Scientific Perspectives Related to Methane Emissions in Maryland

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Maryland Climate Change Commission
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Why Address Methane Emissions?

In order to limit the degree of global warming and associated climate change, most attention has been directed to reducing emissions of carbon dioxide (CO_2). This is appropriate not only because CO_2 is the dominant greenhouse gas emitted by human activities, but also because it can remain in the atmosphere a century or more. Methane (CH_4) is the second-largest contributor to climate radiative forcing—the change in energy trapped in the atmosphere as a result of greenhouse gas emissions—even though its atmospheric concentration is 200 times less than and human emissions rates are much smaller than those for CO_2. On the other hand, methane does not remain in the atmosphere as long as CO_2. The average lifetime of methane is 12 years as opposed to 30-95 years for CO_2. Consequently, the global warming potential for a ton of methane emitted is 72 times that of a ton of CO_2 over a 20-year time horizon, but that potential declines to about 25 times over a 100-year horizon. For that reason, the emissions of greenhouse gases are typically quantified in terms of mass equivalence to CO_2 in global warming potential over the 100-year time horizon as CO_2 equivalents. In other words, the emission of one ton of methane can be equated to the emission of 25 tons of CO_2.

Since the Industrial Revolution methane concentrations in the atmosphere have increased more than three times the percentage increase in CO_2 concentrations.[1] Furthermore, methane concentrations continue to rise as a result of growing emissions from the extraction and use of fossil fuels, expanding agricultural development, waste disposal, and changes in natural ecosystems. Actions to reduce emissions of this potent, but relatively short-lasting greenhouse gas have the potential to lower atmospheric concentrations more quickly, thus slowing the rate of warming over the next few decades while global society works to reduce the emissions of longer-lasting gases such as CO_2.

Recent Scientific Findings on Methane Sources

The reasons for the continuing increase in atmospheric methane concentrations has recently been the focus of intense scientific research. A hiatus in the rise of the global average methane concentrations in the atmosphere occurred between 1999 and 2006, but concentrations have since resumed their upward trend (Figure 1).[2] There is little scientific consensus on whether the plateauing of methane concentration was due to reduction in fossil fuel-related emissions or decreasing emissions from natural sources such as wetlands. However, different approaches to identify the sources responsible for the subsequent increases have yielded divergent conjecture.[3]

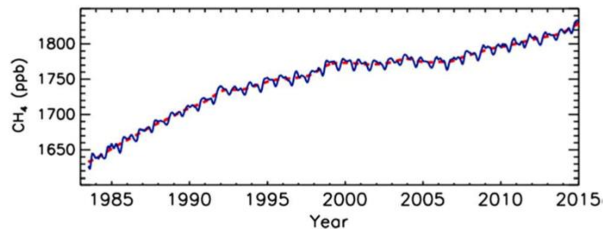

Figure 1. Globally averaged atmospheric methane concentrations from 1883 to 2014.[2]

One approach has used transport models based on emissions inventories to project methane flux and the other approach involves analyzing the stable isotopes of methane in various sources and relating them to the isotopic ratios measured in the atmosphere around the world. Briefly, most carbon atoms have an atomic weight of 12 as indicated on the periodic table, but a small proportion of these atoms have an atomic weight of 13. Unlike the more familiar radioisotope ^{14}C, which decomposes over time, the isotope ^{13}C is stable and will remain so indefinitely. The ratio of ^{13}C to ^{12}C in methane molecules (CH^4) depends on the source of the methane, with proportionately more ^{13}C included in thermophilic methane, such as from coal mines and oil and gas reservoirs, than in biogenic methane produced in wetlands, agriculture and landfills, for example. By measuring the ratios of these stable carbon isotopes in the methane in an atmospheric sample, scientists construct models to estimate its souces.

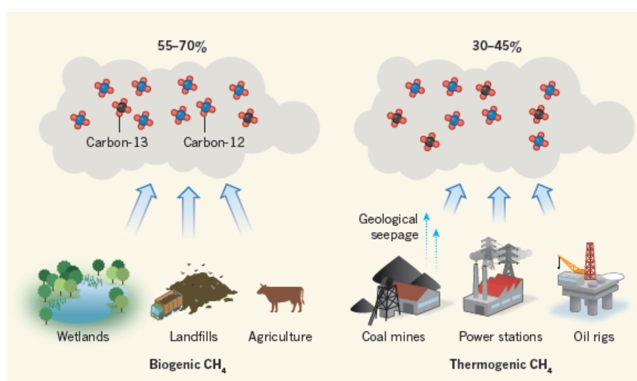

Figure 2. Scientists can use carbon-isotope 'fingerprints' of different sources to estimate their contributions to the methane in the atmosphere.[3]

Recent results using an expanded isotope database indicate that emissions attributable to the fossil-fuel industry (natural gas, oil and coal production) are 20-60% higher that methods based on the emissions inventory approach suggest.[2, 4] However, these contributions appear to have remained steady despite the recent increase in natural gas production. These isotope-based results also indicate that biogenic (microbial) methane emissions were 15-33% lower than suggested by the emissions inventory-based approach. Nonetheless, consistent with other recent findings,[5] such emissions from wetlands and agriculture appear to be mainly responsible for the uptick in atmospheric methane concentrations since 2006.

