Some commonly asked questions:

Aren't carbon dioxide emissions less for natural gas than for coal? Yes, substantially so. But methane emissions are far greater from natural gas, particularly from shale gas. When methane is included, total greenhouse gas emissions are greater from natural gas than from coal, particularly when analyzed on a 20-year period following emission.

I've heard that methane is 21-times more powerful as a greenhouse gas than is carbon dioxide. Is that true? No, that is based on a 20-year old report of the Intergovernmental Panel on Climate Change (IPCC) in 1995. The IPCC now states that methane is more than 100-times more powerful for the first decade after emission, 86-times over a 20-year period, and 34-times over 100 years. The shorter time periods are the most appropriate to use, given the urgency of slowing global warming over the coming 10 to 20 years, and when considering the idea of a "bridge fuel."

Why are the EPA methane estimates so low? The EPA states that methane is 25-fold more powerful than carbon dioxide, considering only the 100-year time scale and using information from an older IPCC report from 2007 rather than the most recent 2013 one. Further, their estimates of methane emission rates are much too low and are not supported by the most recent peer-reviewed science.

Can regulation reduce methane emissions to an acceptable level? Methane emissions come from many sources, from the well site to delivery through pipelines to final customers. Many of these remain poorly characterized. Reducing emissions is expensive, particularly from pipelines and storage tanks that are frequently 50 to 100 years old, and enforcement of regulations is difficult. Society is better off investing in renewable energy infrastructure.

If natural gas is not a bridge fuel, should we burn coal instead? No. The high levels of carbon dioxide emitted from using coal have a lasting influence on the atmosphere and climate for many centuries. It is past time to move away from all fossil fuels, and embrace the renewable energy technologies of the 21st Century.

Aren't cows more important as a source of methane than the natural gas industry? Globally, animal agriculture and the natural gas industry are comparable sources of methane. In the US, the natural gas industry is the far greater source, but both sources should be reduced.

For more information see:
http://www.eeb.cornell.edu/howarth/energy_and_environment.php

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A bridge to nowhere: methane emissions and the greenhouse gas footprint of natural gas

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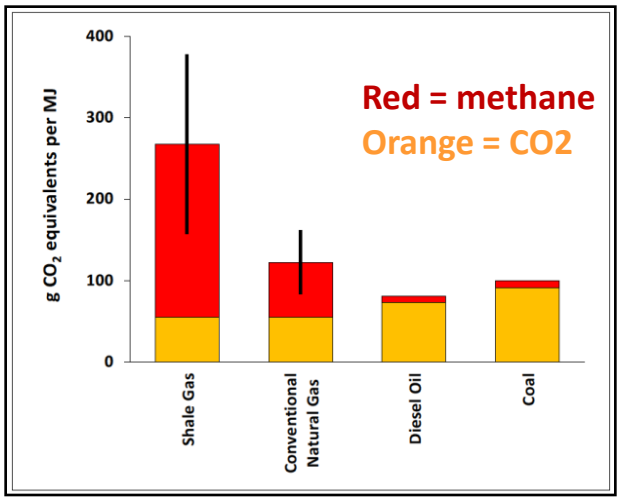
Abstract
In April 2011, we published the first peer-reviewed analysis of the greenhouse gas footprint (GHG) of shale gas, concluding that the climate impact of shale

Natural gas is widely promoted as a "bridge fuel" that allows continued use of fossil fuels while reducing greenhouse gas emissions compared to oil or coal. Increasingly since 2009, natural gas has come from shale gas, as conventional sources of gas have been depleted. Today, over 40% of US natural gas comes from shale. Is shale gas really a bridge fuel?

In the first comprehensive study of greenhouse gas emissions from shale gas, Howarth, Santoro, and Ingraffea concluded that due to methane shale gas has a larger climate impact than either coal or oil (April 2011 in *Climatic Change Letters*). They also called for new measurements to better assess these methane emissions. An explosion of new information has been published since then, reviewed by Howarth in 2014 in *Energy Science & Engineering* and again in 2015 in *Energy & Emission Control Technologies*. This flyer summarizes those updates.

The most recent research supports the 2011 analysis, and indicates greenhouse gas emissions from shale – dominated by methane -- are large and will have disastrous consequences for the Earth's climate.

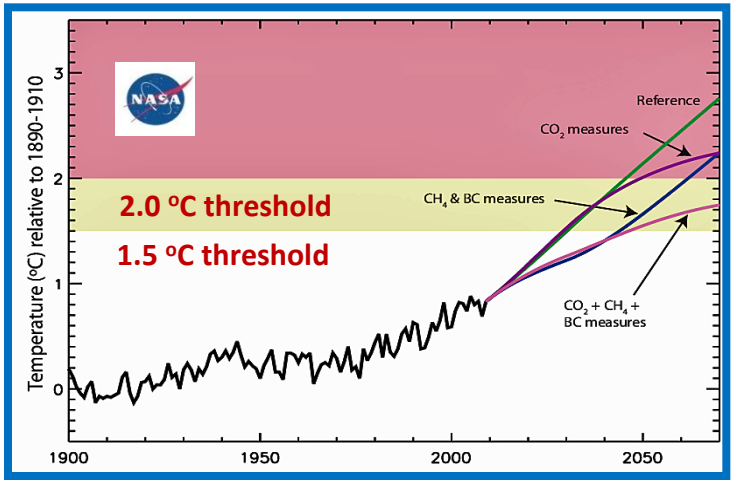


Source: Howarth (2015) *Energy & Emission Control Technologies*

Methane compared to carbon dioxide over a 20-year time period following emission to the atmosphere. Both direct emissions of carbon dioxide and methane emissions expressed as carbon dioxide equivalents are shown. For each fuel, the best estimate for methane emission is used. The vertical bars illustrate the the most probable range of values for shale gas and conventional natural gas.

