Greater focus needed on methane leakage from natural gas infrastructure
Frequently Asked Questions
Paper published in PNAS February 13, 2012

1. **What is radiative forcing?**

Radiative forcing is a concept widely used to describe and quantify the contribution of greenhouse gases (GHGs) on global temperatures. It is the primary index used to track climate change. In effect, increased GHGs in the atmosphere "force" changes in the Earth's temperature by modifying the balance between incoming and outgoing heat energy, formally called thermal radiation. Because GHGs absorb some of the Earth's outgoing radiation and prevent it from being released back into space, they produce a net warming effect. Radiative forcing can thus be used as a measure of how much a given activity that produces GHGs affects the climate; it is measured in units of Watts per square meter (W m-2). A more detailed, yet accessible explanation of radiative forcing is provided in Chapter 1 of the National Academy of Sciences' 2005 report "Radiative Forcing of Climate Change."

2. **What is Global Warming Potential (GWP)?**

GWP is used to compare the cumulative radiative forcing of different greenhouse gases (GHGs), relative to CO2, over a specific time period (usually 20 or 100 years). GWPs account for differing attributes of GHGs: capacity to absorb heat energy, atmospheric lifetime and any indirect effects on other radiatively active molecules or compounds (like methane's contribution to tropospheric ozone and stratospheric water). The larger the GWP, the larger the influence of a unit emission of a GHG on global temperatures. The GWPs for methane are 25 and 72 for 100-year and 20-year time horizons, respectively.

3. **What advantages do Technology Warming Potentials (TWPs) have relative to GWPs?**

TWPs have been proposed by Alvarez et al. as an alternative to conventional GWP analyses to better explain the time-dependent radiative forcing (or climate influence) of different fuel-technology options. While GWPs have been a valuable tool to compare the radiative forcing of individual gases over set time horizons, they are not sufficient when thinking about common fuel switching scenarios that involve multiple GHGs with distinct atmospheric lifetimes. For example, the methane lost during the production and delivery of natural gas diminishes the CO2 benefits of using natural gas as a fuel.

A second limitation of GWP-based comparisons is that they only consider the radiative forcing of single emission pulses, which do not reflect the climatic consequences of real-world investment and policy decisions: these are better simulated as emission streams over multiple years. For example, while an emission pulse can reasonably represent the effect of renting a natural gas car for one day; converting a corporate fleet of cars from gasoline to compressed natural gas (CNG) is better represented by a multi-year stream of emissions.

TWPs use the well-established science of radiative forcing used to calculate GWP, but they package the results in a more transparent way. For example, in the paper we plot the relative radiative forcing between two options as a function of time to reveal time-dependent climate benefits or damages of policy choices and/or investment decisions. We can also calculate the number of years required before a fuel technology choice begins to produce benefits for the climate, an approach that can be used to define the conditions under which a policy choice produces climate benefits on all time frames.

4. How are CO2 and methane different for global climate?

CO2 is the principal GHG and must be significantly reduced to achieve climate stabilization goals. However, methane (CH4) is an important gas because of its potency and the opportunity it affords for short-term mitigation of climate impacts. Each molecule of methane produces around 37 times more radiative forcing than CO2, but methane is removed much more rapidly from the atmosphere. (Figure S1 of the paper illustrates the decay of methane and CO2 emissions.) The GWPs for methane are 25 and 84 for 100-year and 20-year time horizons, respectively. The larger value for 20 years reflects the shorter timeframe during which methane emissions remain in the atmosphere. Methane emissions also contribute to global background levels of tropospheric ozone, which is a GHG and harmful to human health and ecosystems.

5. If methane's effective lifetime is only 12 years, why is it common to use a 100-year time horizon for its GWP?

First, the lifetime does not mean the time after which all of the methane is gone; the lifetime is the time constant of an exponential decay after which 63% of the initial amount is removed. Second, the GWP is a measure of cumulative radiative forcing; even though 98% of a pulse of methane is gone after four lifetimes (48 years), the accumulated radiative forcing in the early years is still contributing to the cumulative total. (Figure S1 of the paper illustrates the time-dependence of methane's GWP.)

6. Your paper emphasizes the importance of timeframes. What timeframe is most important when talking about climate change?

All timeframes are important. Even though the permanent, long-term solution to climate change involves stabilizing CO2 emissions, the shorter time frames affected by methane emissions are also important because they increase the risk of undesirable climate outcomes in the near future. For example, accelerated rates of warming mean ecosystems and humans have less time to adapt to climate change. Given the dire need for concerted global action on climate change, current energy policy should, at a minimum, abide by a "Do No Harm" policy: no policy should contribute to increase radiative forcing on any time frame. Exclusive reliance on the 100-year GWP for methane is not an adequate basis for such a policy. On the other hand, TWPs are suitable to evaluate possible time-dependent tradeoffs, but the key is to ensure that definitive emissions data over entire fuel cycles are available.

