UNIVERSITY OF LIVERPOOL

Where is all the methane coming from?

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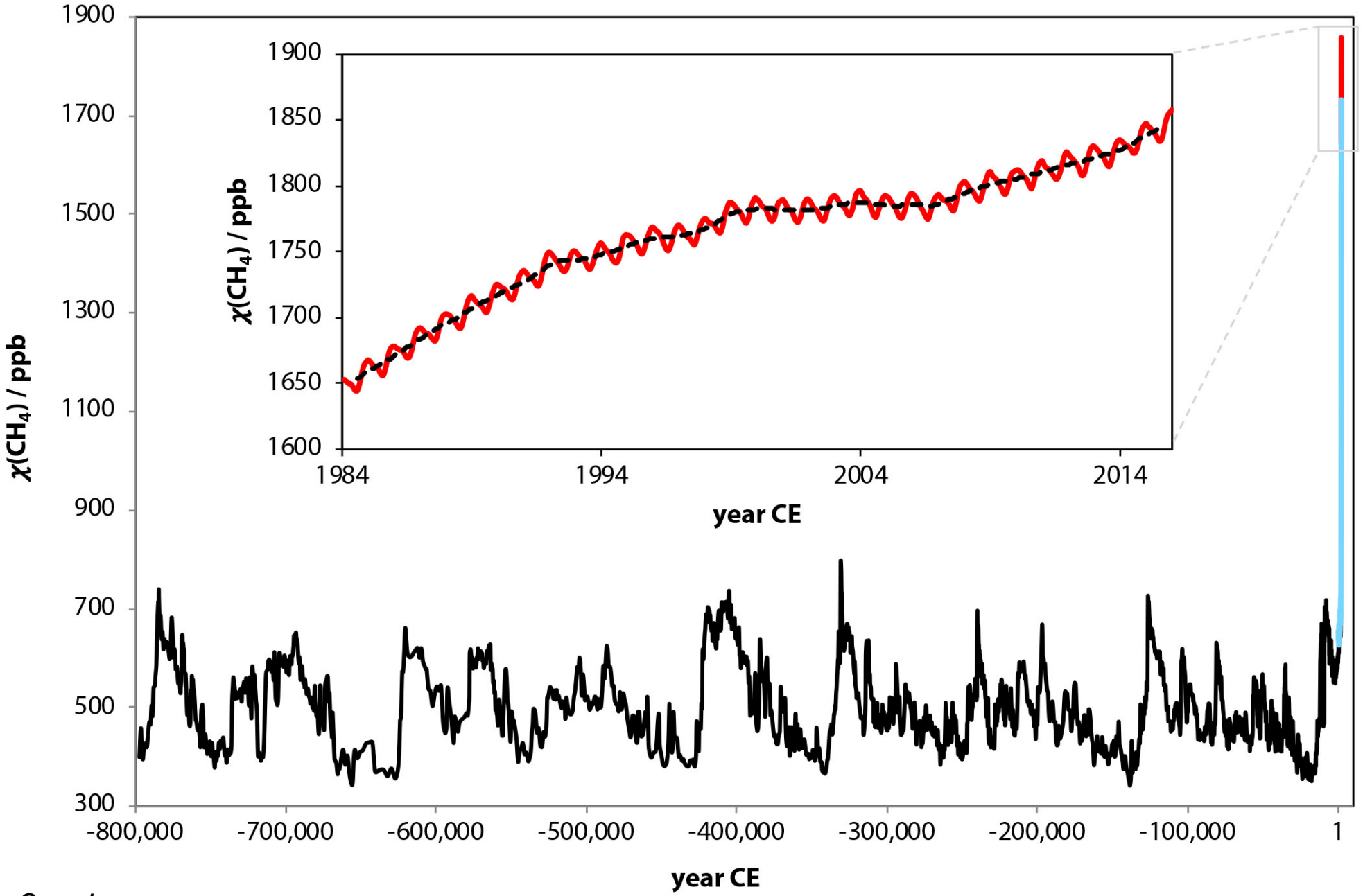
Methane – CH_4

