Draft dated October 24, 2014

Briefing paper on Climate Change and Shale Gas

The climate impact of natural gas is generally evaluated in two ways: the lower CO_2 emissions per kilowatt-hour of electricity generated by burning natural gas instead of coal, and the greenhouse gas impacts of methane that enters the atmosphere by fugitive emissions and leaks. If only the emissions related to combustion in power plants are considered, natural gas emits about half as much CO_2 as coal per kilowatt-hour generated. Methane is a powerful greenhouse gas: it forces about 85 times the global warming of CO_2 in its first 20 years and about 30 times after 100 years. The decline from 85 to 30 is due to the rate at which methane is removed from the atmosphere; methane has a relatively short perturbation lifetime.[1]

There have been varying estimates of the amount of methane that escapes to the atmosphere from production, transmission, and distribution of natural gas. Estimates have been made using emission factors, on site measurements, and atmospheric measurements. The range of estimates has been large, and the issue cannot be considered settled.

According to Jackson et al.[2], EPA's estimates for methane emissions from natural gas production operations have changed over the years, and range from between <0.2% and 1.5%. In 2013, EPA estimated a total leak rate of natural gas from production to be about 0.49% of total gross production, and the total leak rate from well to end user of 1.4%.

A study[3] by Allen et al. based on detailed measurements estimated production losses to be approximately 0.42% of gross production, slightly less than the EPA estimate. Uncertainties in measurements and sampling and limited sampling size contributed to a large confidence interval. Jackson noted that this study found large differences in process-level emissions across regions and the presence of large emitters in most regions. Jackson noted that atmospheric studies found regional-scale leaking rates to be 4% in the oil and gas producing Denver Basin in Colorado and 6.2% to 11.7% in the Uinta Basin in Utah.

A review[4] of 20 years of data emissions from natural gas systems in the United States and Canada found:

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[1] The Perturbation Lifetime (PL) is a standard way of characterizing how long molecules remain in the atmosphere. Methane is estimated to have a PL of 12.4 years, while nitrous oxide (N_2O) has a PL of 121 years. Myhre, G., D. et al., 2013: Anthropogenic and Natural Radiative Forcing. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Table 2.1 and Appendix 8A.

[2] Robert B. Jackson et al., *The Environmental Costs and Benefits of Fracking,* Annu. Rev. Environ. Resource. 2014. 39:7.1-7.36 , doi: 10.1146/annurev-environ-031113-144051.

[3] David t. Allen et al., *Measurements of methane emissions at natural gas production sites in the United States,* PNAS 110:44, 17769, October 29, 2013, http://www.pnas.org/lookup/suppl/doi:10.1073/pnas.1304880110/-/DCSupplemental.

[4] A.R. Brandt et al., *Methane Leaks from North American Natural Gas Systems,* Science 343:733, 14 February 2014.

> (i) measurements at all scales show that official inventories consistently underestimate actual CH_4 emissions, with the NG [natural gas] and oil sectors as important contributors; (ii) many independent experiments suggest that a small number of "superemitters" could be responsible for a large fraction of leakage; (iii) recent regional atmospheric studies with very high emissions rates are unlikely to be representative of typical NG system leakage rates; and (iv) assessments using 100-year impact indicators show system-wide leakage is unlikely to be large enough to negate climate benefits of coal-to-NG substitution.

A 2012 article[5] by Alvarez et al. stated "We estimate that natural gas produces net climate benefits relative to low-gassy coal on all time frames as long as leakage in the natural gas system is less than 3.2% from well through delivery at a power plant (i.e., excluding the local distribution system)."

An analysis by Climate Central[6] provided a tool to answer the question of the global warming impact of switching from coal to natural gas for generation of electricity using different methane leak rates and coal-to-gas conversion rates, projected to 2110. At a 1 percent conversion rate, gas is better than coal for all years until the methane leak rate approaches 5 percent. Using a 2 percent leak rate and a conversion rate of coal to gas sufficient to achieve a 25 percent reduction in coal use by 2030, the tool predicts that by 2030 greenhouse gas emissions from the electricity sector would be about 10 percent lower than today, and that by 2060, the reduction would reach 24 percent.