7. Why do the methane leakage rates in Fig. 2 of the paper increase with time?

The horizontal axis in Fig. 2 actually shows the number of years needed until climate benefits are achieved, what we call the cross-over point. To minimize the climate damages of fuel-technology choices, it is desirable for the cross-over point to be as short as possible (and accordingly the rate of methane leakage). By contrast, the longer one is willing to wait until climate benefits are achieved, the higher the amount of methane leakage that can occur.

8. Isn't natural gas a cleaner fuel in terms of local air pollution?

Yes. Natural gas used to fuel power plants and vehicles instead of coal or petroleum-based fuels produces lower exhaust emissions of almost all pollutants; the exception is formaldehyde. Compared to coal plants, natural gas power plants offer distinct air quality benefits –

dramatically less smog-forming nitrogen oxides, almost no sulfur dioxide and soot, and no mercury per unit of electricity produced. Historically, natural gas vehicles (NGVs) have generally emitted lower emissions of smog-forming pollutants and most hazardous air pollutants (other than formaldehyde) in comparison to gasoline and diesel. When compared to diesel vehicles, NGVs also release less soot (black carbon and particulate matter). However, there is little empirical data comparing emissions of NGVs to conventionally fueled vehicles subsequent to the adoption in the last decade of stringent federal tailpipe exhaust standards. These federal standards will have likely diminished the emission benefits of NGVs [PDF].

9. What is a combined-cycle natural gas power plant?

This is the state-of-art technology to convert natural gas to electricity. The combined cycle refers to the reuse of heat from the combustion of natural gas in a turbine (like a jet engine) that is normally wasted to generate steam for secondary power generation. Because of its increased cost and complexity, this type of power plant is only used for baseload power generation.

10. What is "well-to-wheels?" Why is this important?

"Well-to-wheels" refers to the entire fuel cycle for a transportation fuel. It includes all of the activities that take place before the fuel is used in a vehicle, such as producing, processing and transporting the fuel to the end user ("well-to-pump"), plus any emissions that occur from refueling and from the use of the fuel (pump-to-wheels"). It is important in the case of natural gas because there is very little data about the amount of methane emissions from in-use vehicles, and what little does exist suggests that it adds a measurable amount, roughly 20% more, to the well-to-pump methane losses.

11. How do emissions occur in the natural gas industry?

Leaks and routine venting during the extraction, processing, and transportation of natural gas result in emissions of greenhouse gases and, depending on the local composition of unprocessed gas, other pollutants that contribute to locally- and regionally-elevated air pollution that can threaten public health. There are numerous individual components used throughout natural gas systems that are prone to leaks. These components include pumps, flanges, valves, gauges, pipe connectors, compressors, and tanks among others.

Moreover, routine wear, rust and corrosion, improper installation or maintenance, or overpressure of the gases or liquids in the piping can cause leaks. In addition to unintentional leaks, a number of sources intentionally vent gas. Gas is often vented during well completions or when liquids are unloaded from wells, by design from pneumatic valves, and from oil and condensate storage tanks. Pneumatic valves, which are used throughout natural gas systems, operate on pressurized natural gas and bleed small quantities of natural gas during normal operation.

12. How does the Environmental Protection Agency (EPA) come up with natural gas methane leakage estimates?

EPA reports methane emissions as a tonnage, not as a percentage leak rate. We have calculated the leak rate using reported natural gas production volumes as a way to provide a context for the magnitude of the emissions. Until last year, EPA estimated methane emissions from natural gas systems using data collected in the early 1990s. Last year, EPA discovered some differences in its 1990s-era emission estimates for a small number of key source types and those reported by natural gas companies to EPA in the voluntary Natural Gas STAR program. EPA used the best data it had available, mainly the self-reported estimates under the STAR program, which ended up roughly doubling its previous estimate of total industry emissions.

13. Why are different methane leakage rates used for the transportation and power plant scenarios?

The paper uses different leakage rates because power plants and vehicles obtain their gas from different points in the natural gas distribution network and additional methane can be emitted from vehicle refueling and from the vehicles themselves. We assumed that power plants obtain natural gas from the long-distance pipeline system. Using emissions estimated by the Environmental Protection Agency (EPA), we derived a leakage rate of 2.1% of gas produced through this point in the natural gas supply chain. For vehicles, we derived a "well-to-wheels" leakage rate of 3.0%, which includes an additional 0.3% of gas produced that is lost in local distribution pipelines (based on EPA emission estimates) and 0.6% to account for exhaust emissions of methane from the vehicles themselves (based on the scientific literature). We did not include any emissions from vehicle refueling or leaks in the vehicle fuel systems, though the existence of such emissions is plausible. More work needs to be done to better characterize emissions along the entire natural gas supply chain and from natural gas vehicles.

14. Why are the methane leakage rates used in the PNAS paper different from those in the methane leakage model posted on your website?

The PNAS paper used emission data from 2009, which was the most recent data available at the time the work was done. The model has updated all of the calculations to use 2010 emissions data, which has only recently become available.