Cornell University

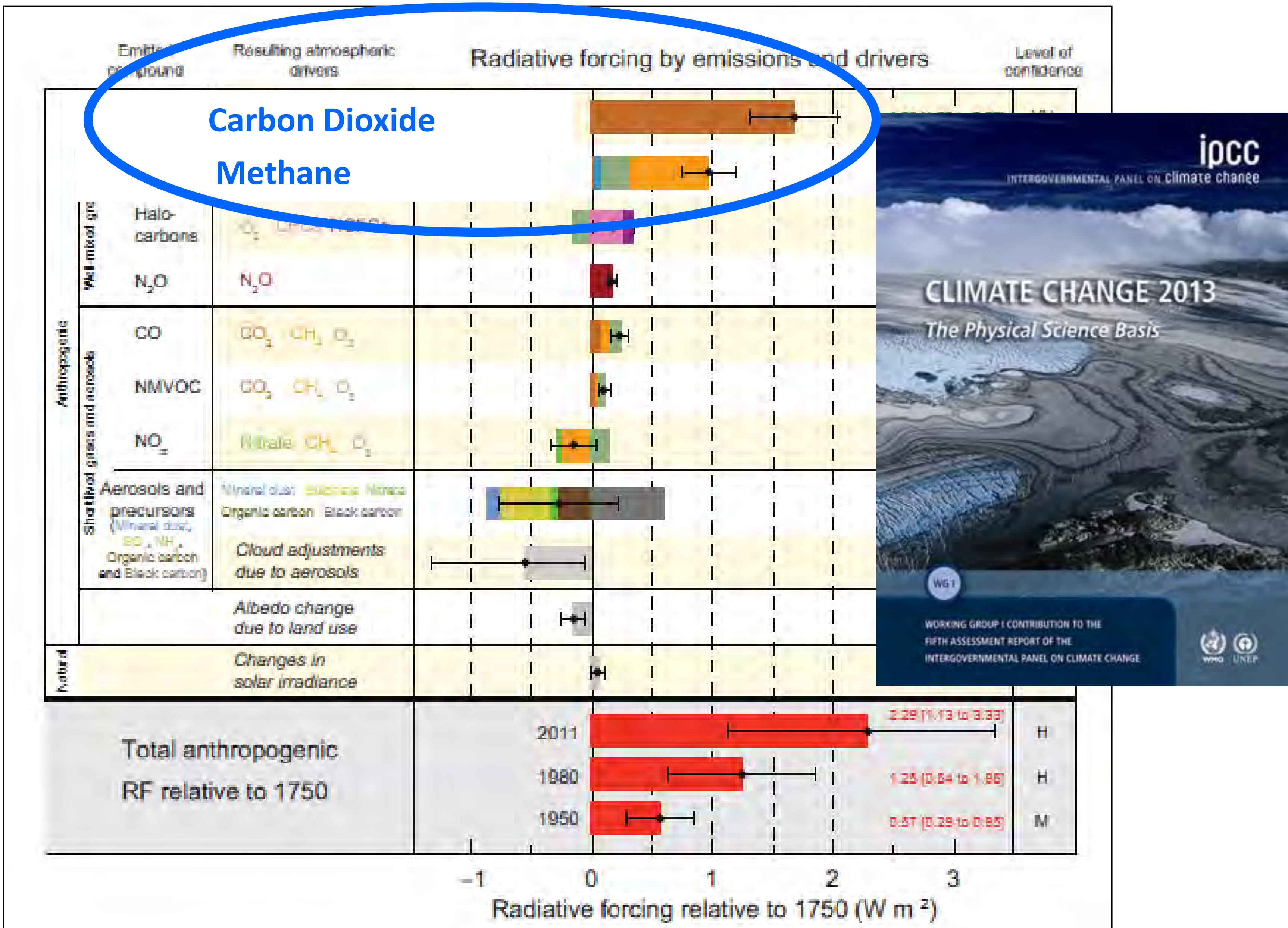
Methane's Role in Global Warming

Bob Howarth

The David R. Atkinson Professor of Ecology & Environmental Biology

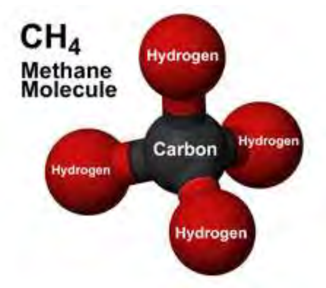
Cornell Cooperative Extension

June 29, 2021


Carbon Dioxide
Methane
Emitted compound
Resulting atmospheric drivers
Radiative forcing by emissions and drivers
Level of confidence
Well-mixed greenhouse gases
Halo-carbons
N₂O
N₂O
Anthropogenic
Short lived gases and aerosols
CO
CO₂ CH₄ O₃
NMVOC
CO₂ CH₄ O₃
NOx
Nitrate CH₄ O₃
Aerosols and precursors (Mineral dust, SO₂, NH₃, Organic carbon and Black carbon)
Mineral dust Sulphate Nitrate Organic carbon Black carbon
Cloud adjustments due to aerosols
Albedo change due to land use
Natural
Changes in solar irradiance
Total anthropogenic RF relative to 1750
2011
1980
1950
2.29 [1.13 to 3.33]
1.25 [0.64 to 1.86]
0.57 [0.29 to 0.85]
H
H
M
−1
0
1
2
3
Radiative forcing relative to 1750 (W m⁻²)
ipcc
INTERGOVERNMENTAL PANEL ON climate change
CLIMATE CHANGE 2013
The Physical Science Basis
WG I
WORKING GROUP I CONTRIBUTION TO THE
FIFTH ASSESSMENT REPORT OF THE
INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE
WMO
UNEP

The two faces of carbon:

Carbon dioxide (CO_2) – climate system responds slowly to changes, but current emissions will influence climate for 100s of years;



