. **63**(2): 165-180
5. USEPA (2011). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2009. EPA 430-R-11-005. US Environmental Protection Agency Washington DC. April 2011
6. USEPA (2012). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2010. EPA 430-R-12-001. US Environmental Protection Agency Washington DC. April 2012.
7. USEPA (2013).Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2011. EPA 430-R-13-001. US Environmental Protection Agency Washington DC. April 2013.
8. Brandt, A. R., *et al. (2014)*. Methane Leaks from North American Natural Gas Systems. *Science* **343:** 733–735.
9. Petrón, G., *et al.* (2012). Hydrocarbon emissions characterization in the Colorado Front Range: A pilot study. *Journal of Geophysical Research: Atmospheres* **117**(D4): 27
10. Peischl, J., *et al.* (2013). Quantifying sources of methane using light alkanes in the Los Angeles basin, California. *Journal of Geophysical Research: Atmospheres* **118:** 4974–4990
11. Karion, A., *et al.* (2013). Methane emissions estimate from airborne measurements over a western United States natural gas field. *Geophysical Research Letters.* **40**(16): 4393-4397.
12. Miller, S. M., *et al. (2013)*. Anthropogenic emissions of methane in the United States. *PNAS* **110:** 20018–20022.
13. Caulton D., et al. (2014). Toward a Better Understanding and Quantification of Methane Emissions from Shale Gas Development. *PNAS* (In press)
14. Wigley, T. M. L. (2011). Coal to gas: the influence of methane leakage. *Climatic Change* **108:** 601–608.
15. Myhrvold, N. P. & Caldeira, K. (2012). Greenhouse gases, climate change and the transition from coal to low-carbon electricity. *Environ. Res. Lett.* **7,** 014019.
16. Alvarez, R. A., et al. (2012). Greater focus needed on methane leakage from natural gas infrastructure. *PNAS*. **109**(17): 6435–6440.