It should be kept in mind that the contributions and trends in methane sources on a global scale may be different that those for the United States or for different states in this country. National inventory estimates compiled by the U.S. Environmental Protection Agency indicate no significant trend in U.S. anthropogenic methane emissions (i.e. from fossil fuel production, agriculture, landfills, etc.) from 2002 to the present. However, satellite data and surface observations suggest that U.S. emissions have increased by more than 30% over the 2002-2014 period, mainly in the central part of the country.[6] This increase is so large that these U.S. contributions alone could account for a significant portion of the increase in global methane concentrations over the past decade.

The estimated increases in methane emissions based on satellite and surface observations measurements could not be attributed to a specific source category. However, the substantial expansion of natural gas production using hydrofracturing in the United States, coupled with measurements of elevated methane concentrations in the atmosphere near gas fields raise concerns that this expansion has contributed to these increased emissions. The discrepancy between EPA's national inventories and emerging scientific measurements underscores the need for greater verification of the assumptions about the rate of emissions from important sources of methane based on field measurements.

Emissions of methane from natural systems may also be influenced by human activities. A clear example is the destruction or creation of wetlands, which generate methane as a result of the microbial decomposition of organic matter in their oxygen depleted (anaerobic) soils. The release of methane from the world's human-created water reservoirs was recently estimated to be about 10% of that emitted by wetlands.[7] Reservoirs that had the highest biological productivity and, thus, likely to experience low oxygen concentrations in bottom waters released more methane. Similarly, the first studies of methane dynamics in the nutrient over-enriched Chesapeake Bay recently showed that methane generation was associated with anaerobic bottom waters that when mixed with surface waters resulted in release of methane to the atmosphere.[8] While such 'natural' sources are not included in the greenhouse gas emission inventories discussed next, they are clearly influenced by human actions and management strategies.

Inventories of Sources in the U.S. and Maryland

In its latest *Inventory of U.S. Greenhouse Gas Emissions and Sinks*, the U.S. Environmental Protection Agency estimated methane emissions for the United Sates in 2015 from various source categories as shown in Figure 3.[9] Overall, methane emissions comprised 10.6% of all national greenhouse gas emissions in terms of global warming potential (CO_2 equivalents). Natural Gas Systems represented the largest source category, but agricultural sources (Enteric Fermentation and Manure Management), Landfills, Petroleum Systems, Coal Mining, and Wastewater Treatment were also noteworthy contributors.