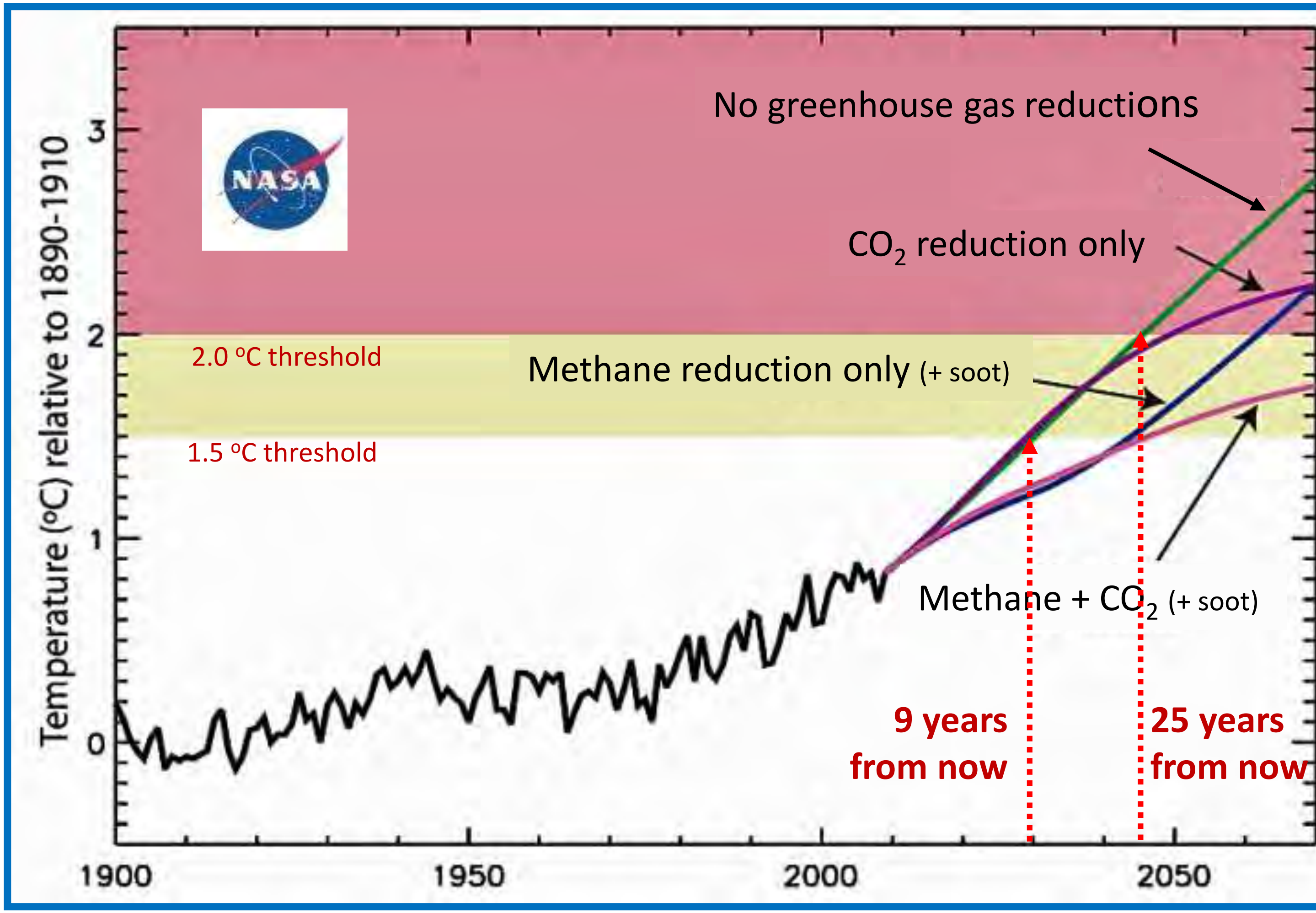
Methane (CH_4) – much faster response by climate system, but methane has a half life in atmosphere of only 12 years;

220 times more CO_2 in atmosphere, but CH_4 is 105 times more powerful as a greenhouse gas (by weight)

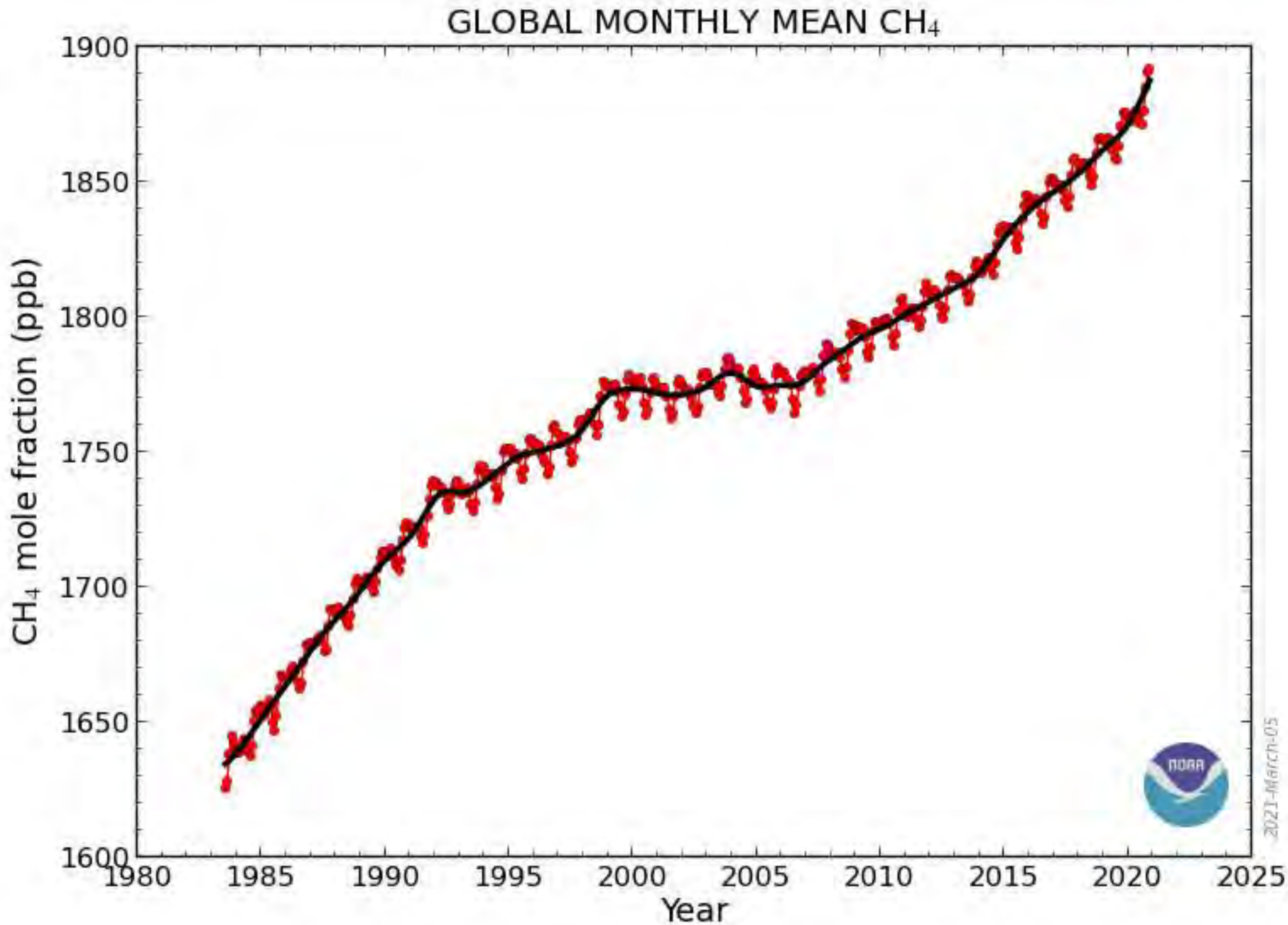
COP21: United Nations Conference of the Parties
Le Bourget, Paris -- December 2015

- COP21 Paris Accord target: “well below 2º C”
- Clear recognition that warming beyond 1.5º C is dangerous

- **Methane reductions are critical; cannot reach COP21 target with CO_2 reductions alone**



Shindell et al. 2012, *Science*


GLOBAL MONTHLY MEAN CH4
CH4 mole fraction (ppb)
1600
1650
1700
1750
1800
1850
1900
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
Year
NOAA
2021-March-05

Global greenhouse gas emissions (2015):

CO_2 = 36 billion metric tons

CH_4 = 0.38 billion metric tons

CH_4 is 105-fold more potent as greenhouse gas at first and 86-fold more on average over 20 years following the emission (IPCC 2013).