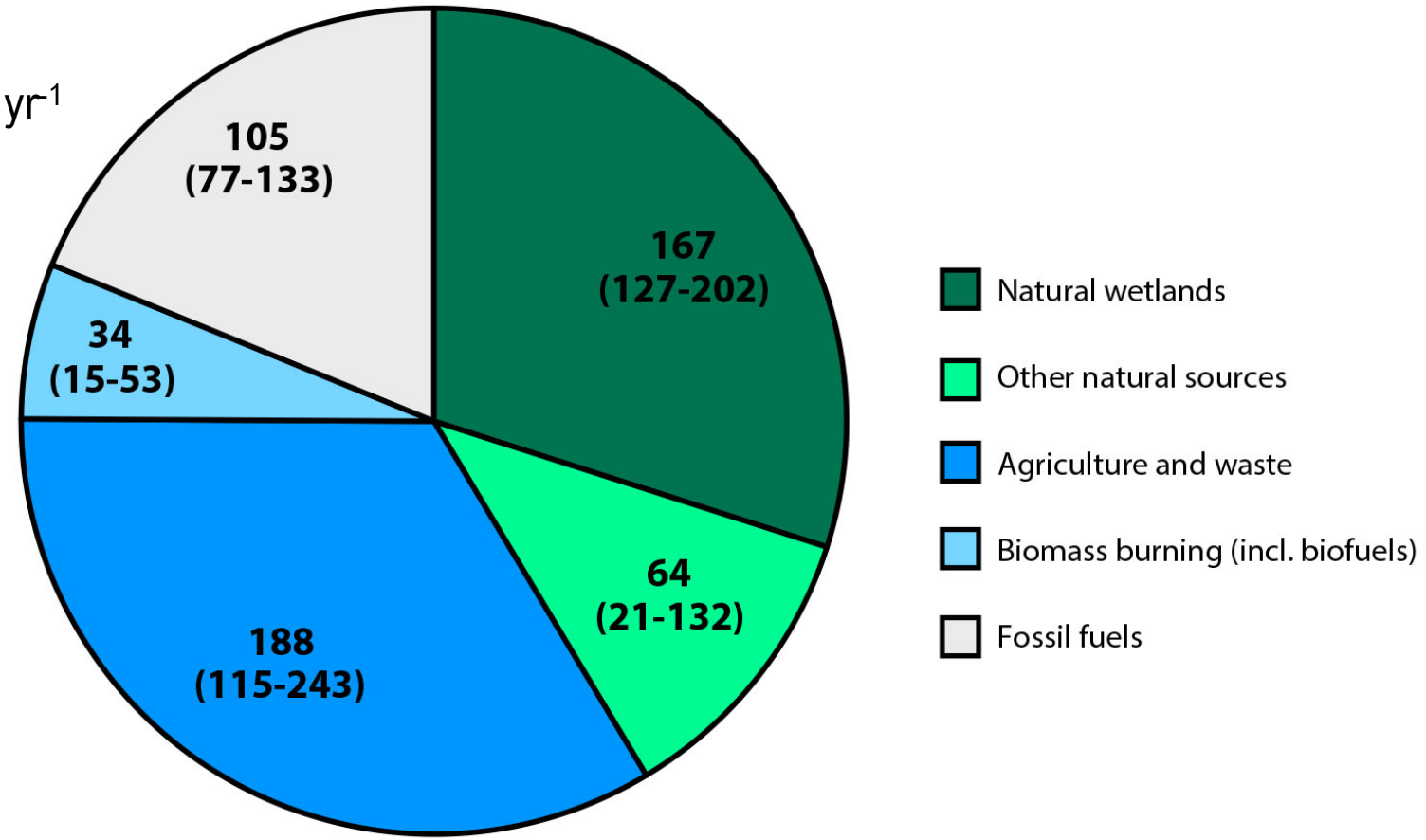
- Methane is a “short-lived climate forcer”
- Average lifespan in the atmosphere ~10 years
- Global Warming Potential (GWP):
  - **34** over a 100-year time span
  - **86** over a 20-year time span
- Methane has attributed equivalent to ~60% of the radiative forcing of CO_2 since 1750

Atmospheric methane concentration (mole fraction)



Dean *et al*. (2018) *Rev. Geophys.*

All values in Tg CH_4 yr^{-1}



Dean *et al*. (2018) *Rev. Geophys.*

Radiocarbon – ^{14}C

- Carbon exists as two stable isotope (^{12}C and ^{13}C) and one radioactive isotope (^{14}C)

- ^{14}C has a half life of 5,730 years

- Produced in the lower stratosphere and upper troposphere by cosmic rays which create neutrons and these can strike ^{14}N atoms forming ^{14}C

Radiocarbon – ^{14}C

- Different sources of methane can also have different $^{14}CH_4$ signatures depending on the age of the carbon they are formed from.

