Contributory Role of Atmospheric Methane and the Natural Gas Industry on Global Warming Radiative Forcing

INTRODUCTION

How much of a role does atmospheric methane play in radiative forcing (i.e., global warming)? What impact do worldwide methane emissions from fossil fuel use, including the United States (U.S.) natural gas industry, have on radiative forcing? The answer to these questions is available by combining three independent information resources, as shown in Figure 1.

SUMMARY ANALYSIS

- Based on the National Oceanic and Atmospheric Administration's (NOAA's) Annual Greenhouse Gas Index (AGGI), **all atmospheric methane contributed to 16.7% of radiative forcing** in 2016.
- Estimates within the Global Carbon Project's (GCP) 2016 Global Methane Budget indicate that 52.5% of annual worldwide methane emissions result from human activities (e.g., fossil fuels, agriculture, and waste). Applying this percentage to NOAA's AGGI percentage for methane radiative forcing (i.e., 16.7% x 0.525) indicates **methane emissions from human activities contributed to about 8.8% of radiative forcing** in 2016.
- The GCP estimates worldwide fossil fuel activities (coal, oil, and natural gas) contribute to about 18.8% of total annual methane emissions; applying this to NOAA's AGGI percentage for methane radiative forcing (i.e., 16.7% x 0.188) indicates **worldwide fossil fuel activities contributed to about 3.1% of radiative forcing** in 2016.
- Using the U.S. Environmental Protection Agency's (EPA) estimate of U.S. gas industry methane emissions, we find U.S. gas industry methane emissions comprise about 1.2% of worldwide annual methane emissions; therefore, **U.S. natural gas industry methane emissions contributed to about 0.2% of radiative forcing** in 2016 (i.e., 16.7% x 0.012).

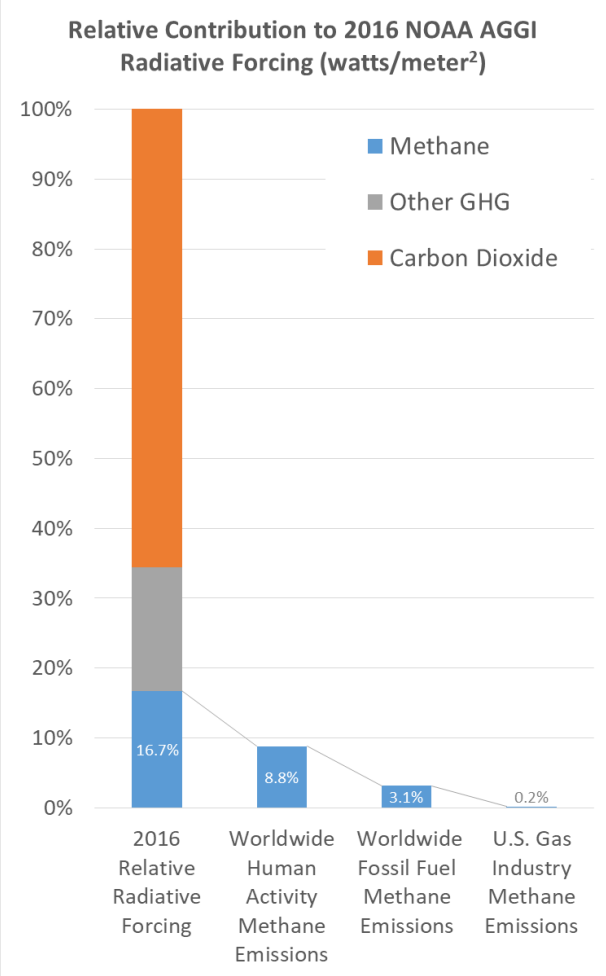

Figure 1: Contribution to NOAA AGGI Radiative Forcing

The following pages detail the methodology used to ascertain these findings.

RADIATIVE FORCING AND ATMOSPHERIC METHANE

NOAA has compiled an AGGI, starting with data from 1979. It is calculated by combining the total radiative forcing for 20 different greenhouse gases, the most significant being carbon dioxide (CO_2) and methane (CH_4), followed by nitrous oxide (N_2O) and various other compounds. The NOAA AGGI provides a ratio of the changes in total radiative forcing from this suite of greenhouse gases compared to a base year of 1990. The NOAA AGGI database contains yearly changes in radiative forcing for these 20 greenhouse gases, in watts per meter squared (W/m^2). Radiative forcing for each greenhouse gas is a quantitative estimate of how much that gas disrupts the balance between incoming radiation from the sun and outgoing radiation reflected from the Earth's surface. The direct radiative forcing calculation is based on an empirical equation derived from well-established atmospheric radiative energy transfer models and serves as a first-order proxy for global warming impact.