Global greenhouse gas emissions (2015):

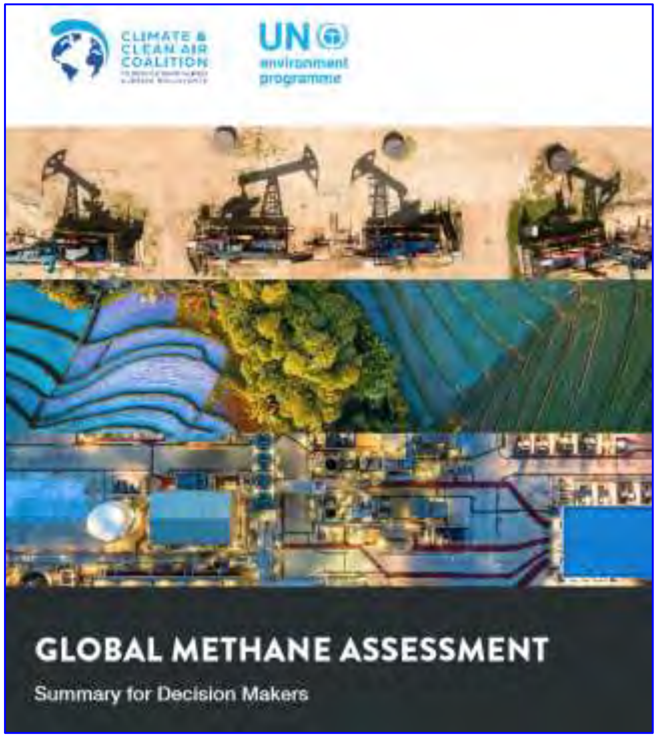
CO_2 = 36 billion metric tons

CH_4 = 0.38 billion metric tons

CH_4 is 105-fold more potent as greenhouse gas at first and 86-fold more on average over 20 years following the emission (IPCC 2013).

Therefore, CH_4 emissions = 32 to 39 billion metric tons CO_2-eq

Warming from CH_4 equals that of CO_2 for next 20 years!



May 6, 2021

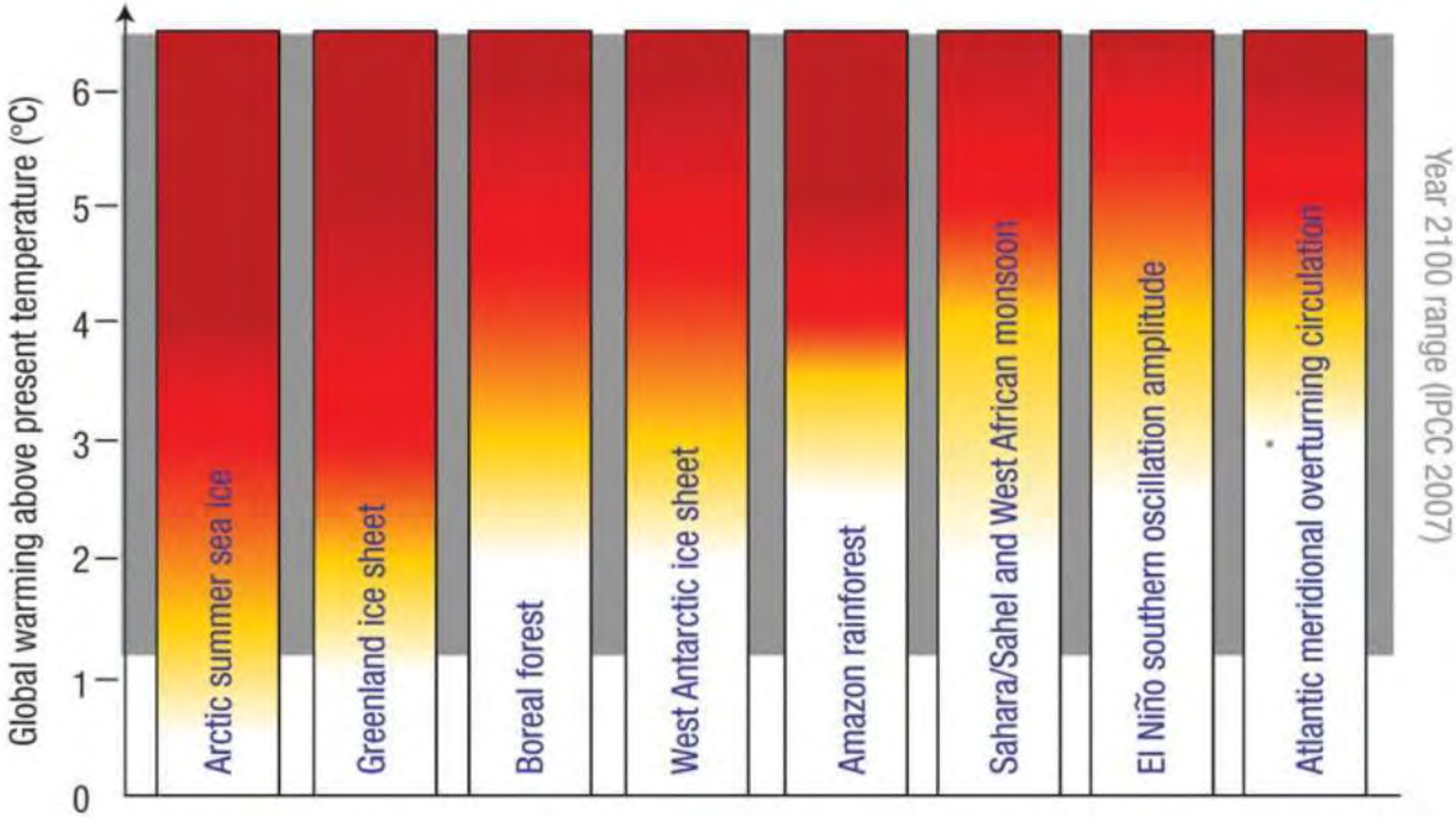
UN environment programme

Reducing human-caused methane emissions is one of the most cost-effective strategies to rapidly reduce the rate of warming and contribute significantly to global efforts to limit temperature rise to 1.5°C. Available targeted methane measures, together with additional measures that contribute to priority development goals, can simultaneously reduce human-caused methane emissions by as much as 45 per cent, or 180 million tonnes a year (Mt/yr) by 2030. This will avoid nearly 0.3°C of global warming by the 2040s and complement all long-term climate change mitigation efforts. It would also, each year, prevent 255 000 premature deaths, 775 000 asthma-related hospital visits, 73 billion hours of lost labour from extreme heat, and 26 million tonnes of crop losses globally (Figure ES1).