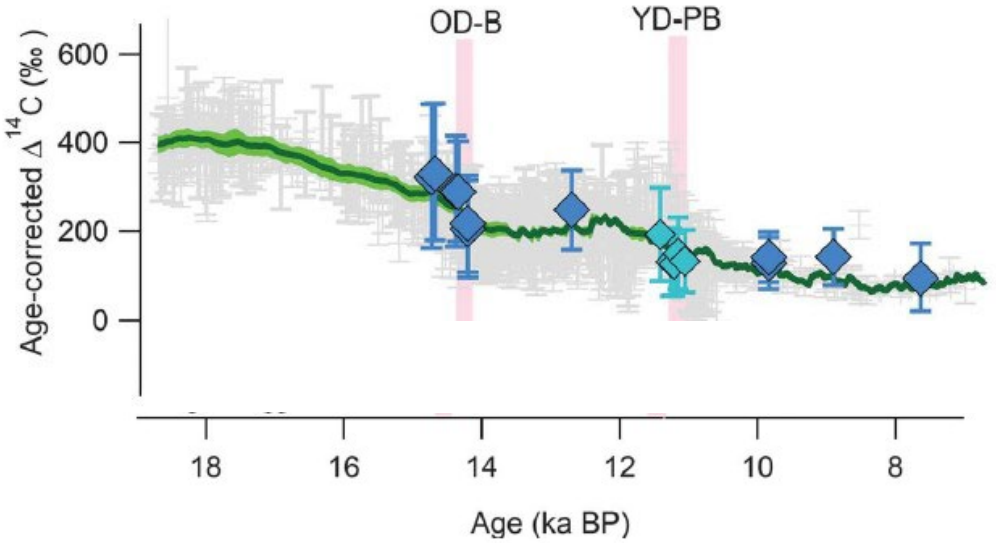
- For example:
  - Natural gas methane (fossil methane) is radiocarbon “dead” – has no ^{14}C in it any more.
  - Methane from a cow belch has the same ^{14}C signature as the contemporary atmosphere.

Methane in ice cores

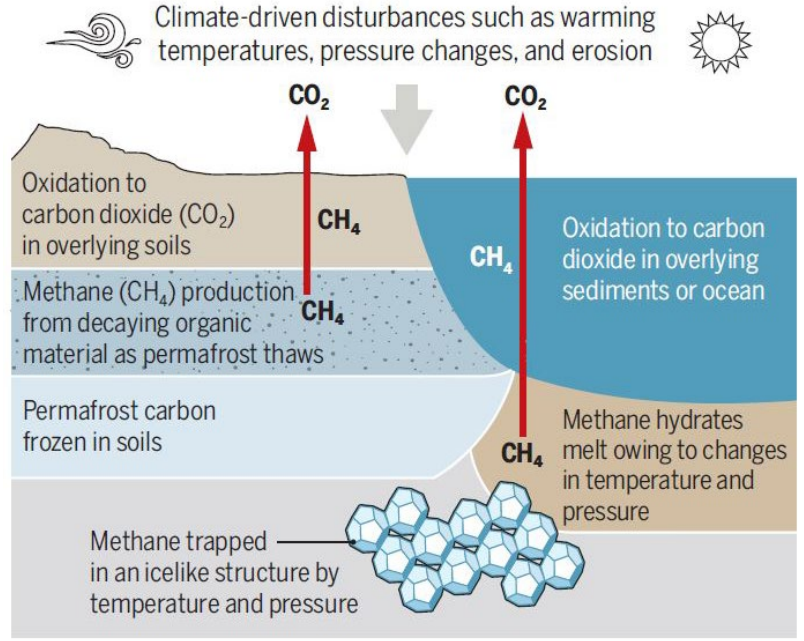
- The last deglaciation when Earth last showed warming similar to what is predicted for our immediate future (~4°C)

Methane in ice cores

- The last deglaciation when Earth last showed warming similar to what is predicted for our immediate future (~4°C)
- Emission from other old methane sources were small (permafrost thaw and methane hydrates)
- These old methane sources may not be triggered by current and near-future climate change