Carbon dioxide vs. methane:

- **Methane is greater than 100 times more powerful as an agent of global warming, while both gases are in the atmosphere.**
- **The atmosphere contains more carbon dioxide than methane, making it the larger driver behind global warming, but methane is also important: 1.66 watts per square meter for carbon dioxide vs. 1.0 for methane.**
- **The effective residence times of the two gases in the atmosphere are very different: a little over a decade for methane and hundreds of years for carbon dioxide.**
- **Because of its long residence time, reductions in carbon dioxide emissions can only slowly change the atmospheric concentration, leading to a lag of many decades before global warming is slowed.**
- **With methane's short residence time, emissions reductions lead to almost immediate reductions in atmospheric concentrations; thus, reducing methane emissions now will significantly slow the rate of global warming almost immediately.**



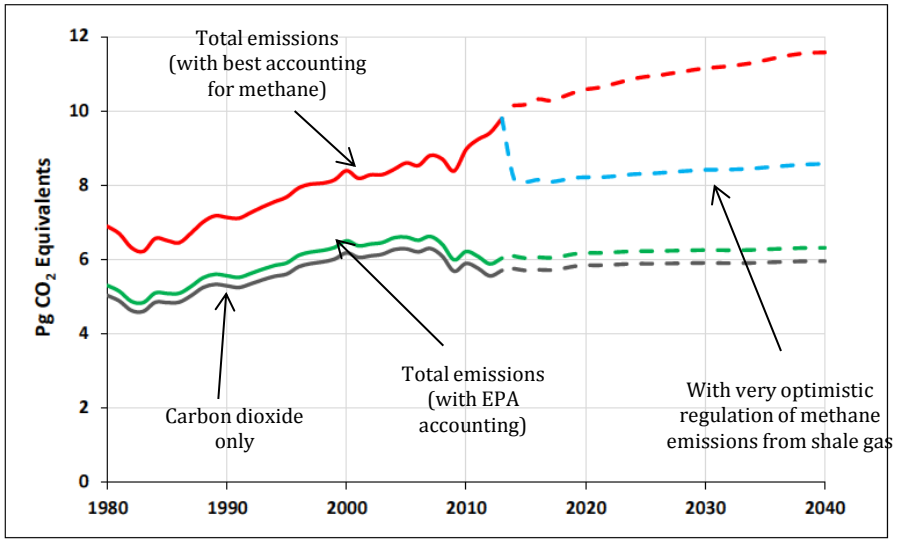
Source: Shindell and others (2012). *Science* 335: 183-189.

Within the next 15 years, the Earth will warm to very dangerous levels, doubling the total increase in the average temperature that has occurred since the start of the industrial revolution to now. Tipping points in the climate system may kick in and lead to runaway global warming. Only by reducing methane emissions and emissions of soot (black carbon, or BC) can society slow the rate of warming and buy precious time while moving aggressively toward a renewable energy economy. The natural gas industry is by far the largest source of methane emissions in the United States.

How much methane does the natural gas industry emit?

Methane emissions are better known now than in 2011, but estimates remain uncertain. The best current estimate of emissions from conventional natural gas comes from an analysis of over 12,000 monitoring observations taken before large-scale shale gas development began (Miller et al., 2003, *Proceedings of the National Academy of Sciences*). The best estimate of emissions from shale gas comes from satellite observations of increases in methane in the atmosphere before and after shale gas development began (Schneising et al., 2014, *Earth's Future*). Most other observations are for short periods of time, making it difficult to relate to gas production over the lifetime of a well. The lowest estimates -- part of a study promoted by the Environmental Defense Fund in coordination with industry -- have been called into question because of sensor failures with the instrumentation used (Howard, 2015, *Energy Science & Engineering*).

Carbon dioxide emissions from fossil fuels in the US have fallen since 2007 due largely to economic recession but also to switching from coal to shale gas. However, when methane emissions are properly included, total fossil-fuel greenhouse gas emissions have increased rapidly in recent years. In 2013, methane emissions contributed 40% of all fossil-fuel emissions in the US. The EPA accounting approach hugely underestimates the importance of methane emissions.



Total greenhouse gas emissions from fossil fuel use in the US through 2013 and predicted future trends based on US Dept. of Energy predictions for energy use. Grey line is for just carbon dioxide emissions. Red line includes methane. Green line shows total emissions as estimated by the US EPA, which greatly underestimates methane emissions and their importance. Blue line indicates a possible future scenario of reducing methane emissions from shale gas, with very optimistic assumptions on the ability of regulations to cut emissions. Source: Howarth (2015) *Energy and Emission Control Technologies.*