Methane and the Greenhouse Gas Inventory for Cornell University

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In analyzing the greenhouse gas inventory in the past, Cornell has followed the common practice of focusing on emissions for use of fossil fuels on campus, which are overwhelming dominated by emissions of carbon dioxide as the fuels are burned. The switch from using coal to generate the heat for the campus to using natural gas to cogenerate heat and electricity led to a large decrease in carbon dioxide emissions, from 176,000 metric tons CO_2 per year in 2008 to 142,000 metric tons CO_2 per year in 2012.

Since the central plant was converted to natural gas, a growing body of new scientific information (much of it by Cornell faculty) has focused attention of the importance of methane as a greenhouse gas, particularly in light of the shale gas revolution in the United States and in the context of meeting the climate goals set by the nations of the world in the United Nations COP21 negotiations in Paris in December 2015. According to the 5th synthesis report of the Intergovernmental Panel on Climate Change in 2013, methane is more than 100-times more potent than carbon dioxide as a greenhouse gas, and current global emissions of methane from human activity match or exceed those of carbon dioxide when viewed on the time scale of the first decade following the emission of the two gases. Other greenhouse gases are far less important in driving the current rate of global warming.

While both carbon dioxide and methane are major drivers of global warming, the gases differ in some fundamental ways. The carbon dioxide emitted today will continue to influence the climate for many centuries into the future, in part because of exchange of the gas between the atmosphere, oceans, and terrestrial biosphere; for the same reason, the planet's rate of global warming is slow to respond to changes in carbon dioxide emissions. If carbon dioxide emissions were reduced today, the rate of global warming would continue at its current rate for at least the next 30 years. Methane on the other hand stays in the atmosphere for only 12 years or so, and has no long-term consequences on the climate unless while it is in the atmosphere it contributes to sufficient warming to fundamentally alter the climate system, as tipping points are encountered. Also unlike carbon dioxide, the Earth's climate system responds quickly to changes in methane: if we reduce methane emissions today, the rate of global warming would slow immediately.

The issue of tipping points is important to understand. The Earth has already warmed by 0.9^{o} C above the pre-industrial baseline level and is on a trajectory to reach 1.5^{o} C in just 13 years and 2^{o} C in 30 years. As the planet warms above 1.5^{o} C or 2^{o} C, the risk of reaching tipping points increases dramatically, with increased risk of catastrophic runaway global warming. It is for this reason that the United Nations and all of the nations of the world agreed at the COP21 event to keep the temperature of the planet well below 2^{o} C, with a clear recognition that even 1.5^{o} C is dangerous. One possible tipping point is the melting of the major Antarctic and Greenland ice sheets, which would not only lead to an incredible rate of sea-level rise but could also fundamentally change ocean circulation; that in turn could reduce the ability of the oceans to help mitigate the release of carbon dioxide from burning fossil fuels (currently, 25% of these fossil-fuel emissions are absorbed by the oceans) and would also change the climatic patterns across the continents. Another tipping point is the release of carbon dioxide from the carbon-rich soils of the Arctic tundra as permafrost is melted and microbial respiration rates increase. And a third is the release of methane gas from a frozen form of methane called clathrates on the continental shelves of the world's oceans, particularly in the Arctic Ocean as it warms.

Given this context, the only way to meet the COP21 climate target is to reduce methane emissions. Unfortunately, though, methane emissions have been increasing globally, in part because of the shale gas revolution in the United States. This potential problem with shale gas was first noted by Cornell professors Robert Howarth and Tony Ingraffea in a peer-reviewed paper published in April of 2011, the first published analysis of the role of methane in the greenhouse gas footprint of shale gas. Shale gas is simply natural gas obtained from shale, where it is tightly held until released through high-volume hydraulic fracturing in combination with high-precision directional drilling. As with conventional natural gas, shale gas is composed mostly of methane. Small leaks and venting of unburned natural gas can therefore have a major impact on the climate. In their original analysis, Howarth and Ingraffea estimated that methane emissions might be twice as great from shale gas than from conventional natural gas. Their study helped spark an explosion of subsequent research, and the latest information, presented in a review paper by Howarth in the fall of 2015, indicates methane emissions from shale gas are in fact probably 3-fold greater: on average 3.8% of conventional natural gas and 12% of shale gas are emitted to the atmosphere as methane when considered over the full lifecycle, from development of the gas well to delivery to final consumer.

The ability to obtain shale gas is a modern phenomenon, and almost all shale gas production globally has occurred since 2005. The largest shale gas play in the world, the Marcellus shale in Pennsylvania, has largely been developed since 2009. A paper published in 2014 used satellite data to conclude that the global increase in methane since the start of the shale gas revolution is largely due to emissions from shale gas and shale operations in the United States. In his 2015 review, Professor Howarth estimated that while carbon dioxide emissions in the United States have been decreasing since 2008 in part due to substitution of coal by natural gas to generate electricity, total greenhouse gas emissions including methane have been rising at their fastest rate ever over this time period, due to methane emissions from the use of shale gas. As of 2013, unburned methane accounted for 40% and carbon dioxide 60% of total greenhouse gas emissions from using fossil fuels in the United States.

Because of the critical nature of methane emissions in global warming highlighted in recent research, and particularly in meeting the COP21 targets set last December, Cornell has decided to expand our approach to estimating our greenhouse gas inventory to include emissions of unburned methane from upstream sources, that is the methane released at the gas well sites and from pipelines and storage facilities. To do so, we are following the approach applied nationally for the United States in the Howarth (2015) review. As of 2008, the natural gas delivered to the Cornell campus would have come almost entirely from conventional sources, but in recent years virtually all of this gas is shale gas from the Marcellus play in Pennsylvania. We assume an average of 3.8% of conventional natural gas and 12% of shale gas is emitted to the atmosphere as unburned methane, and we compare methane and carbon dioxide over a 20-year period following emission using the global warming approach outlined in the 2013 IPCC 5^{th} synthesis report. Including the upstream emissions in the inventory for 2008 increases total emissions by 13%, from 176,000 metric tons CO_2-equivalents per year to 199,000 metric tons per year.

The conversion from coal to natural gas, while decreasing carbon dioxide emissions, resulted in a large increase in total greenhouse gas emissions when upstream methane is included. If the natural gas used in 2012 had been from conventional sources, the total inventory emissions would have been 2.2-fold greater than just the carbon dioxide emissions, 313,000 metric tons CO_2-equivalents per year vs 142,000 metric tons CO_2 per year. However, the shale gas revolution has increased the greenhouse gas inventory even further, since natural gas supplied to Cornell now is shale gas, and not the conventional gas supplied in 2008. Therefore, total inventory emissions for 2012 are more than 5-fold greater than just the carbon dioxide emissions, 733,000 metric tons CO_2-equivalents per year vs 142,000 metric tons CO_2 per year.