Figure 2 shows the trend in carbon dioxide and methane as a portion of annual total radiative forcing in the NOAA AGGI. Since 1980, CO_2 has moved from 60.6% to 65.6% in 2016; CO_2 radiative forcing increased by 0.927 W/m^2 from 1980-2016. Methane (CH_4) has seen a relative decline from 23.6% in 1980 to 16.7% in 2016; net radiative forcing from methane increased by 0.094 W/m^2 since then. The other 18 greenhouse gases comprise the balance (17.7%) of 2016 radiative warming impact, with a net increase in radiative forcing of 0.259 W/m^2 since 1980.

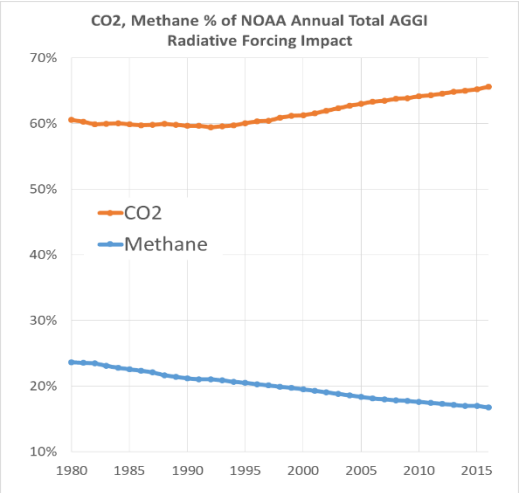

Figure 2: CO_2 and Methane Relative Total NOAA AGGI Radiative Forcing

Table 1 shows a breakdown of (1) total radiative forcing in 2016 and (2) an incremental (or marginal) analysis of the radiative forcing change and relative contribution from these 20 greenhouse gases over two time intervals (i.e., 1979-2016 and 1990-2016). While Figure 1 uses a more conservative total radiative forcing in 2016, a case can be made that marginal analysis is more suitable for presenting contemporary changes in greenhouse gas impact. In this marginal analysis, the relative impact of methane shifts from 16.7% (in the 2016 total) to 7.6% using the 1979-2016 time interval (a 55% decline) and to 5.6% using changes from 1990-2016 (about 65% decline). That is, while methane radiative forcing is increasing, its rate of change is considerably lower than CO_2 in particular. A marginal analysis decreases the methane impact values in Figure 1 by nearly 55-65%. For example, fossil fuel methane impact goes from 3.1% to 1.1% (1990-2016) to 1.4% (1979-2016) of changes in forcing that are taking place in recent decades.

Table 1: Total and Marginal Changes and Contribution to Radiative Forcing

	Radiative Forcing (W/m^2)	% From CO_2	% From CH_4	% From 18 Other GHG
Total (in 2016)	3.027	65.6%	16.7%	17.7%
Marginal (From 1979-2016)	1.328	72.1%	7.6%	20.3%
Marginal (From 1990-2016)	0.862	80.4%	5.6%	14.0%

METHANE EMISSIONS INVENTORY ANALYSIS

Table **2** provides values for estimated annual emissions of methane and the portion from different sources. This data is from two sources: (1) The Global Carbon Project's (GCP) 2016 Global Methane Budget and (2) U.S. EPA Inventory of U.S Greenhouse Gas Emissions and Sinks: 1990-2015. This data is applied to the NOAA AGGI radiative forcing for methane (e.g., 16.7% of total radiative forcing in 2016, as previously noted) to determine the influence of various methane emission sources on radiative forcing in 2016 (as shown earlier in Figure 1).

Table 2: Summary of Methane Emission Sources and Pro Rata Radiative Forcing Due to Methane

Category	Annual Emissions in Teragrams (Tg)	% of Total	% Total 2016 Radiative Forcing Based on NOAA AGGI
- Natural Sources	265	47.5%	7.9%
- Human Activity [1]	293	52.5%	8.8%
Total Worldwide Methane Emissions [1]	**558**	**100%**	**16.7%**
- Agriculture and Waste [1]	188	33.7%	5.63%
- Fossil Fuels [1]	105	18.8%	3.14%
Total Human Activity Methane Emissions	**293**	**52.5%**	**8.8%**
- Coal [1, 2]	35.9	6.4%	1.07%
- Oil and Gas [1, 2]	69.1	12.4%	2.07%
Total Fossil Fuels Methane Emissions	**105**	**18.8%**	**3.14%**
- U.S. Natural Gas Production, Delivery, and Use [1, 3]	6.55	1.2%	0.20%

Source:

1) Global Carbon Project, 2016 Global Methane Budget, Dec. 12, 2016. Source 1 refers to the Top-Down global mean values.

