Global Carbon Project

Briefing on key messages for Global Methane Budget 2024

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This document is intended as a background briefing for the co-authors and journalists covering the release of the Global Methane Budget 2000-2020.
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The Global Carbon Project is an international research project within the Future Earth research initiative on global sustainability and a research partner of the World Climate Research Programme. It aims to develop a complete picture of the global carbon cycle and budgets of carbon dioxide, methane, and nitrous oxide, including both its biophysical and human dimensions, together with the interactions and feedbacks between them.

This Global Methane Budget 2024 is the fourth such budget and the third one as a living data collection in the journal *Earth System Science Data* (Saunois et al., 2024). Data and methods are provided in the publication, with links at the end of this document.

Headline 1:
Human activities are now responsible for at least two-thirds of global methane emissions.

Headline 2:
The increase rate of methane concentrations in the atmosphere has accelerated in the atmosphere over the last five years.

Headline 3:
Atmospheric concentrations of CH_4, the second most important contributor to global warming, are increasing at rates consistent with carbon-intensive emissions scenarios used by the IPCC emission scenarios

Headline 4: To date, we have not yet observed a decrease in global methane emissions from human activities as expected to reach the demands of the Global Methane Pledge due in 2030.

Headline 5:
While global CO_2 emissions from human activities (fossil fuel and land use change) have been rather stable over the past decade, global CH_4 emissions from fossil fuel, agriculture and waste have continued to increase.

Headline 6:
The trends of CH_4 emissions from human activities are tracking scenarios that assume no or minimal climate mitigation policies proposed by the IPCC, and are not consistent with the Global Methane Pledge commitment of 30% reductions of 2020 levels by 2030.

We report the CH_4 trends and budgets for the last two decades using observations, modeling of the land biosphere, observation-upscaled synthesis flux products, activity-based inventories, and atmospheric observations and modeling. We report on a total of 17 natural and anthropogenic source sectors and 4 sinks of global CH_4. In what follows, we emphasize the connections between emissions from human activities relevant to climate change, the goals of the Paris Climate Agreement, and the national mitigation commitments.

Highlights

- CH_4 emissions from human activities have increased by 20% (61 million metric tons of CH_4 per year) in the past two decades.
- Direct anthropogenic CH_4 sources include emissions from fossil fuel exploitation and use, agriculture, waste handling, and biomass and biofuel burning. Those sources represent around 60% of total CH_4 sources. Together with other indirect anthropogenic emissions (eg, from reservoirs & climate impacts on wetlands) account for at least two-thirds of Earth's (natural and anthropogenic) CH_4 emissions.
- Methane emissions from fossil fuels are now comparable in size to methane emissions from cows and other ruminants globally, but overall emissions from agriculture and waste sector (e.g., ruminants, rice paddies, landfills) remain approximately twice of those associated with fossil fuels.
- CH_4 accumulation in the atmosphere has accelerated in the past decade, with higher growth rates over the past three years (2020-2022) than any previous observed year since 1986 when reliable measurements from a wider network began.
- The concentration of atmospheric CH_4 reached 1923 parts per billion (yearly average) in 2023. This is an increase by a factor of 2.6 compared to the pre-industrial level (722 parts per billion) and the highest value in at least 800,000 years.
- The observed atmospheric CH_4 concentrations in the past decade follow the trends of the IPCC most pessimistic illustrative future GHG trajectories, which lead to global mean temperatures above 3°C by the end of this century.
- For net-zero emission pathways consistent with the Paris Agreement (stabilizing temperatures below 2°C) from pre-industrial levels), anthropogenic CH_4 emissions must decline by 45% relative to 2019 levels by 2050
- The top five country emitters by volume of anthropogenic CH_4 in 2022 were China (16%), India (9%), USA (7%), Brazil (6%), Russia (5%). EU27 is 6^{th} with 4% of the global anthropogenic emissions.
- The EU and Australasia have successfully reduced their anthropogenic CH_4 emissions over the past two decades through policies related to landfills and waste
- The major emitter of CH_4 from coal exploitation is China (53%). The major emitters of CH_4 from the oil and gas sector are the Middle East (24%), Russia (18%) and USA (12%).

Methane 101

1. Methane (CH_4) is the second most important anthropogenic greenhouse gas (after carbon dioxide, CO_2) leading to human-induced global warming
2. CH_4 is a 28 times more powerful greenhouse gas than CO_2 over a time horizon of 100 years, but 80 times more powerful than CO_2 over a time horizon of 20 years.
3. CH_4 lifetime in the atmosphere is around 9 years, making it a good target for short-term climate mitigation. This means that, of one tonne of CH_4 emitted today, about

half will be oxidized (gone) from the atmosphere in 9 years. Only 10% of emissions will remain in the atmosphere after 30 years since the initial release, and CH_4 will be almost completely gone after 50 years.