"Tipping Points"

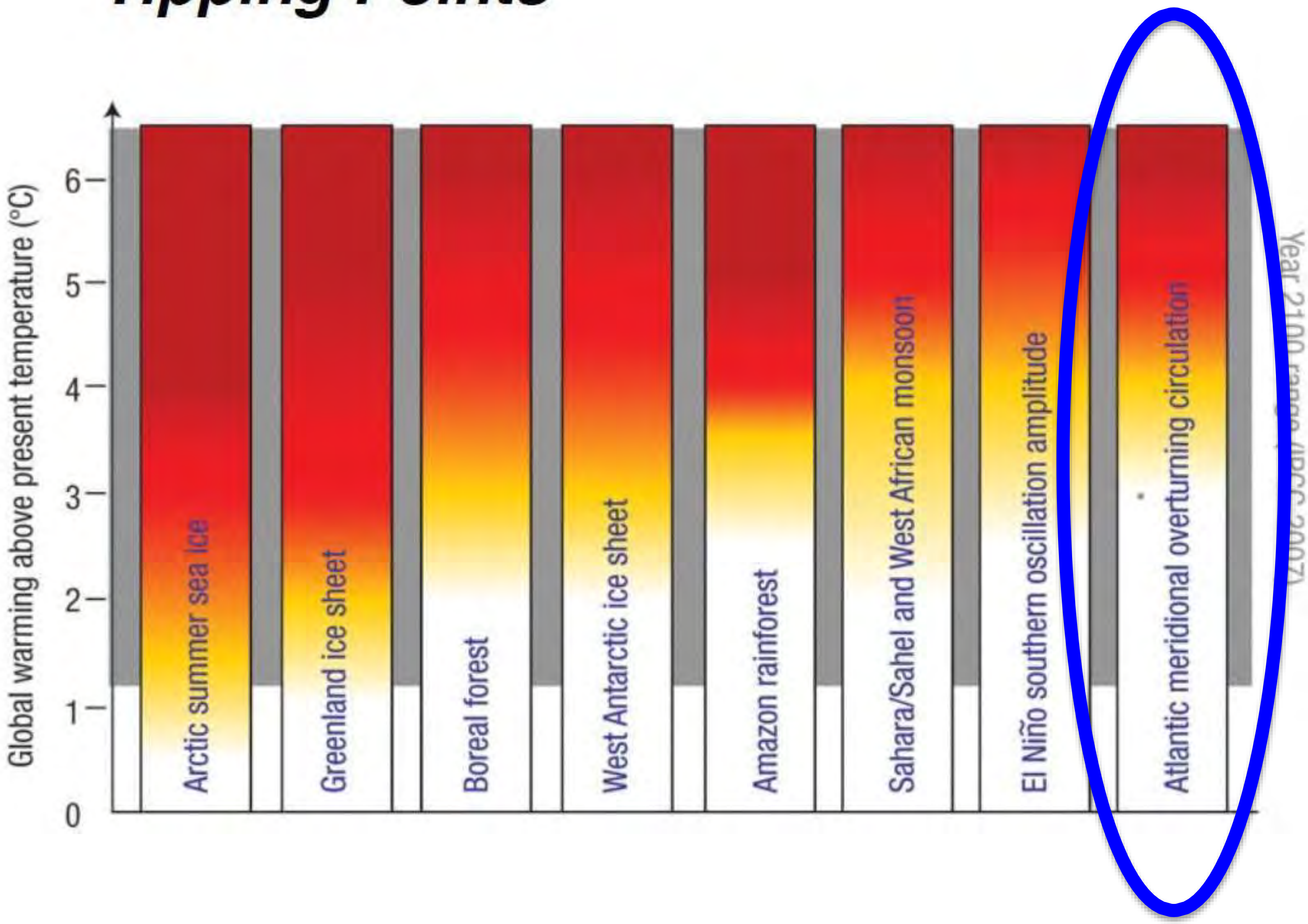
Uncertainty as to when tipping points will be hit, but increasing risk in yellow, high risk shown by red.

Best estimates as of 2007 .....



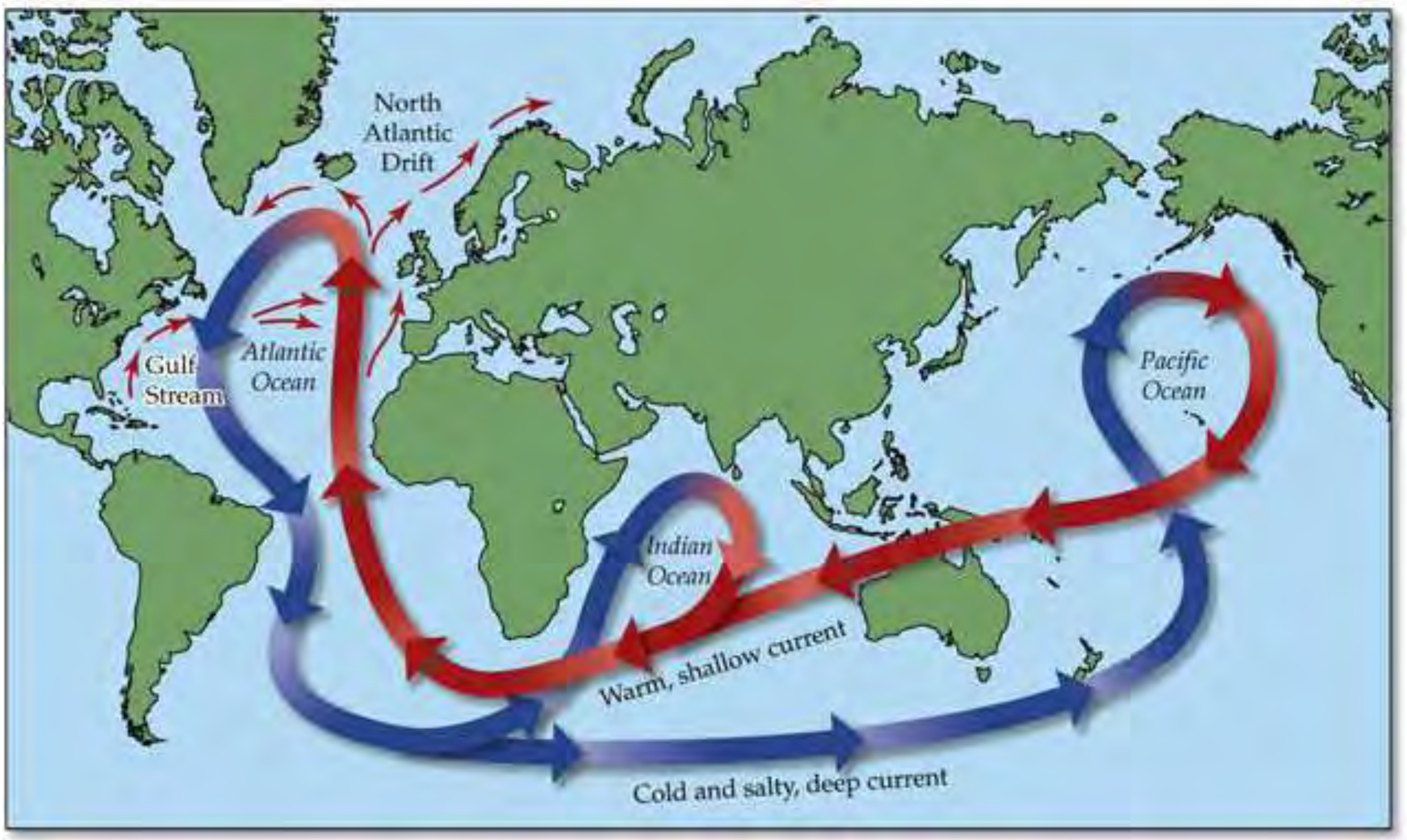
Also called the Great Ocean Conveyor Belt, and is probably much more sensitive to global warming than thought in 2007

"Tipping Points"



The great conveyor belt is slowing…

…. Caused by melting of Arctic ice and Greenland ice sheet, making North Atlantic very slightly less salty.