2) Global Carbon Project, 2016 Global Methane Budget, Dec. 12, 2016. Source 2 refers to using the Bottoms-Up global mean percentage value in a category to determine, for example, the fossil fuel split between oil and gas and coal.

3) U.S. EPA Inventory of U.S. Greenhouse Gas Emissions. U.S. natural gas industry emissions divided into the GCP total worldwide methane emissions to determine the percentage of total worldwide methane emissions.

The Global Carbon Project includes two methane emission methodologies: (1) Top-Down inventory and (2) Bottoms-Up inventory. For this analysis, we used the Top-Down inventory as a more conservative assumption (i.e., it shows a larger radiative forcing for fossil fuel methane emissions). The GCP's most recent Top-Down estimate of total annual worldwide methane emissions is 558 Teragrams (Tg), with 105 Tg due to fossil fuels (i.e., natural gas, oil, and coal) – or 18.8% of worldwide methane emissions. The GCP's Bottoms-Up inventory of methane emissions shows a worldwide total of 736 Tg and a fossil fuel portion of 121 Tg – or 16.4% of methane emissions. Using the Top-Down estimate yields a larger, more conservative estimate of fossil fuel methane emissions (18.8%) versus the Bottoms-Up value (16.7%). The last column in

Table **2** shows these percentages for different methane emission sources applied to the NOAA AGGI percentage for atmospheric methane radiative forcing; these data are used in Figure 1. Notably, despite the significant growth in U.S. natural gas production in recent years, studies by NOAA and others indicate that recent increases in atmospheric methane concentration mainly from biological sources and less from fossil fuels.

CONCLUSION

Methane is an important greenhouse gas that is steadily increasing and contributing to global warming. In recent years, methane's relative contribution to global warming is declining – mainly due to the more significant increase in CO_2 atmospheric concentration; this has led to a relative dilution of radiative forcing impact from other greenhouses gases, like methane, on a percentage basis. In 2016, atmospheric methane is estimated to contribute to about 16.7% of total GHG radiative forcing. On a marginal basis, methane has contributed to 5.6% to 7.6% of increases in radiative forcing over the time intervals of 1990-2016 and 1979-2016, respectively.

Global fossil fuel methane emissions are estimated by the Global Carbon Project to be 18.8% of annual worldwide methane emissions. Applying this to NOAA's 2016 radiative forcing percentage for atmospheric methane implies global fossil fuel methane emissions from worldwide oil, natural gas, and coal activities contributed to 3.1% of radiative forcing in 2016 (1.1-1.4% on a marginal basis). U.S. natural gas use is estimated to contribute to about 1.2% of total worldwide methane emissions. When applied to NOAA's 2016 radiative forcing percentage for methane, this implies that U.S. natural gas industry activities contributed to about 0.2% of all NOAA greenhouse gas radiative forcing in 2016 (0.07-0.09% on a marginal basis).

Progress is being made in reducing the relative contribution of methane to global warming. Continued advancements in minimizing methane releases from human activities such as fossil fuel use, agriculture, and waste material – along with reductions from the estimated 47.5% methane emissions from natural sources – offers the potential to decrease the relative and total impact of atmospheric methane on global warming in coming years, due to the relatively short atmospheric lifetime of methane (8-12 years).

REFERENCES

Global Carbon Project, 2016 Global Methane Budget.
http://www.globalcarbonproject.org/methanebudget/
http://lsce-datavisgroup.github.io/MethaneBudget/ (interactive graphic)

National Oceanic and Atmospheric Administration, The NOAA Annual Greenhouse Gas Index (AGGI), Spring, 2017. https://www.esrl.noaa.gov/gmd/aggi/aggi.html

NOAA, "NOAA Study Shows as US Drilling Surged, Methane Emissions Didn't," March 24, 2017.
http://research.noaa.gov/InDepth/Features/CurrentFeature/TabId/728/ArtMID/1884/ArticleID/12123/NOAA-study-shows-as-US-drilling-surged-methane-emissions-didn%E2%80%99t.aspx

United States Environmental Protection Agency, Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2015, April 15, 2017.
https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2015