Background Note on Methane

Methane has a 100-year global warming potential 28 times that of CO_2, and an atmospheric lifetime of approximately 12 years.[1] The radiative forcing of methane in 2011 was 0.48 W/m^{-2} [±0.05], which is more than a quarter of CO_2 radiative forcing.[2] Methane is the third most important climate pollutant, behind CO_2 and black carbon.

About 60% of global methane emissions are due to human activities.[3] The main sources of anthropogenic methane emissions are oil and gas systems (methane is the primary component of natural gas); agriculture, including enteric fermentation, manure management, and rice cultivation; landfills; wastewater treatment; and emissions from coal mines.[4]

According to a 2011 UNEP and WMO assessment, anthropogenic methane emissions are expected to grow 25% over 2005 levels by 2030, driven by increased production from coal mining and oil and gas production, and growth in agricultural and municipal waste emissions.[5] Recent analysis suggests that current estimates of methane emissions from gas extraction, transmission, and distribution may be substantially underestimated, which could have a large impact on emissions estimates as world consumption of natural gas is expected to increase by 64% by 2040.[6] According to the International Energy Agency, reduction of methane emissions from upstream oil and gas operations can provide 18% of the emissions reductions needed for a 2°C path.[7]

Methane is also an important precursor gas of another powerful air pollutant, tropospheric ozone. Globally, increased methane emissions are responsible for half of the observed rise in tropospheric ozone levels.[8] While methane does not cause direct harm to human health or crop production, one study calculates that it causes as much as 15% of the premature deaths due to air pollution, and more than 20% of deaths related to respiratory illnesses associated with tropospheric ozone in South America, Europe, Africa, the Middle East, and Asia.[9]

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[1] The 100-yr GWP of methane is estimated to be 28, and on the shorter timeframe of 20-yr the GWP is estimated at 84. If carbon-cycle feedbacks are included the 100-yr GWP of methane is 34. Myhre G., *et al.* (2013) CHAPTER 8: ANTHROPOGENIC AND NATURAL RADIATIVE FORCING, *in* IPCC (2013) CLIMATE CHANGE 2013: THE PHYSICAL SCIENCE BASIS, Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Table 8.A; *and* Alexander L., *et al.* (2013) SUMMARY FOR POLICYMAKERS, *in* IPCC (2013) CLIMATE CHANGE 2013: THE PHYSICAL SCIENCE BASIS, Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

[2] When methane's contribution to the production of tropospheric ozone, CO_2, and stratospheric water vapour are included, its radiative forcing is much higher at 0.97 Wm^{-2}. Alexander L., *et al.* (2013) SUMMARY FOR POLICYMAKERS, *in* IPCC (2013) CLIMATE CHANGE 2013: THE PHYSICAL SCIENCE BASIS, Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, 11 ("Emissions of CO_2 alone have caused an RF of 1.68 [1.33 to 2.03] W m^{-2} (see Figure SPM.5). Including emissions of other carbon-containing gases, which also contributed to the increase in CO_2 concentrations, the RF of CO_2 is 1.82 [1.46 to 2.18] W m^{-2}…. Emissions of CH_4 [methane] alone have caused an RF of 0.97 [0.74 to 1.20] W m^{-2} (see Figure SPM.5). This is much larger than the concentration-based estimate of 0.48 [0.38 to 0.58] Wm^{-2} (unchanged from AR4). This difference in estimates is caused by concentration changes in ozone and stratospheric water vapour due to CH_4 emissions and other emissions indirectly affecting CH_4.").

[3] IPCC (2013) CLIMATE CHANGE 2013: THE PHYSICAL SCIENCE BASIS, Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change; *see also* U.S. EPA (2010) METHANE AND NITROUS OXIDE EMISSIONS FROM NATURAL SOURCES, ES-2.

[4] UNEP/WMO (2011) INTEGRATED ASSESSMENT OF BLACK CARBON AND TROPOSPHERIC OZONE.

[5] UNEP/WMO (2011) INTEGRATED ASSESSMENT OF BLACK CARBON AND TROPOSPHERIC OZONE.