The Washington Post
Democracy Dies in Darkness

Energy and Environment

The oceans' circulation hasn't been this sluggish in 1,000 years. That's bad news.

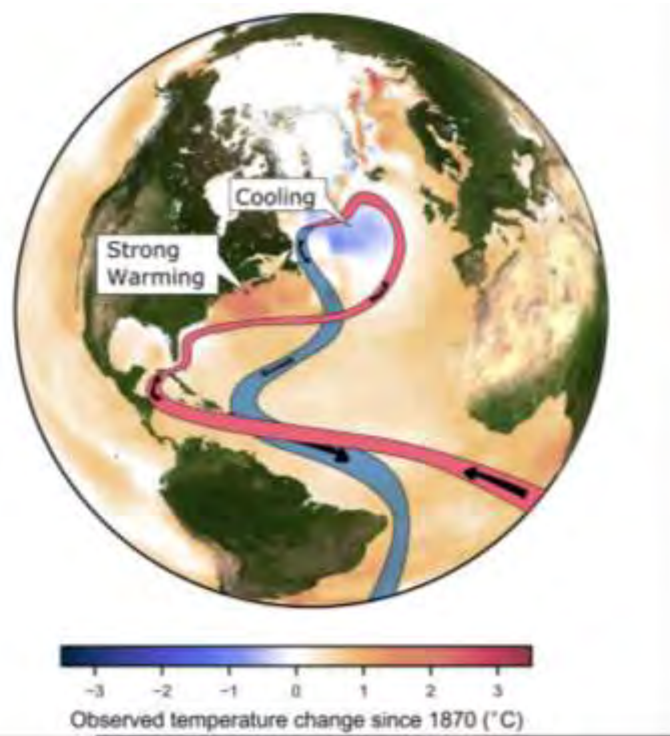
By Chris Mooney April 11 Email the author

Caused in part by melting of Greenland and Arctic Ocean ice.

April 11, 2018

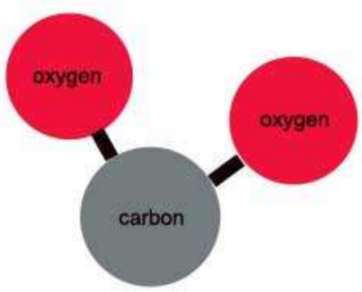
Consequences?

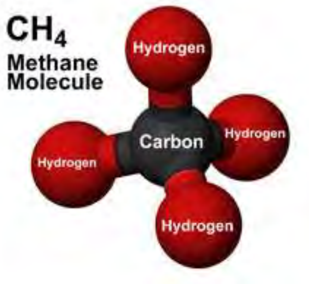
- **-- greater weather extremes (cold, heat, floods, droughts, hurricane).**
- **-- faster build-up of CO_2 in the atmosphere?**



May become far worse.

How do we account for methane relative to CO_2 in terms of contribution to global warming, given the huge differences between the two gases?





Many approaches, but most commonly used in policy (and easiest to understand):

Global Warming Potential (GWP)

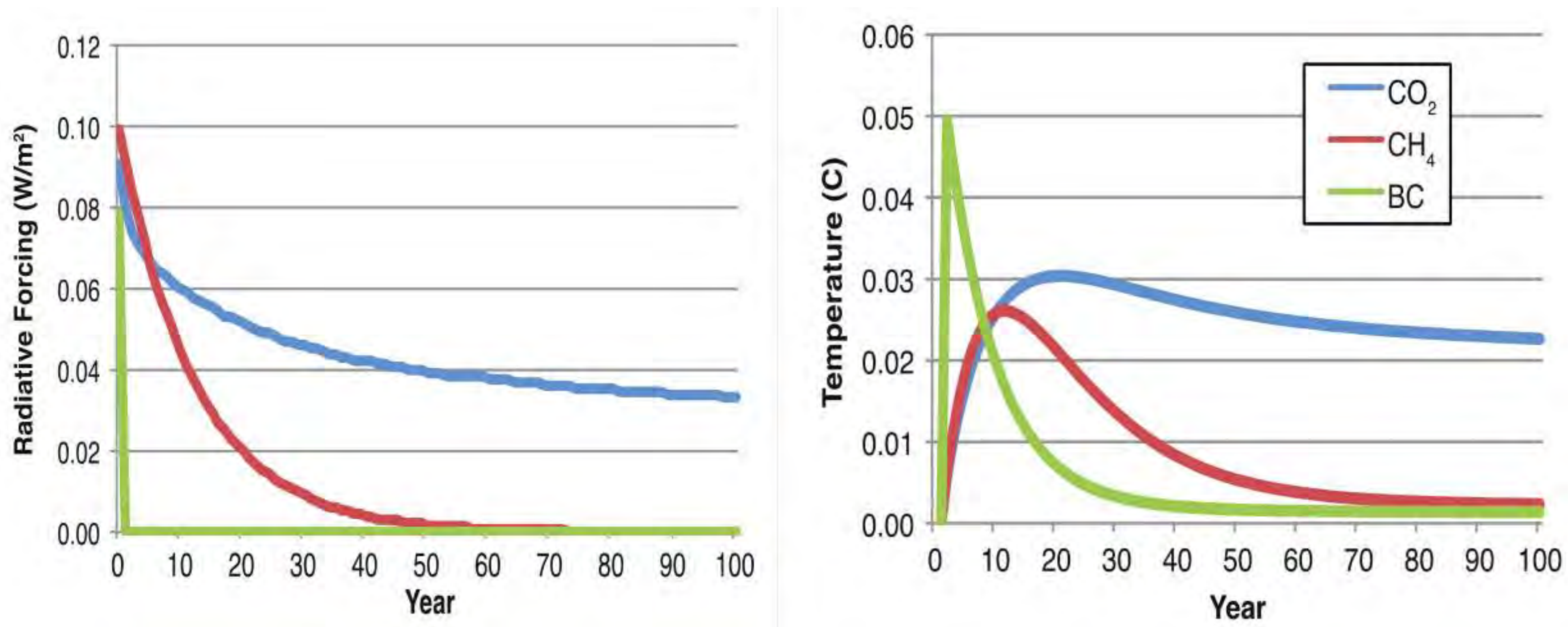
Ratio of radiative forcing caused by methane divided by radiative forcing caused by carbon dioxide following pulses of equal masses (weights) of the gases for a defined period of time into the future (20 years, 100 years, etc.).

