Climate benefits of U.S. EPA programs and policies that reduced methane emissions 1993-2013

Authors:
April M. Melvin,[1] Marcus C. Sarofim,[2*] Allison R. Crimmins[2]

Author Affiliations:
[1]AAAS S&T Policy Fellow *hosted by* the Climate Change Division, U.S. Environmental Protection Agency, Washington, DC 20460, USA
[2]Climate Change Division, U.S. Environmental Protection Agency U.S. Environmental Protection Agency, Washington, DC 20460, USA

[*]**Corresponding Author:**
Marcus C. Sarofim
Climate Change Division
U.S. Environmental Protection Agency
1200 Pennsylvania Ave. NW
Washington, DC 20460, USA
Phone: (202) 343-9993
Email: sarofim.marcus@epa.gov

Number of pages: 5

Supporting Information

Steps and equations for estimation of radiative forcing and change in global mean air temperature for methane (CH_4):

1. Radiative forcing (ΔF in equation) due to reduced CH_4 emissions was calculated using the simplified expression provided in Myhre et al.[1]:

   $\Delta F = \alpha(\sqrt{M}-\sqrt{M_0})-(f(M,N_0)-f(M_0,N_0))$ (equation 1)

   Where:

   $\alpha = 0.036$

   $f(M,N) = 0.47 \ln[1+2.01x10^{-5} (MN)^{0.75}+5.31x10^{-15} M(MN)^{1.52}]$

   M is the counterfactual CH_4 concentration in ppb

   M_0 is the observed CH_4 concentration in ppb

   N_0 is the observed N_2O in ppb

2. ΔF values were multiplied by 1.65 to account for forcing resulting from the production of tropospheric O_3 and stratospheric water vapor during the degradation of CH_4 in the atmosphere.[1]

3. Radiative forcing estimates obtained from steps 1 and 2 were then used to determine the change in global mean air temperature (ΔT) attributed to reduced CH_4 emissions using an equation provided by Shine et al.[2]:

$$\Delta T(t) = 1/C \int_0^t \Delta F\,(t')\exp((t'-t)/(\lambda C))dt' \qquad \text{(equation 2)}$$

Where:

C is the heat capacity, 4.2×10^8 J K^{-1} m^{-2}

λ is the climate sensitivity

We use λ consistent with a best estimate of climate sensitivity of 3[3] and bounds of 1.5 and 4.5[4]

Steps and equations for estimation of radiative forcing and change in global mean air temperature for carbon dioxide (CO_2):

1. Using the assumption that all CH_4 accounted for in this analysis would become CO_2 immediately, we calculated an immediate increase in atmospheric loading of CO_2 equal to 44/16 times the mass of the CH_4. The lifetime of CO_2 for these purposes was assumed to be 12.4 years (which is the CH_4 lifetime[1]) as that is the time period in which the CO_2 would have been created in any case due to oxidation of the CH_4. Factors due to the carbon cycle itself, or reductions of CO_2 in the future resulting from earlier absorption of the emitted CO_2, were not accounted for, and would likely lead to a reduction in the impact calculated here.

2. Radiative forcing was calculated using the equation from Myhre et al.[1]:

$$\Delta F = \alpha \ln (C/C_0) \qquad \text{(equation 3)}$$

Where:

$\alpha = 5.35$

C is the counterfactual CO_2 concentration in ppm

C_0 is the observed CO_2 concentration in ppm

Global mean CO_2 concentration data from NOAA[5] were used for observed concentrations.

3. Global mean air temperature changes were calculated using the same approach described for CH_4.

References

1. Myhre, G.; Schindell, D.; Breon, F.-M.; Collins, W.; Fuglestvedt, J.; Huang, J.; Koch, D.; -F., L. J.; Lee, D.; Mendoza, B.; Nakajima, T.; Robock, A.; Stephens, G.; Takemura, T.; Zhang, H., Anthropogenic and natural radiative forcing. In *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, Stocker, T. F.; Qin, D.; Plattner, G.-K.; Tignor, M.; Allen, S. K.; Boschung, J.; Nauels, A.; Xia, Y.; Bex, V.; Midgley, P. M., Eds. Cambridge University Press: Cambridge, United Kingdom and New York, NY, USA, 2013.

2. Shine, K. P.; Fuglestvedt, J. S.; Hailemariam, K.; Stuber, N., Alternatives to the global warming potential for comparing climate impacts of emissions of greenhouse gases. *Climatic Change* **2005,** *68*, (3), 281-302.

3. Meehl, G. A.; Stocker, T. F.; Collins, W. D.; Friedlingstein, P.; Gaye, A. T.; Gregory, J. M.; Kitoh, A.; Knutti, R.; Murphy, J. M.; Noda, A.; Raper, S. C. B.; Watterson, I. G.; Weaver, A.

J.; Zhao, Z.-C., Global climate projections. In *Climate Change 2007: The Physical Science Basis. Congribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Solomon, S.; Qin, D.; Manning, M.; Chen, Z.; Marquis, M.; Averyt, K. B.; Tignor, M.; Miller, H. L., Eds. Cambridge University Press: Cambridge, United Kingdom and New York, NY, USA, 2007.

4. Collins, M.; Knutti, R.; Arblaster, J.; Dufresne, J.-L.; Fichefet, T.; Friedlingstein, P.; Gao, X.; Gutowski, W. J.; Johns, T.; Krinner, G.; Shongwe, M.; Tebaldi, C.; Weaver, A. J.; Wehner, M., Long-term climate change: projections, commitments and irreversibility. In *Climate Change 2013: The Physcial Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, Stocker, T. F.; Qin, D.; Plattner, G.-K.; Tignor, M.; Allen, S. K.; Boschung, J.; Nauels, A.; Xia, Y.; Bex, V.; Midgley, P. M., Eds. Cambridge University Press: Cambridge, United Kingdom and New York, NY, USA, 2013.

5. National Oceanic & Atmospheric Administration, Earth System Research Laboratory, global greenhouse gas reference network; http://www.esrl.noaa.gov/gmd/ccgg/trends/global.html