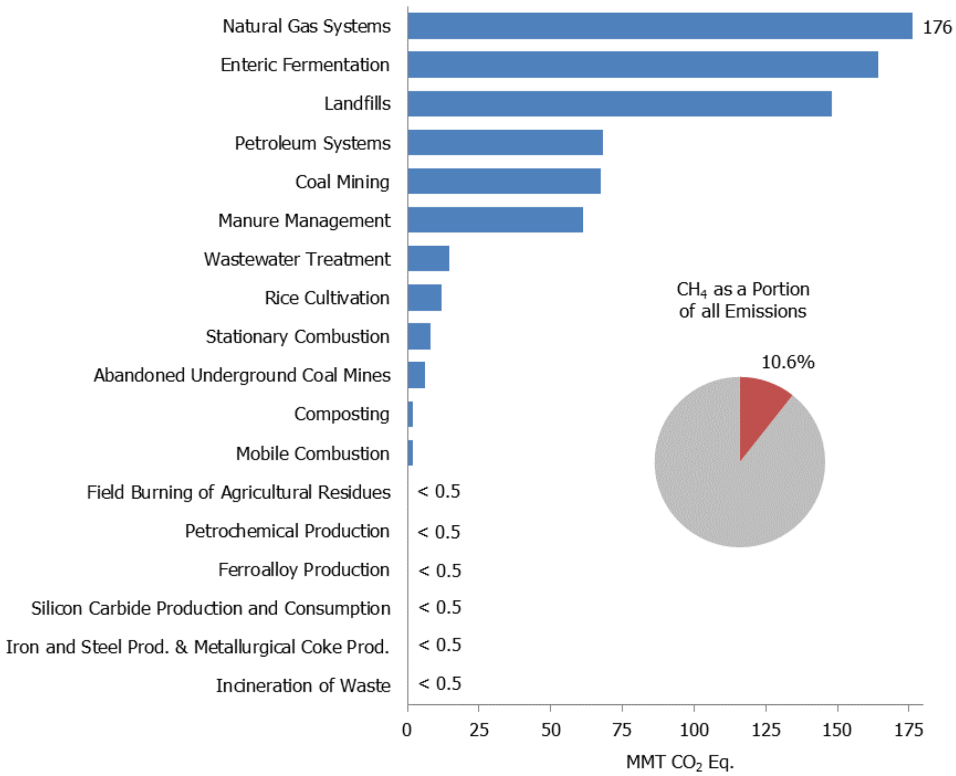

Figure 3. Estimates of the emissions of methane (million metric tons of CO_2 equivalents) in the United States in 2014, by source.[9]

As required by the Greenhouse Gas Reduction Act, the Maryland Department of the Environment produces a Greenhouse Gas Emissions Inventory every three years. The most recent inventory was for 2014 and was released in June 2016.[10] For most source categories, emissions were inferred based on standard conversion factors rather than directly measured. For example, these factors assume a certain amount of methane released on an annual basis for a head of cattle or a gas well.

The MDE inventory indicates that methane is proportionally a much smaller contributor to the state's GHG emissions than EPA's estimate for the U.S. as a whole, 2.6% versus 10.6%. Presumably this is because Maryland produces very little natural gas and petroleum and proportionally less meat and dairy products than the nation as a whole. Maryland is a significant importer of both of these commodities. Of course, this means that the potential to have much effect on the state's net greenhouse gas emissions by reducing methane emissions within the state is relatively constrained.

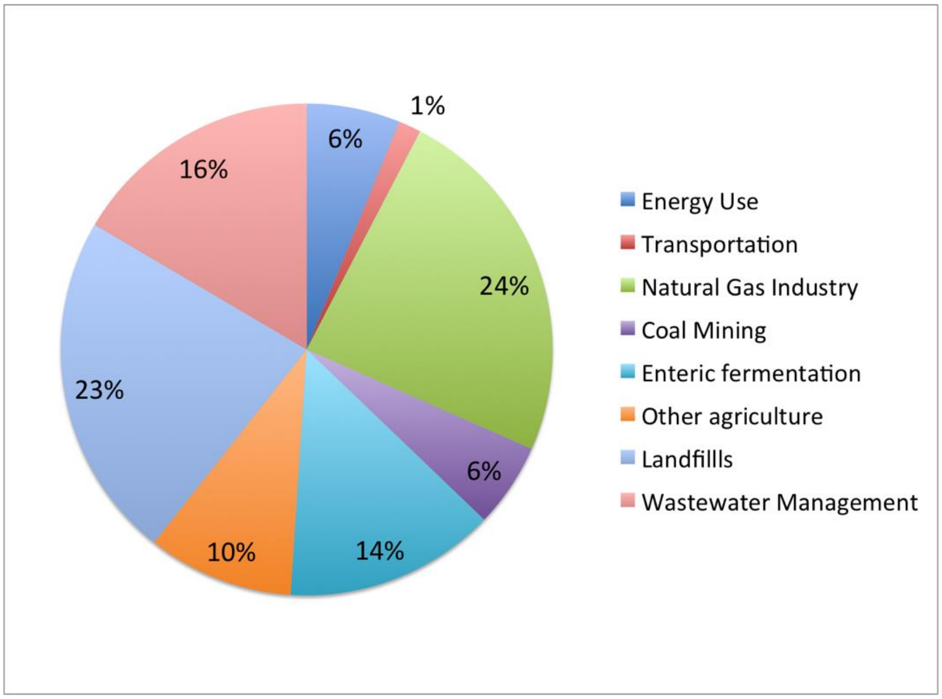

Figure 3. Sources of methane emissions in Maryland based on the Maryland Department of the Environment's *2014 GHG Emissions Inventory*.[10]

Options for Reducing Emissions by Source Category

Natural Gas Systems. The EPA Inventory estimates the proportion of methane emissions from stages of the Natural Gas Systems as follows: Field Production, 62%; Processing, 14%; Transmission and Storage, 18%; and Distribution, 6%. According to data from the U.S. Energy Information Administration, present natural gas production in Maryland is *de minimis* (32 million cubic feet per year over 2011-2015), in comparison both to the state's natural gas consumption (214,906 million cubic feet in 2015) and to the natural gas production of the U.S. as a whole (29,000,000 million cubic in 2015). Thus, within the present Natural Gas Systems, any significant methane emissions reductions within the boundaries of Maryland would have to come from the Transmission and Storage and Distribution stages. This leaves about 76% of the associated methane emissions that occur as a result of Maryland's natural gas consumption (based on the national percentages) to be dealt with by other states where the natural gas is produced or through which it is transported.