Global Warming Potential (GWP) for methane:

	20 year	100 year
IPCC 1996	56	21
IPCC 2007	72	25
IPCC 2013	86	34

The changes over time in table reflect improved science, including indirect effects of methane on global warming

Comparison of Carbon Dioxide, Methane, and Black Carbon as Agents of Global Warming



Courtesy of Drew Shindell, Feb 2019

Global Warming Potential (GWP) for methane:

	20 year	100 year
IPCC 1996	56	21
IPCC 2007	72	25
IPCC 2013	86	34

Most governments and almost all standard life-cycle assessments still use 21 or 25.

IPCC (2013): "There is no scientific argument for selecting 100 years compared with other choices."

"The choice of time horizon …. depends on the relative weight assigned to the effects at different times."

100 year accounting time greatly discounts damage from methane over shorter time scales.

I and many others have argued for 20-year GWP, combined with separate accounting for carbon dioxide by itself.

Energy Science & Engineering
Open Access
PERSPECTIVE

A bridge to nowhere: methane emissions and the greenhouse gas footprint of natural gas

Robert W. Howarth

Abstract

JOURNAL OF INTEGRATIVE ENVIRONMENTAL SCIENCES
https://doi.org/10.1080/1943815X.2020.1789666
Taylor & Francis
Taylor & Francis Group
OPEN ACCESS

Methane emissions from fossil fuels: exploring recent changes in greenhouse-gas reporting requirements for the State of New York

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ABSTRACT
In 2019, New York State passed aggressive new climate legislation to reduce greenhouse gas (GHG) emissions and laid out major changes for how emissions are reported. One change is the inclusion of emissions from outside of the boundaries of the State if they are associated with energy use within NY; the traditional inventory considered emissions only within the State. The new legislation also mandated that methane emissions be compared with carbon dioxide over a 20-year time frame rather than the 100-year time frame previously used by NY and still used by virtually all other governments globally. This reflected the desire of NY's policymakers for a tool that evaluates emissions from the standpoint of energy consumption and that more heavily weighs the role of methane as an agent of warming over the next few decades. This paper compares emissions based on the new approach for GHG reporting with the traditional inventory. The traditional inventory is driven almost

ARTICLE HISTORY
Received 12 September 2019
Accepted 5 June 2020

KEYWORDS
Greenhouse gas emissions; greenhouse gas footprint; CLCPA; methane emissions; climate and energy policy; global warming potential; GWP

Briefing by Robert Howarth for the White House Office of Science and Technology Policy May 27, 2016

Beginning in 2016, I worked with Assembly Person Englebright and others in NY Assembly in various versions of legislation leading to the 2019 Community Leadership & Community Protection Act (CLCPA).

The CLCPA mandates a 20-year GWP for methane.

Climate Act | Advisory Panels | New York Climate Action Council | Climate Justice Working Group | Resources | Events

NEW YORK CLIMATE ACTION COUNCIL

Meetings and Materials

Climate Action Council

The New York State Climate Action Council (Council) is a 22-member committee that will prepare a Scoping Plan to achieve the State's bold clean energy and climate agenda.

Climate Action Council Members

Co-Chairs

- Doreen Harris, Acting President and CEO, New York State Energy Research and Development Authority
- Basil Seggos, Commissioner, New York State Department of Environmental Conservation

State Agencies & Authorities

- Richard Ball, Commissioner, New York State Department of Agriculture and Markets
- Marie Therese Dominguez, Commissioner, New York State Department of Transportation
- Thomas Falcone, CEO, Long Island Power Authority
- Eric Gertler, Acting Commissioner and President & CEO-designate of Empire State Development
- Gil C. Quiniones, President and Chief Executive Officer, New York Power Authority
- Roberta Reardon, Commissioner, New York State Department of Labor
- John B. Rhodes, Chair, New York State Public Service Commission
- Rossana Rosado, Secretary of State, New York State Department of State
- RuthAnne Visnauskas, Commissioner and CEO, New York State Homes and Community Renewal
- Howard A. Zucker, Commissioner, New York State Department of Health

Council Appointees

- Donna L. DeCarolis, President, National Fuel Gas Distribution Corporation
- Gavin Donohue, President and CEO, Independent Power Producers of New York
- Dennis Elsenbeck, Head of Energy and Sustainability, Phillips Lytle LLP
- Rose Harvey, Senior Fellow for Parks and Open Space, Regional Plan Association
- Bob Howarth, Professor, Ecology and Environmental Biology at Cornell
- Peter Iwanowicz, Executive Director, Environmental Advocates NY
- Jim Malatras, Chancellor of the State University of New York
- Anne Reynolds, Executive Director Alliance for Clean Energy New York
- Raya Salter, Lead Policy Organizer, NY Renews
- Paul Shepson, Dean, School of Marine and Atmospheric Sciences at Stony Brook University

What about GWP* ?

First introduced in a 2017 paper, already altered in a series of follow-up papers. Fairly complicated, and unlike GWP20 and GWP100, GWP* is not constant. It changes as emissions change.

Very popular in some agricultural circles, as some have suggested methane from animal agriculture is not a problem under this approach. I believe this is based on a mis-use of GWP*

What about GWP* ?

My take:

GWP* is defined in multiple and changing ways. Unlike GWP20 or GWP100, it is not a constant. It changes as emissions change.

Paradoxically, GWP* can be negative: this implies more methane is good for climate, which is nonsense.

I do not believe GWP* is likely to have long legs in policy world.

In any case, for greenhouse gas accounting in NY State, GWP20 is mandated by law (CLCPA of 2019).

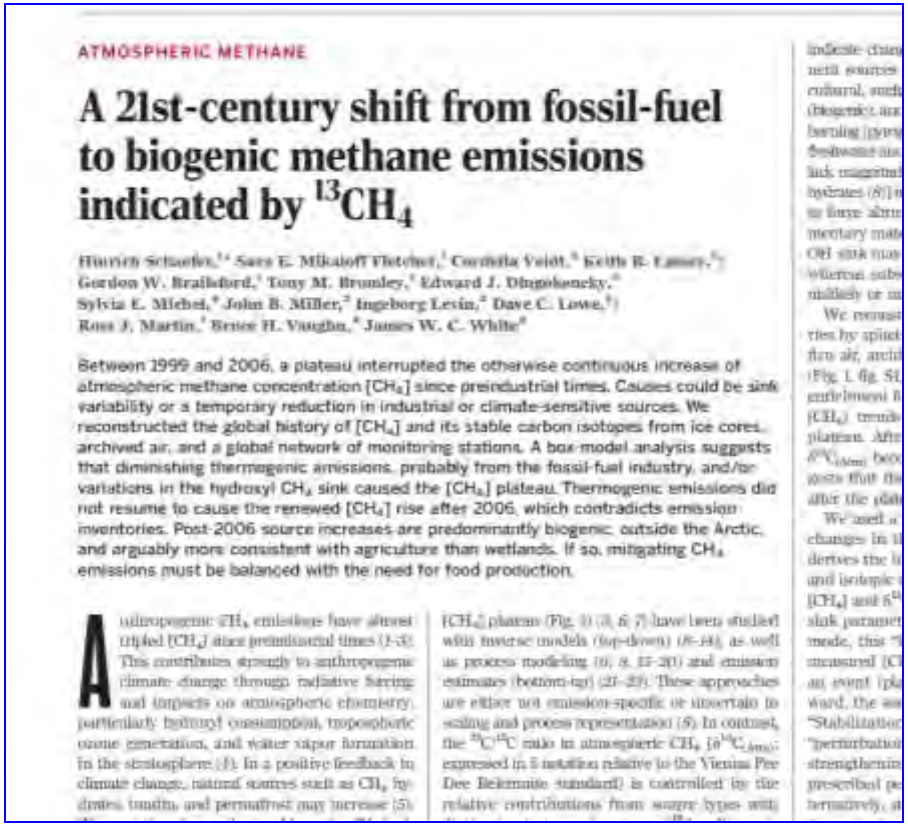
Where does atmospheric methane come from?

