Agricultural Methane Confusion

Prepared by David Griffiths , cymru3249@gmail.com

All Data Used Here Can be Found at Websites Referenced at the End

Numbers and calculations are approximate and subject to correction.

Contents

1. Primary Sources of Confusion

There are many sources of confusion, the most important being:

- The distinction between emissions and forcings since 1750
- Units such as Gt CO2 equivalent (Gte), Tg CH4, ppm, ppmv,………………………..
- The distinction between total emissions and net emissions
- Natural vs. Anthropogenic Emissions (Emissions due human activity)
- The distinction between US and global emission statistics
- The distinction between on-farm and off-farm carbon emissions
- Percentages are percentages of what (Global greenhouse gases, US CH4,………)
- Years for which published numbers are given

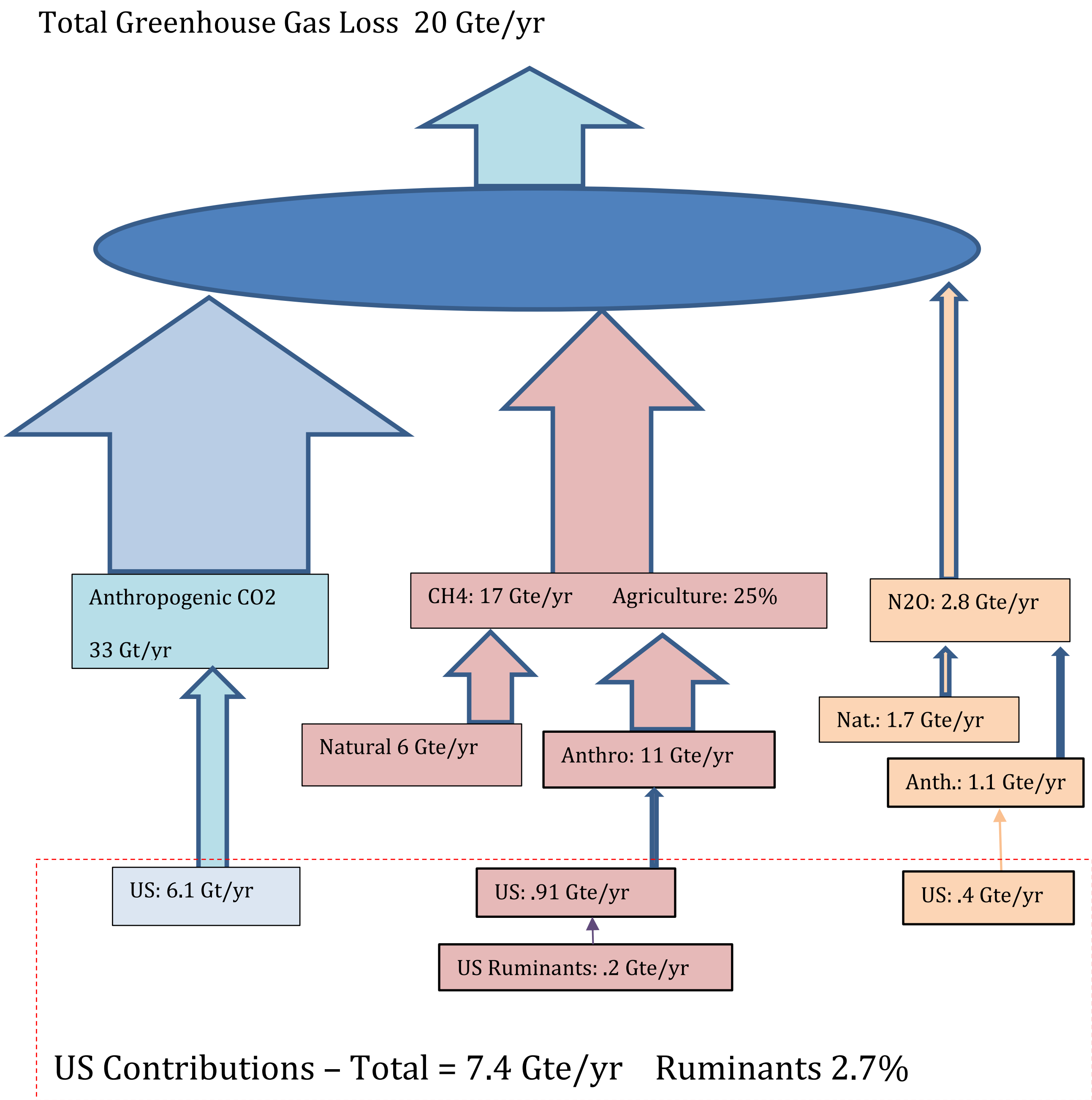
The following chart (section 2) outlines the emissions and flows of the top three greenhouse gases (CO2, methane - CH4, nitrous oxide -N2O) in 2005, the base year for the Paris Climate Accords. The units are GTE or gigatons of equivalent CO2. The US contributions and the contributions of US ruminants are shown. Natural flows of methane and nitrous are given, but not the very large flows of CO2.