4. CH_4 emissions from human activities are responsible for around 40% of the effective radiative forcing of greenhouse gases and have added about 0.5°C to current global — warming.
5. As a result of increased anthropogenic CH_4 emissions, the CH_4 concentration in the atmosphere is now 2.6 times higher than its pre-industrial (1750) level.
6. In addition to climate impacts, CH_4 is a precursor of tropospheric ozone formation, a greenhouse gas and a pollutant for air quality, damaging human and ecosystem and crop health

Emissions and Atmospheric Accumulation

- Total annual CH_4 emissions from human activities increased by 20% (61 Million metric tons of CH_4 per year) in the past two decades (2000-2020) and have continued to increase to 2022.
- These emissions have accumulated in the atmosphere at an increasing rate. The annual atmospheric CH_4 growth increased from 6.1 million metric tons per year during the 2000s to 20.9 million metric tons per year in the 2010s. The growth has further accelerated over the past three years (2020-2022), with annual growth rates higher than any previously observed since 1986 (the start year for the continuous measurement) – accumulation of 41.8 million metric tons of CH_4 in 2020, twice that of the past decade.
- Atmospheric CH_4 concentrations reached 1923 parts per billion (ppb) on average in 2023, 2.66 times the pre-industrial levels. Between 2000 and 2023, atmospheric CH_4 concentrations have increased by 149 parts per billion, an additional 8% from 2000 levels.
- The atmospheric increase is smaller than the emissions increase because chemical sinks remove some CH_4 from the atmosphere. The main sink is the oxidation by the hydroxyl radical (OH). The quantity of this radical in the atmosphere depends on many factors, some meteorological factors, but also on other pollutant concentrations such as nitrogen oxide (NOx).
- A reduced chemical sink in 2020 during the pandemic lockdown, due to a reduction in the emissions of nitrogen oxides (NOx) that help form OH radicals – emitted mainly by the transport sectors – contributed to about half of the 2020 atmospheric accumulation (Peng et al., 2022). This illustrates the entanglement between climate and air quality issues.
- The observed atmospheric CH_4 concentrations in the past decade follows the trends of the most pessimistic illustrative future GHG trajectories used by the IPCC that lead to global mean temperatures above 3°C by the end of this century, underscoring the urgency of reducing anthropogenic CH_4 emissions.
- CH_4 anthropogenic emissions have continued to increase until 2022 (the latest year of global data available). If this trend were to continue for the years after, this could jeopardize the success of the Global Methane Pledge (international commitment to reduce by 30% methane emissions of 2020 levels by 2030).
- Natural emissions of CH_4 from aquatic ecosystems such as wetlands, lakes, ponds and rivers have been revised to 248 million metric tons of CH_4 per year for the 2010 decade. From these emissions, about a third are considered as indirect

anthropogenic emissions because they result from human activity perturbations through climate change, eutrophication and land use.
- Emissions from aquatic ecosystems, and in particular wetlands are climate sensitive. Wetland emissions have increased by 4% between the 2000s and the 2010s, mainly from the tropics and the mid-latitude regions. Rising temperatures was the primary driver of the increase while precipitation and rising atmospheric CO_2 concentrations played secondary roles. This climate feedback on natural emissions may require a stronger reduction in anthropogenic emissions to limit climate warming.

Sources of Anthropogenic Emissions

- Direct anthropogenic CH_4 sources include emissions for fossil fuel exploitation and use, agriculture, waste handling, and biomass and biofuel burning. Those sources represent around 60% of total CH_4 sources.
- Agriculture (livestock and rice paddies) is the main anthropogenic source and contributes 40% of global anthropogenic emissions, followed closely by the fossil fuel sector (34%). Solid waste and wastewater contribute 19% while biomass and biofuel burning represent 7%.
- Between the early 2000s and the late 2010s, all major sectors of anthropogenic CH_4 emissions rose substantially. Emissions from cows (and other ruminants) and from landfills (and other waste) both rose by ~15 millions metric tons of CH_4 per year between 2000-2002 and 2018-2020, representing an increase of 14% from agriculture and around 24% from waste. Fossil fuel emissions rose by an estimated 18 to 27 million metric tons of CH_4 (18 to 28%), as estimated by different approaches.

Top Regional and Country Anthropogenic Emitters

- The top five emitters by volume of anthropogenic CH_4 emissions in 2022 were China (16%), India (9%), USA (7%), Brazil (6%), Russia (5%). EU27 is 6th with 4% of the global anthropogenic emissions.
- The global increase in methane emissions from 2000 to 2020 arises largely from four regions or countries: China (28%), South Asia (15%), South East Asia (12%) and the Middle East (12%) based on inventories.
- In China, increasing emissions are primarily due to coal exploitation, followed by waste emissions. In the Middle East, increasing emissions are due to intense oil and gas exploitation followed by waste emissions. In South Asia, the main sector of increasing emissions is agriculture followed by waste, while in South East Asia the main sectors responsible for the increase are coal mining and agriculture.
- Europe and Australia (Australia and New Zealand) are the two regions showing a decrease of emissions over the last two decades. European emission decrease is mostly occurring in the landfills and waste sector (half of the decrease) followed by fossil fuel and agriculture. The slight emission decrease in Australia is from agriculture.
- Emissions in Africa have continued to increase mostly from agriculture followed by the waste sector, while the fossil emissions seem to have decreased.
- In Brazil, emissions have increased due to the agriculture sector and to a lesser extent the waste sector, which is also the case for Central America and the rest of South America.