Another study[7] looked at the impacts of expanded use of natural gas in both electricity generation and transportation. The authors identified emissions from shale gas well completions and emissions from conventional natural gas liquid unloading as important upstream production activities and assumed that downstream emissions for shale and conventional gas would be similar. The analysis showed that shale gas was better than conventional gas and that both were better than coal from a global warming potential for power plants on a 100-year timeframe. The benefit is diminished but does not disappear for the 20-year timeframe. There was no statistical difference between vehicles using petroleum or compressed natural gas (CNG) on the 100-year timeframe, but emissions were about 25 percent higher for CNG vehicles for the 20-year timeframe. The authors noted that there was considerable uncertainty in the data for emissions from conventional gas well liquid unloadings and shale gas well completions and for estimated

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[5] Ramon A. Alavarez, et al., *Greater focus needed on methane leakage from natural gas infrastructure,* PNAS 109:17. 6435-6440. April 24, 2012, www.pnas.org/cgi/doi/10.1073/pnas.1202407109.
[6] Climate Central, *Methane Leak Rate Proves Key to Climate Change Goals,* reprinted in Scientific American online edition August 5, 2014, http://www.scientificamerican.com/article/methane-leak-rate-proves-key-to-climate-change-goals/
[7] Andrew Burnham and Corrie Clark, Examining the Impacts of Methane Leakage on Life-Cycle Greenhouse Gas Emissions of Shale and Conventional Natural Gas, EM Magazine (June 2012)

ultimate recovery. They cautioned that the uncertainties could potentially support erroneous conclusions.

A recent article[8] evaluated the impact up to the year 2050 of increased use of natural gas on climate change for two scenarios: a conventional gas scenario and an abundant gas scenario. The authors modeled the impact using five different integrated assessment models that represent prices, demand, and supply for different fossil fuels and low-carbon energy sources. The uses were not limited to power production. The models were run based upon climate change policies already in effect, and did not simulate future climate policies.

The model results showed that abundant natural gas leads to greater consumption of natural gas. Coal loses the largest market share to natural gas, but natural gas also gains market share at the expense of nuclear and renewables. Overall, low-cost, abundant natural gas leads to increased economic activity, reduced incentive for energy efficiency, and an overall expansion of the total energy use. The five models predicted that the impact of abundant natural gas on CO_2 emissions would range from -2 percent to +11%, and the impact on climate forcing would range from -0.3 percent to +7 percent.

The authors noted

> The core finding of this research is that increases in unconventional gas supply in the energy market could substantially change the global energy system over the decades ahead without producing commensurate changes in emissions or climate forcing. The result stems from three effects: abundant gas substituting for all energy sources; lower energy prices increasing the scale of the energy system; and changes in non- CO_2 emissions. This result is potentially sensitive to a range of model assumptions.

Among the assumptions that could alter the result are: policies that would restrict the use of natural gas as a substitute for low-carbon energy; technology changes that make other forms of energy more available or less expensive; and changing rates of fugitive methane emissions. The authors also noted that climate change is not the only implication of abundant natural gas, which can also positively affect air and water quality[9], energy security, access to modern energy, and economic growth.

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[8] Haewon McJeon et al., Limited impact on decadal-scale climate change from increased use of natural gas, Nature 2014, doi:10.1038/nature13837

[9] Emissions of mercury from burning natural gas are negligible. Burning coal for energy production has been the single largest component of anthropogenic mercury emissions in the United States, accounting for more than half the total. Wentz, D.A., Brigham, M.E., Chasar, L.C., Lutz, M.A., and Krabbenhoft, D.P., 2014, *Mercury in the Nation's streams—Levels, trends, and implications*: U.S. Geological Survey Circular 1395, 90 p., http://dx.doi.org/10.3133/cir1395. The report stated "Mercury is a potent neurotoxin that accumulates in fish to levels of concern for human health and the health of fish-eating wildlife. Mercury contamination of fish is the

These articles support a conclusion that minimizing fugitive emissions of methane is necessary to realize any significant radiative forcing advantage over coal. Improved energy efficiency, greater reliance on sources of power other than fossil fuels, and good climate policy will be necessary to address climate change regardless of changes in the use of natural gas.

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primary reason for issuing fish consumption advisories, which exist in every State in the Nation. Much of the mercury originates from combustion of coal and can travel long distances in the atmosphere before being deposited." The study found that methylmercury concentrations in fish exceeded levels protective of human health in about one in four streams across the United States. The Maryland Department of the Environment has issued statewide advisories for gamefish and panfish in all freshwater lakes, streams, and rivers and has also monitored mercury levels of numerous species inhabiting the Chesapeake Bay and other tidal waters.