Multiple sources, both natural and human-caused.

Total global flux estimate well constrained, since rate of destruction by photo-oxidation in atmosphere is well know.

Two major sources of methane:

- **Methane formed in rock formations over geological time frame** (fossil fuels)
- **Methane formed by decomposition of organic matter by bacteria in absence of oxygen** (wetlands, lake sediments, rice fields, sewage treatment plants, landfills, manure piles, animal guts)



ATMOSPHERIC METHANE

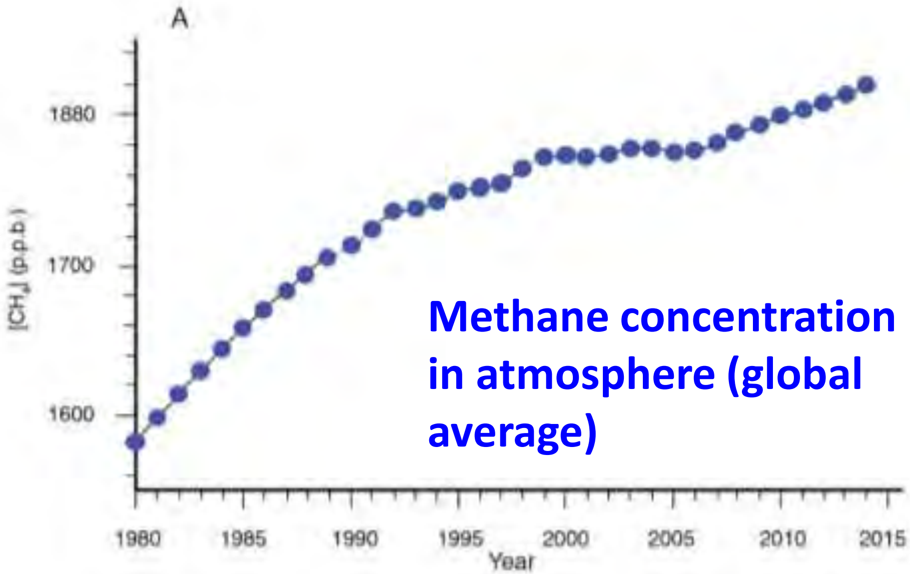
A 21st-century shift from fossil-fuel to biogenic methane emissions indicated by $^{13}CH_4$

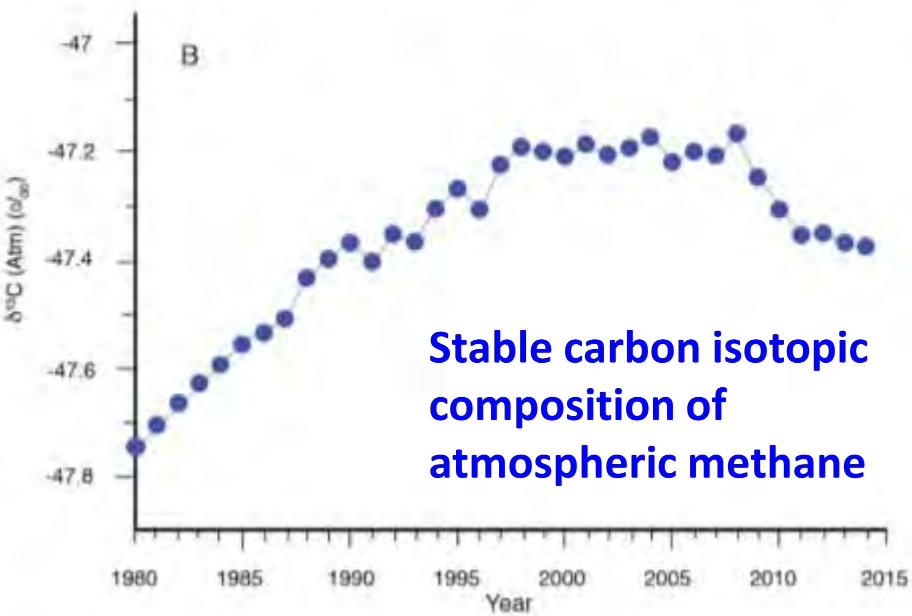
Hinrich Schaefer, Sara E. Mikaloff Fletcher, Cordelia Veidt, Keith R. Lassey, Gordon W. Brailsford, Tony M. Bromley, Edward J. Dlugokencky, Sylvia E. Michel, John B. Miller, Ingeborg Levin, Dave C. Lowe, Ross J. Martin, Bruce H. Vaughn, James W. C. White

Between 1999 and 2006, a plateau interrupted the otherwise continuous increase of atmospheric methane concentration [CH_4] since preindustrial times. Causes could be sink variability or a temporary reduction in industrial or climate-sensitive sources. We reconstructed the global history of [CH_4] and its stable carbon isotopes from ice cores, archived air, and a global network of monitoring stations. A box-model analysis suggests that diminishing thermogenic emissions, probably from the fossil-fuel industry, and/or variations in the hydroxyl CH_4 sink caused the [CH_4] plateau. Thermogenic emissions did not resume to cause the renewed [CH_4] rise after 2006, which contradicts emission inventories. Post-2006 source increases are predominantly biogenic, outside the Arctic, and arguably more consistent with agriculture than wetlands. If so, mitigating CH_4 emissions must be balanced with the need for food production.

High visibility paper published in March 2016 in *Science*: Increase in atmospheric methane since 2006 is most likely biogenic in large part, probably from cows.

Based largely on stable carbon isotopic composition (^{13}C vs. ^{12}C) in atmospheric methane.






Biogeosciences, 16, 3033–3046, 2019
https://doi.org/10.5194/bg-16-3033-2019

Ideas and perspectives: is shale gas a major driver of recent increase in global atmospheric methane?

