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Preliminary Assessment of the Greenhouse Gas Emissions from Natural Gas obtained by Hydraulic Fracturing

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Natural gas is being widely advertised and promoted as a clean burning fuel that produces less greenhouse gas emissions than coal when burned. While it is true that less carbon dioxide is emitted from burning natural gas than from burning coal per unit of energy generated, the combustion emissions are only part of story and the comparison is quite misleading. **A complete consideration of all emissions from using natural gas seems likely to make natural gas far less attractive than oil and not significantly better than coal in terms of the consequences for global warming.**

There is an urgent need for a comprehensive assessment of the full range of emission of greenhouse gases from using natural gas obtained by high-volume, slick water hydraulic fracturing (HVSWHF, or "hydrofracking"). I am aware of no such analysis that is publicly available. Some information suggests that one or more assessments may have been conducted by industry groups, but if so these are available only to industry on a confidential basis. If such assessments exist, they have not been subjected to external, unbiased scientific review.

A first attempt at comparing the total emissions of greenhouse gas emissions from HVWWHF-obtained natural gas suggests that they are 2.4-fold greater than are the emissions just from the combustion of the natural gas. This estimate is highly uncertain, but is likely conservative, with true emissions being even greater. When the total emissions of greenhouse gases are considered, Greenhouse gas emissions from HVSWHF-obtained natural gas are estimated to be 60% more than for diesel fuel and gasoline. HVSWHF-obtained natural gas and coal from mountain-top removal probably have similar releases. These numbers should be treated with caution. Nonetheless, until better estimates are generated and rigorously reviewed, society should be wary of claims that natural gas is a desirable fuel in terms of the consequences on global warming. **Far better would be to rapidly move towards an economy based on renewable fuels. Recent studies indicate the U.S. and the world could rely 100% on such green energy sources within 20 years if we dedicate ourselves to that course.** See Jacobson & Delucchi (2009) A Path to Sustainable Energy by 2030, *Scientific American* 301: 58-65.

Presentation of assumptions and uncertainties behind estimates:

Considering the release during combustion alone, greenhouse gas emissions from burning natural gas average 13.7 g C of CO_2 per million joules of energy compared to 18.6 for gasoline, 18.9 for diesel fuel, and 24.0 for bituminous coal (U. S. Department of Energy: http://www.eia.doe.gov/oiaf/1605/coefficients.html). Additional emissions of greenhouse gas occur during the development, processing, and transport of natural gas (due to the use of fossil fuels to build pipelines, truck water, drill wells, make the compounds used in drilling and fracturing, and treat wastes, and the loss of carbon-trapping forests). I am aware of no rigorous estimate for these additional greenhouse gas emissions, but they appear likely to equal at least one third of those released during combustion (4.5 g C of CO_2 per million joules of energy). For comparison, the greenhouse gas emissions from obtaining, processing, and transporting diesel fuel and gasoline are in the range of 8% (Howarth et al. 2009: http://cip.cornell.edu/biofuels/), or perhaps 1.5 g C of CO_2 per million joules of energy. Note that as fossil fuel energy resources become more diffuse and difficult to obtain (as is gas in the Marcellus Shale), the energy needed to extract them and the greenhouse gas emissions associated with this effort go up substantially.

The leakage of methane gas during production, transport, processing, and use of natural gas is probably a far more important consideration. Methane is by the far the major component of natural gas, and it is a powerful greenhouse gas: 72-times more powerful than is CO_2 per molecule in the atmosphere (Table 2.14 in the Intergovernmental Panel on Climate Change Fourth Assessment Report (AR4), Climate Change 2007: The Physical Science Basis. http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_wg1_report_the_physical_science_basis.htm). Note that this comparison of the global warming potential of methane with CO_2 is based on a 20-year assessment time; the factor decreases to 25-fold for for an 100-year assessment time. The shorter time with the higher relative global warming potential is the appropriate one, if one is concerned about the effects of methane during the time a natural gas field is developed, and for the few decades after production in the field ends. Since methane is such a powerful greenhouse gas, even small leakages of natural gas to the atmosphere have very large consequences on global warming. The most recent data I could find for the US (from 2006) suggest a leakage rate from the oil and gas industry of an amount of methane equal to 1.5% of the natural gas consumed (based on leakage data reported in EPA (2008) Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990 – 2006 and consumption data from the U.S. Department of Energy: http://www.eia.doe.gov/pub/oil_gas/natural_gas/data_publications/natural_gas_monthly/current/pdf/table_02.pdf). This leakage rate is roughly equal to that estimated by the EPA in 1997 (http://p2pays.net/ref/07/06348.pdf). However, as noted by Andrew Revkin in the New York Times in October 2009, the actual leakage is not well known, as monitoring is quite limited, and "government scientists and some industry officials caution that the real figure is actually higher" (http://www.nytimes.com/2009/10/15/business/energy-environment/15degrees.html?_r=2&scp=1&sq=natural%20gas%20leaks%20tanks&st=cse).

If we assume a 1.5% leakage rate, this would have a greenhouse gas warming potential equal to 14.8 g C of CO_2 per million joules of energy. This would be additive to the emissions during combustion (13.7 g C of CO_2 per million joules of energy) and to the emissions associated with obtaining and transporting the natural gas (very roughly estimated above as 4.5 g C of CO_2 per million joules of energy). Total greenhouse gas emissions from natural gas from hydraulic fracturing may, therefore, be equivalent to 33 g C of CO_2 per million joules of energy. For diesel fuel or gasoline, the total greenhouse gas emissions are equivalent to approximately 20.3 g C of CO_2 per million joules of energy.

The comparison with coal is difficult, as the energy needs and greenhouse gas emissions from mining and transporting the coal are not well known. As a first cut, it may make sense to assume that these are roughly equal to those for obtaining shale gas. Some methane leakage also occurs when mining coal, but the amount varies greatly with the type and location of the coal and the mining technology used. A preliminary assessment suggests methane leakage is less than for natural gas. If so, total emissions from coal are probably quite similar to those for natural gas obtained from shale formations such as the Marcellus Shale.