Adapted from: Dyonisius *et al*. (2020) *Science*

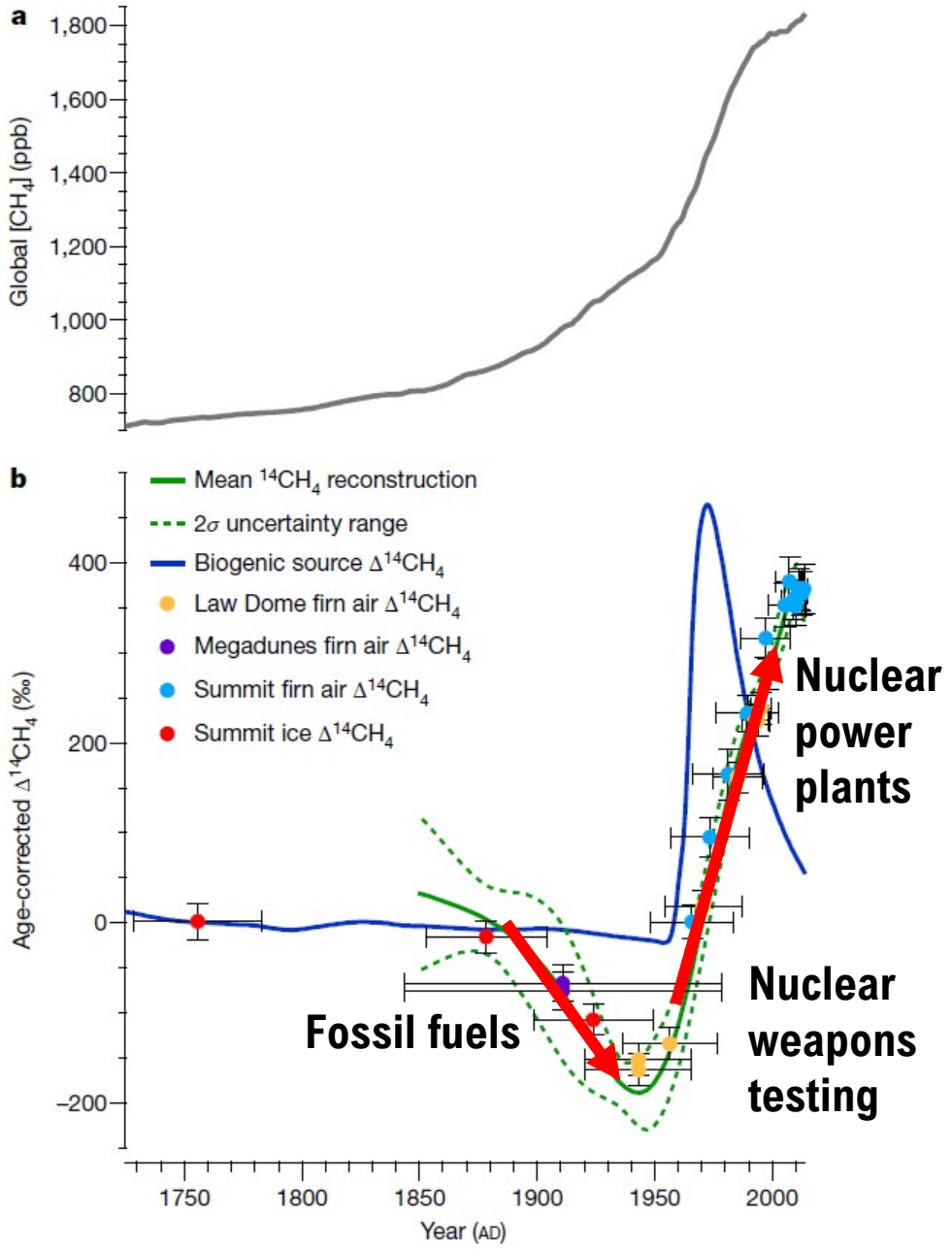


Adapted from: Dean (2020) *Science*

Contemporary ice cores

- Fossil methane emissions increased from “negligible” in preindustrial times to 64.8 Tg CH_4 yr^{-1} in 1940

- Preindustrial geologic methane emissions = 1.6 (max 5.4) Tg CH_4 yr^{-1}
  - Compared to 40—60 Tg CH_4 yr^{-1} in previous estimates



Adapted from: Hmiel *et al*. (2020) *Nature*

Fossil fuels?

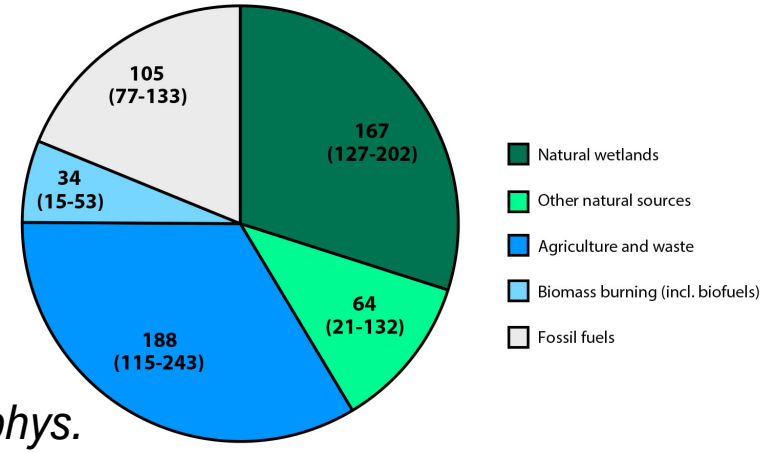


- If 1.6 (max 5.4) Tg CH_4 yr^{-1} is correct, these are the probable level of background (natural) emissions of fossil methane today
  - What does that mean for today's methane accounts?