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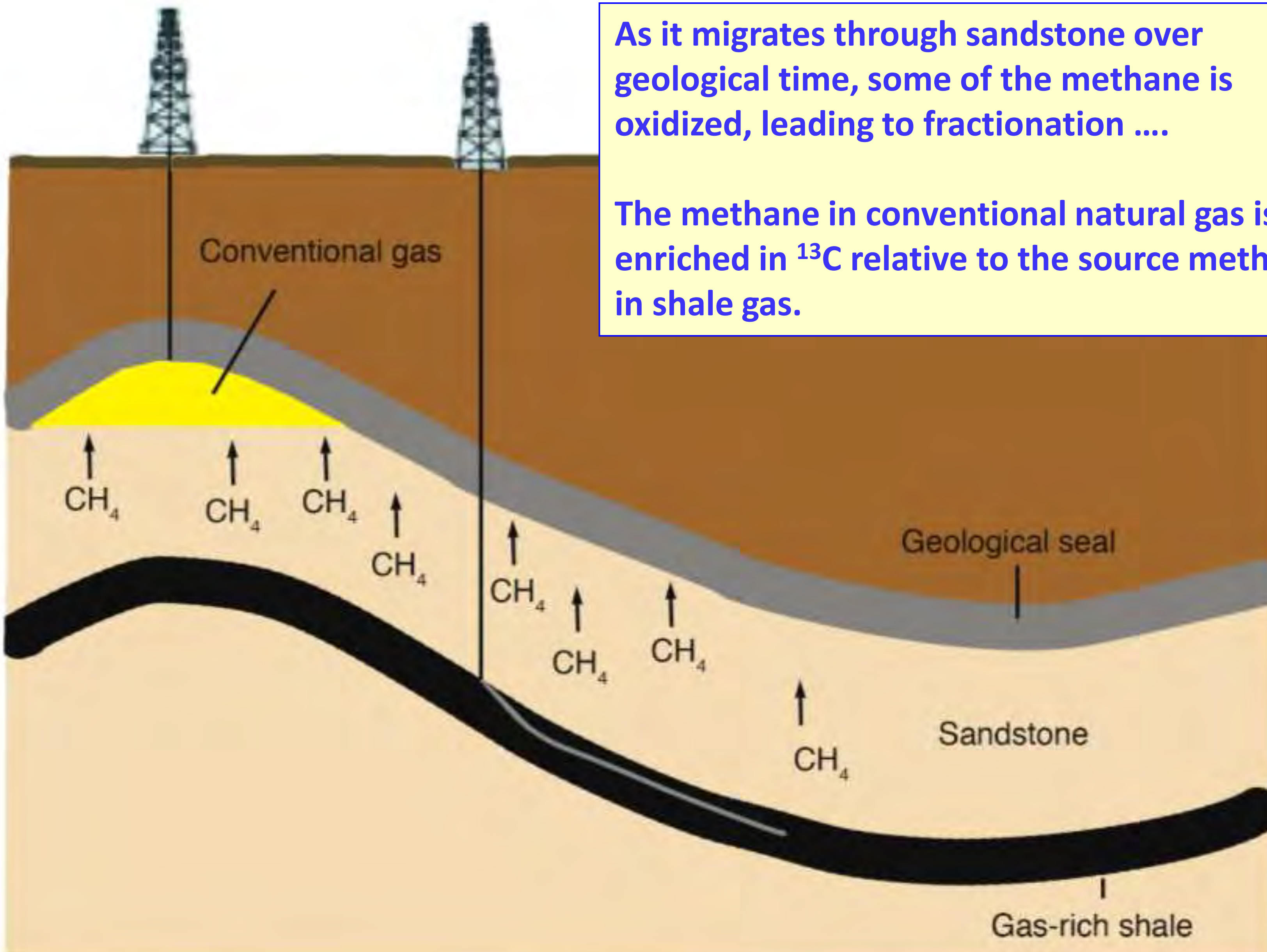
Correspondence: Robert W. Howarth (howarth@cornell.edu)

Received: 10 April 2019 – Discussion started: 23 April 2019
Revised: 31 July 2019 – Accepted: 12 July 2019 – Published: 14 August 2019

Howarth (2019), based on Schaefer et al. (2016)



As it migrates through sandstone over geological time, some of the methane is oxidized, leading to fractionation ….

The methane in conventional natural gas is enriched in ^{13}C relative to the source methane in shale gas.

Howarth (2019)

Global methane sources (Tg per year)

	1995		2015
Total	**570**	→	**595**
Total natural	**220**		
Geological seeps	~ 0		
Wetlands & lakes	220		
Total anthropogenic	**350**	→	**375**
Natural gas and oil	136	→	154
Coal	32	→	33
Animal agriculture	67	→	77
Rice	44		
Landfills & sewage	41		
Biomass burning	30	⋯→	27

R. W. Howarth, based on Begon et al. (2014), modified 6/2/2019

Is methane from animal agriculture the same as from fossil fuels?

- When in atmosphere, methane is methane with same warming potential: 105 times that of CO_2
- When the methane is eventually oxidized to CO_2, that which came from fossil fuels is a new source of CO_2. The CO_2 for the agricultural source is not new.
- This difference is small (2.5%). When expressed as GWP-20, changes agricultural methane to 84 instead of 86 for fossil fuels.

Although fossil fuel emissions of methane far larger than those from animal agriculture, animal ag is important globally:

77 Tg/yr (20% of all human sources)

Animal agriculture in NY State contributes 0.23% of the global total.

This accounts for 1.2% of all greenhouse gas emissions in New York State. So relatively small, but still worth trying to reduce, and NY can help lead the way for other states and nations.

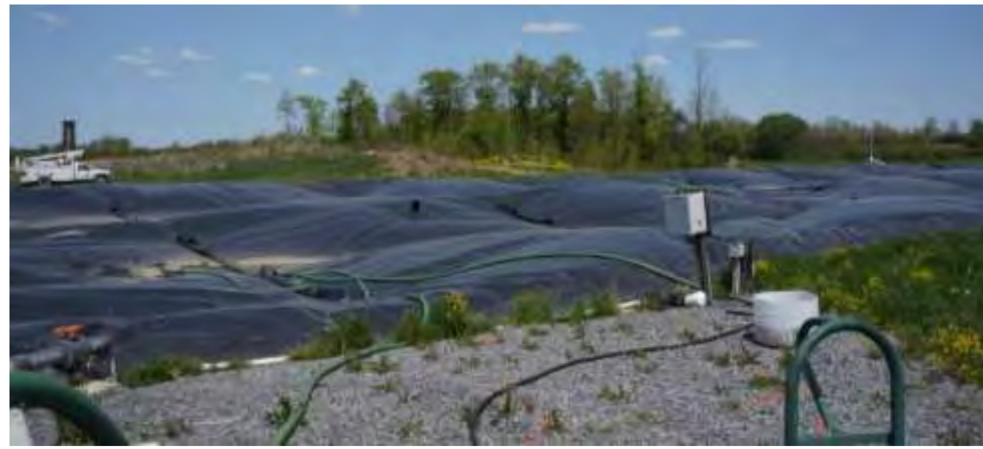
Dairy farms and cattle operations produce methane in two ways:

1) **Released from manure (~ 20% of total)**

2) **Produced in the rumen and breathed or belched out (~80% of total) – Tom Overton will discuss in a moment.**

Should NY promote anaerobic digestors to produce and use methane from manure?

Spruce Haven Farm, Union Springs, NY
Doug Young & family, proprietors



Should NY promote anaerobic digestors to produce and use methane from manure?

Maybe….. but limited potential. At most could produce 370 million cubic meters (very optimistic assumptions).

This would replace 0.9% of current use of natural gas in NY State.

And could actually increase atmospheric methane emissions, if there were significant leakage from the digestors.

Manure management practices need to be improved, but is anaerobic digestion the best approach?

Cornell University

Tom Overton will now discuss methane from cows & cattle as influenced by feeds.

Funding:

Cornell University

Park Foundation

For more information:

howarthlab.org