[6] Brandt A. R., *et al.* (2014) *Methane Leaks from North American Natural Gas Systems*, SCIENCE 343:733-735, 735 ("We include in the second chart a range of excess CH4 from all sources (7 to 21 × 1012 g or Tg/year) based

on normalized national-scale atmospheric studies from the inset in the fi rst chart. This excess is conser- vatively defi ned as 1.25 to 1.75 times EPA GHGI estimates."); *see also* Leifer I., *et al.* (2013) *Transcontinental methane measurements: Part 2, Mobile surface investigation of fossil fuel industrial fugitive emissions*, ATMOS. ENV'T 74:432-441; Peischl R., *et al.* (2013) *Quantifying sources of methane using light alkanes in the Los Angeles basin, California*, J. OF GEOPHYS. RES. – ATMOS. 118(10):4974-4990; Townsend-Small A. (2012) *Isotopic measurements of atmospheric methane in Los Angeles, California, USA reveal the influence of "fugitive" fossil fuel emissions*, J. OF GEOPHYS. RES. (in press) doi:10.1029/2011JD016826; O'Sullivan F. & Paltsev S. (2012) *Shale gas production: potential versus actual greenhouse gas emissions*, ENVIRON. RES. LETT. 7(4):044030; *and* Allen D. T., *et al.* (2013) *Measurements of methane emissions at natural gas production sites in the United States*, PROC. NATL. ACAD. SCI. USA (in press).

[7] International Energy Agency (2013) REDRAWING THE ENERGY-CLIMATE MAP, WORLD ENERGY OUTLOOK SPECIAL REPORT, 43 ("In the 4-for-2 °C Scenario, energy-related CO_2 and CH_4 emissions increase from 33.3 Gt in 2010 to 34.9 Gt in 2020 (measured on a CO_2-eq basis) and decline thereafter. Emissions in 2020 are 3.1 Gt lower than the course on which we otherwise appear to be set, delivering 80% of the abatement needed to be on track with a 2 °C trajectory. Energy efficiency accounts for 49% of the savings realised, limitations on inefficient coal-fired power plants for 21%, lower methane emissions in upstream oil and gas for 18%, and the partial phaseout of fossil-fuel subsidies for 12%.")

[8] UNEP/WMO (2011) INTEGRATED ASSESSMENT OF BLACK CARBON AND TROPOSPHERIC OZONE, 57; *see also* UNEP (2011) NEAR-TERM CLIMATE PROTECTION AND CLEAN AIR BENEFITS: ACTIONS FOR CONTROLLING SHORT-LIVED CLIMATE FORCERS ("Methane contributes around 50 per cent of the increases in background ozone, with smaller contributions from non-methane volatile organic compounds and carbon monoxide"); Royal Society (2008) GROUND-LEVEL OZONE IN THE 21ST CENTURY: FUTURE TRENDS, IMPACTS AND POLICY IMPLICATIONS: SCIENCE POLICY REPORT; *and* Myhre G., *et al.* (2013) CHAPTER 8: ANTHROPOGENIC AND NATURAL RADIATIVE FORCING, *in* IPCC (2013) CLIMATE CHANGE 2013: THE PHYSICAL SCIENCE BASIS, Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, FAQ8.2 ("Controls on anthropogenic emissions of methane (FAQ 8.2, Figure 1) to lower surface ozone have been identified as "win-win" situations. Consequences of controlling other ozone precursors are not always as clear. Nitrogen oxide emission controls, for instance, might be expected to have a cooling effect as they reduce tropospheric ozone, but their impact on methane lifetime and aerosol formation is more likely instead to cause overall warming.").

[9] Fang Y., *et al.* (2013) *Air pollution and associated human mortality: the role of air pollution emissions, climate change and methane concentration increases from the preindustrial period to present*, ATMOS. CHEM. PHYS 13: 1377-1394, 1377, 1390 ("[C]hanging climate and increasing CH_4 concentrations also contribute to premature mortality associated with air pollution globally (by up to 5% and 15 %, respectively.... Increased CH_4 concentrations alone contribute more than 20% to respiratory mortalities associated with industrial O_3 exposure over South America, Europe, Africa, Middle East and Rest of Asia.... CH_4 is projected to increase in almost all SRES and RCP emission scenarios (except RCP2.6 and SRES B2). As a result, the relative contribution of increased CH_4 to O_3 mortality will likely continue to rise, increasing the relative health benefits of CH_4 mitigation.)."