- Hmiel *et al*. (2020) estimate modern-day methane emissions from fossil fuel industry:
- **177 ± 37 Tg CH_4 yr^{-1}**

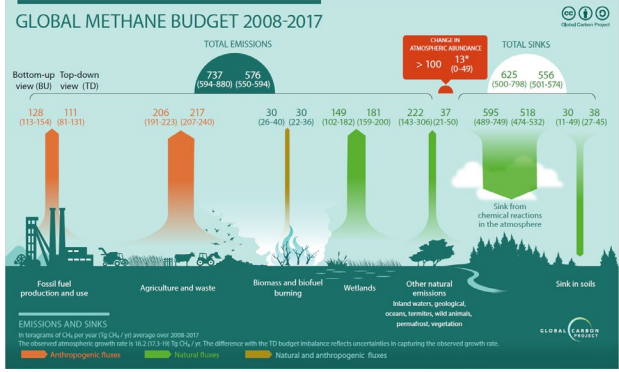
- 22% higher than previous estimate: 145 ± 23 Tg CH_4 yr^{-1}
  - Schwietzke *et al*. (2016) *Nature*

- Much higher than "bottom up" estimates of 114—133 Tg CH_4 yr^{-1}
  - Saunois *et al*. (2020) *Earth Sys. Sci. Data*



Dean *et al*. (2018) *Rev. Geophys.*

globalcarbonproject.org



"Bottom up"?

- "Bottom up" accounting:
  - Inventories of methane emissions from measurements and calculations around the emissions source, upscaled to national or global scale

- Vs.

- "Top down" accounting:
  - Measure the total emissions from atmospheric content (e.g. current measurements, satellites or ice core bubbles), and estimate possible sources
  - e.g. Hmiel *et al*. (2020) *Nature*

- Recent study suggested that US Environmental Protection Agency methane emission estimates from fossil fuel industry (bottom up) were 60% lower than actual (top down) estimates, likely due to under-reporting by industry
  - Alvarez *et al*. (2018) *Science*

Conclusions

"Our results imply that anthropogenic fossil CH_4 emissions now account for about 30% of the global CH_4 source and for nearly half of anthropogenic emissions, highlighting the critical role of emission reductions in mitigating climate change"

Hmiel *et al*. (2020) *Nature*

- Leaky gas pipes and legacy infrastructure (especially in USA and Russia) are crucial places to start (Pardikar 2021, *EOS*)

- Especially if natural gas is to be used as a 'bridging fuel' or as part of a shift to 'renewable' hydrocarbons.

GLOBAL METHANE BUDGET 2008-2017

Global Carbon Project

TOTAL EMISSIONS

Bottom-up view (BU): 737 (594-880)

Top-down view (TD): 576 (550-594)

CHANGE IN ATMOSPHERIC ABUNDANCE

> 100

13* (0-49)

TOTAL SINKS

625 (500-798)

556 (501-574)

Fossil fuel production and use		Agriculture and waste		Biomass and biofuel burning		Wetlands		Other natural emissions		Sink from chemical reactions in the atmosphere		Sink in soils	
128 (113-154)	111 (81-131)	206 (191-223)	217 (207-240)	30 (26-40)	30 (22-36)	149 (102-182)	181 (159-200)	222 (143-306)	37 (21-50)	595 (489-749)	518 (474-532)	30 (11-49)	38 (27-45)

Other natural emissions: Inland waters, geological, oceans, termites, wild animals, permafrost, vegetation

EMISSIONS AND SINKS

In teragrams of CH_4 per year (Tg CH_4 / yr) average over 2008-2017

The observed atmospheric growth rate is 18.2 (17.3-19) Tg CH_4 / yr. The difference with the TD budget imbalance reflects uncertainties in capturing the observed growth rate.

Anthropogenic fluxes | Natural fluxes | Natural and anthropogenic fluxes

GLOBAL CARBON PROJECT

Thank you

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