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Assessment of the Greenhouse Gas Footprint of Natural Gas from Shale Formations Obtained by High-Volume, Slick-Water Hydraulic Fracturing

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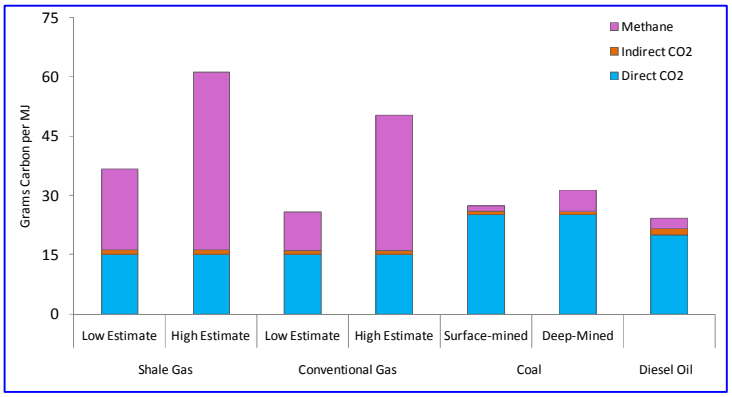
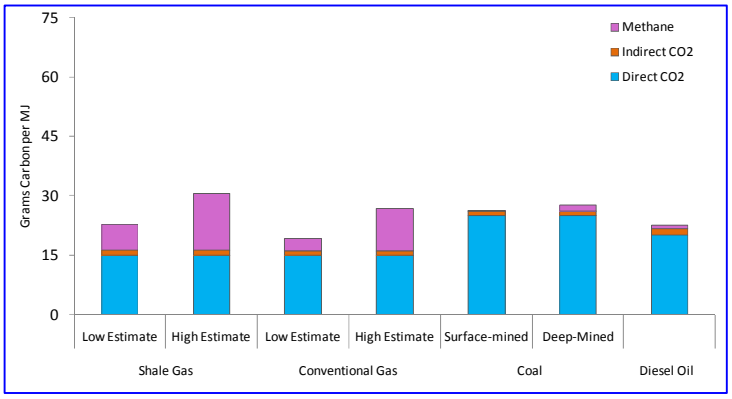
(*Revised April 11, 2011*)

Natural gas is 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. With funding from the Park Foundation, my colleagues Renee Santoro, Tony Ingraffea, and I have assessed the likely footprint from natural gas in comparison to oil or to coal. An advance copy of our paper will be published on-line this week in the peer-reviewed journal *Climatic Change Letters*.

A. 20-year time frame



B. 100-year time frame



Top panel is 20-year time frame, and bottom panel is 100-year time frame. Estimates include direct emissions of CO_2 during combustion (blue bars), indirect emissions of CO_2 necessary to develop and use the energy source (red bars), and fugitive emissions of methane, converted to equivalent value of CO2 for global warming potential (pink bars).

Our analysis is based in part on a November 2010 report from the EPA. The EPA report is the first significant update by the agency on natural gas emission factors since 1996, and concludes that emissions – particularly for shale gas – are larger than previously believed. Our research further supports this conclusion.

The summary figure from our research shown here to the left compares shale gas with two estimates of methane emissions to the atmosphere (low and high, two bars to the left), conventional natural gas with two estimates of methane emissions (high and low estimates, next two bars), coal from surface mines (3rd bar from right), coal from deep mines (2nd bar from right) and diesel oil. Note that particularly when viewed on the 20-year time horizon after emission, the greenhouse gas

footprint of shale gas is considerably greater than that for coal or diesel oil, when the full effects of the methane emissions are considered.

We urge caution in viewing natural gas as good fuel choice for the future, particularly as a transportation fuel where natural gas is no more efficient than diesel oil or gasoline, and where additional fugitive methane emissions beyond those in our study or the EPA (2010) analysis seem likely during refueling operations.

Note that both the National Academy of Sciences and the Council of Scientific Society Presidents have urged great caution before proceeding with the development of diffuse natural gas from shale formations using unconventional technology. See:

National Research Council (2009). Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use. National Academy of Sciences Press.

Letter to President Obama and senior administration officials, May 4, 2009, from the Council of Scientific Society Presidents.
http://www.eeb.cornell.edu/howarth/CCSP%20letter%20on%20energy%20&%20environment.pdf

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Our paper should be cited as:

> Howarth, R. W., R. Santoro, and A. Ingraffea. 2011. Methane and the greenhouse gas footprint of natural gas from shale formations. *Climatic Change Letters*, **DOI: 10.1007/s10584-011-0061-5**

The paper is available through the web site of Climatic Change Letters under the open-access policy of the journal, and can also be viewed at the Howarth/Marino lab web site.