The greenhouse gas emissions resulting from the generation of electricity in another state that is imported to Maryland are presently included in MDE's Greenhouse Gas Emissions Inventory. These estimates are influenced by the fuel source (coal, oil, natural gas, or nuclear) used to generate the power. Both consumer demand and energy policies could affect Maryland's natural gas consumption, thus it seems consistent to estimate the upstream consequences of this consumption for methane emissions to the atmosphere.

Furthermore, two new developments could actually increase methane emissions from Natural Gas Systems within Maryland: (1) increased emissions from Field Production and Processing as a result of the exploitation of shale gas in the Marcellus Shale Formation that might be possible using hydrofracturing technologies; and (2) increased emissions from Processing and Transmission and Storage as a result of the proposed conversion of the Dominion's LNG import facility at Cove Point to a liquefaction and export facility. In either case, very strict controls on emissions would be required to avoid adding to Maryland's methane emissions inventory, effectively cancelling out reductions to existing sources. While these controls may be under the aegis of Federal rather than State regulations, Maryland may be able to require offsets of the associated methane emissions.

Agriculture. Of the estimated 0.57 $MMtCO_2e$ of methane emitted annually from Maryland agriculture, about 60% comes from enteric fermentation in the rumen of livestock and 25% from agricultural burning. Surprisingly, MDE estimates only 16% (0.14 $MMtCO_2e$) is generated through manure management. Dietary management, particularly the use of probiotics, could decrease methane emissions in cattle, but this is still in the R&D phase. With regard to manure management, methane-rich biogas is being captured and used in energy generation in some Maryland farm operations and off-farm electricity generation using anaerobic digestion of manure is in the planning stage. Application of this energy production technology is often in response to reducing losses of nitrogen and phosphorus to the environment, with energy generation a co-benefit. A closer examination of methane release from agricultural burning practices is warranted to determine if it is as large a source of methane as the MDE inventory implies.

Waste Management. Methane releases from waste management come from wastewater treatment practices (0.40 $MMtCO_2e$) and landfills (0.55 $MMtCO_2e$). While methane is already captured and used in many wastewater treatment systems, additional emission reductions could be attained through management of anaerobic digestion, composting, etc. Methane is collected at some, but not all, of the major landfills in Maryland. Collection efficiencies range from 13% to 95%. Methane collection could be installed where feasible and collection efficiencies increased. New methane measurement instruments developed by the National Institute of Standards and Technology and deployed on aircraft flown by the University of Maryland have identified atmospheric methane hotspots near certain landfills in Maryland.

Emissions from Altered Natural Systems. The net emissions of greenhouse gases, not only of methane but also of carbon dioxide and nitrous oxide, from Maryland's natural systems are largely unquantified. Such emissions are greatly affected by human uses, management and unintended consequences. The new measurements of methane releases from reservoirs and the over-enriched Chesapeake Bay are cases in point. Forestry practices and fertilization and cropping practices and how they affect carbon sequestration and nitrous oxide generation are other examples. As Maryland refines its climate change mitigation and adaptation approaches, improved understanding of the net emissions of greenhouse gases from natural and managed ecosystems will be critical to informed decision making.

Conclusions

1. Present methane emissions comprise only 2.6% of Maryland's greenhouse gas emissions on a CO_2 equivalent basis, substantially less than for the U.S. as a whole. Even if these emissions could be cut in half, this would contribute only about 3% of Maryland's greenhouse gas emission reduction goal for 2030.
2. Incremental reductions in methane emissions may still be achieved in natural gas transmission, storage and distribution systems, livestock management, wastewater treatment and landfill management.
3. As a more comprehensive basis of energy policy, methane emissions resulting from the production and processing of natural gas consumed in Maryland but produced out of state (virtually all of it), could be accounted for in a manner very similar to the inclusion of greenhouse gas emissions associated with out-of-state electricity generation.
4. Potential natural gas production and transshipment in Maryland should have strict controls on emissions (or State-mandated offsets where Federal regulation prevails) in order to avoid adding to the state's methane emissions.
5. Greater understanding of the emissions of methane and other greenhouse gases from Maryland's natural systems is required so that they can be managed to reduce greenhouse gas emissions.

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