- In the USA, anthropogenic emissions seem to have slightly increased in the fossil fuel sector, while agriculture emissions remained stable and waste emissions slightly decreased over the past two decades.

Implication for Reaching Net-zeros Emissions

- The observed atmospheric CH_4 concentrations in the past decade follows the trends of the most pessimistic illustrative future GHG trajectories used by the IPCC that lead to global mean temperatures above 3°C by the end of this century.
- CH_4 emissions from human activities must decline to be consistent with mitigation pathways leading to temperatures below 2°C as established by the Paris Agreement with a reduction of 45% relative to 2019 levels required by 2050. From the IPCC WGIII Figure SPM.5 or C.1.2: "There are similar reductions of non-CO_2 emissions by 2050 in both types of pathways: CH4 is reduced by 45% [25–70%]; N_2O is reduced by 20% [–5 to +55%]; and F-gases are reduced by 85% [20–90%]."
- The Paris Agreement reduction also aligns with the Global Methane Pledge, signed by more than 155 countries, representing a little more than 50% of the global anthropogenic emissions. The pledge engages countries to collectively reduce global anthropogenic emissions by 30% relative to 2020 levels by 2030.
- The need for emissions reductions is further underscored by the fact that no technologies are available or currently in development capable of directly removing CH_4 from the atmosphere (as they exist or are identified for CO_2).

How to Reduce CH_4 Emissions (background information, but not the emphasis in the paper) – mainly from the Global Methane Assessment - UNEP

- Methane is a short-lived greenhouse gas compared to CO_2; its lifetime in the atmosphere is around 9 years, meaning that after a couple of decades, the methane that has been emitted has been largely destroyed in the atmosphere.
- Due to its short lifetime, methane is a good target for short-term mitigation of global warming.
- Strategies for reducing methane emissions already exist and have been deployed in some regions. The sector with the largest relative potential of reduction is the fossil fuel sector, followed by the waste sector. Agriculture solutions are less straightforward than the two other sectors.
- Countries signatories of the Global Methane Pledge have already taken actions to reduce their emissions or define a roadmap to do so.
- Meeting the Global Methane Pledge would reduce methane emissions to a level consistent with 1.5°C pathways while delivering significant benefits for human and ecosystem health, food security and our economies. It has the potential to reduce warming by at least 0.2 °C by 2050 and prevent annually 26 million tons of crop losses, 255,000 premature deaths, 775 thousand asthma-related hospitalizations and 73 billion hours of lost labour due to extreme heat.
- Available measures could reduce emissions from the major emission sectors by as much as 45% by 203 (approximately 180 million metric tons per year). Most of these technical solutions can be implemented at a negative or low cost, especially in the fossil fuel and waste sectors.

- In the fossil fuel sector, 60-80% of oil and gas measures and 55-98% of coal measures could be implemented at a negative or low cost. These measures include:
    - Upstream and downstream leak detection and repair
    - Recovery and utilization of vented gas
    - Improved control of unintended fugitive emissions from the production of oil and natural gas
    - Coal mine methane management through pre-mining degasification, recovery and oxidation of ventilation air methane
    - Flooding abandoned coal mines
- In the waste sector, 30-60% of measures have either negative or low cost. Such measures include:
    - Sources separation with recycling/reuse
    - Covering landfills and valoring the produced biogas
    - No landfills of organic waste
    - Treatment with energy recovery of collection and flaring of landfill gas
    - Upgrade to secondary/tertiary anaerobic treatment with biogas recovery and utilization
- The agriculture sector is the most difficult to mitigate. However, solutions include:
    - Reduce enteric fermentation through feed changes and supplements; selective breeding to improve productivity and animal health /fertility
    - Treatment of livestock manure in biogas digester; decrease manure storage time; improve manure storage covering…
    - Improved water management or alternate flooding/drainage wetland rice; composting rice straws; use alternative hybrid species
    - Prevent burning agricultural crop residues
- Additional beneficial measures to mitigate methane emissions include:
    - Use renewable energy for power generation
    - Improve energy efficiency and energy demand management
    - Reduce consumer waste and improve waste separation
    - Reduce food waste and loss
    - Adoption of healthier diets to decrease consumption of ruminant products.

Sources

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Global Methane Budget paper as pre-print
Journal: *Earth System Science Data*
Open Access: https://essd.copernicus.org/preprints/essd-2024-115/ , 2024.

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For more resources on this release and data availability, visit Global Carbon Project https://www.globalcarbonproject.org/methanebudget/

Emissions data and display interface with national emissions at the Global Carbon Atlas: https://globalcarbonatlas.org/

Emissions data per decades and regions are available under the ICOS website: https://www.icos-cp.eu/GCP-CH4-2024

Other reference:
About The Global Methane Pledge: https://www.globalmethanepledge.org/

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