The conclusions of section 3 are based on the emission and flow diagram. Following sections give details.

2. 2005 Greenhouse Gas Emissions & Flows Gte/yr

Widths of Arrows Approximately Proportional to Flow Gte/yr

Date: 2005 or average 2000-2009



3. Summary Conclusions

Based on the emissions and flow chart we can see that:

- Decreasing meat and dairy production in the US should provide some benefits, but to fix the global warming problem requires massive changes in many areas.

- Reducing US meat and dairy consumption would provide a quick if small benefit. (Also, it would improve the health of most Americans.)

- So this step could be considered an example of 'picking the low hanging fruit', even if the fruit is rather small.

4. Percentages of Greenhouse Gas Emissions

Dates & Accuracy

The numbers given here generally refer to estimates for 2005 or for average estimates for 2000-2009. In some cases, such as fossil fuel emitted CO_2, the estimates are probably accurate to within a few %, in other cases, such as ruminant emitted methane, the uncertainty is more likely +- 20%.

Gte – GWP

The effect of a greenhouse gas will be given in Gte, the equivalent mass of CO_2 in Gigatonnes (billions of metric tonnes). To obtain this amount we multiply the emitted mass of gas by the Global Warming Potential of the Gas, GWP, which we take it to be 34 for methane. The EPA typically uses an earlier number, 25, and occasionally 21, an even earlier number (see section on GWP).

Main Anthropogenic Greenhouse Gases

We will consider only the top 3 anthropogenic gases, the effect of the rest is less than the accuracy of our estimates.

	Amount of Emitted Gas in Gte	Percent of Total Anthropogenic
CO_2	33	73.2%
CH_4	11	24.4%
N_2O	1.1	2.4%

Global Agricultural Methane

Approximately 4.2 Gte of methane were emitted globally by agriculture (ruminants and rice) in the indicated time period. Below we show this as a percentage of the total anthropogenic methane and the total greenhouse gas emitted.

	Amount in Gte	4.2 Gte Agricultural Methane as a %
Total Anthropogenic Methane	17	24.7%
Total Anthropogenic Greenhouse Gas	45.1	9.3%

US Ruminant Methane

We consider 0.23 Gte of US ruminant methane as a % of various anthropogenic quantities.

	Amount in Gte	0.23 Gte US Ruminant Methane as a %
US Total Anthropogenic Methane	.95	24%
Global Agricultural Methane	4.2	4.8%
Total Anthropogenic Methane	17	1.2%
Total Anthropogenic Greenhouse Gas	45.1	0.4%

5. Global Methane Emission Details

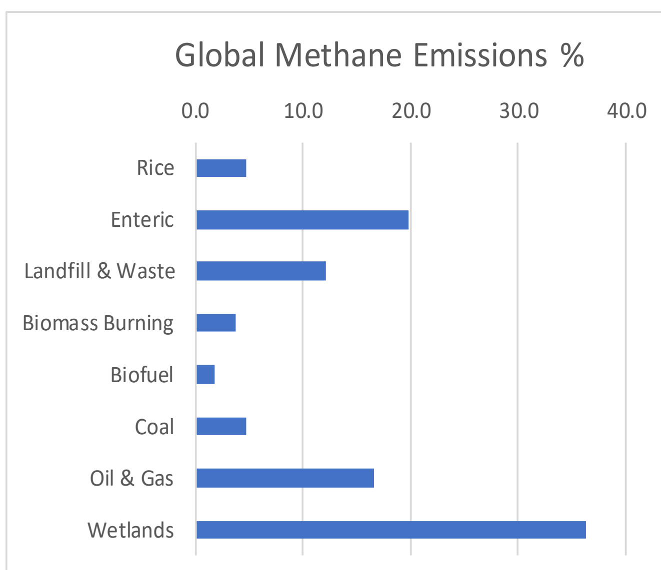
Anthropogenic CO2 emissions are easy to estimate to within a few percent since the amount of coal and oil burned worldwide is well known and documented. The number given in the flow chart is for 2005

Determining the amount of methane is more difficult because it involves things which are not usually measured, such as bovine flatulence. As a result, it must be realized that methane numbers are rough estimates, and the uncertainty is at least of order +-20%. (1).

Here we give 'middle of the road' EPA numbers which give a reasonable representation of the situation. They can be found at (2). These are used on the flow chart.

The mass of of emitted methane is first given in millions of metric tons. This is then divided by 1000 to give Gigatonnes (billions of metric tonnes) and then multiplied by 34 to give the equivalent amount of CO2 in Gte.

Source	**Mmt**	**Gte**	**% Total**
Rice	24	0.82	4.7
Enteric (ruminants)	100	3.4	19.8
Landfill & Waste	61	2.07	12.1
Biomass Burning	19	0.65	3.8
Biofuel	9	0.31	1.8
Coal	24	0.82	4.7
Oil & Gas	84	2.86	16.7
Wetlands	183	6.22	36.3
Total	504	17.1	100
Anthopogenic	321	10.9	64
Natural (Wetlands)	183	6.2	36
Mmt: Millions of Metric Tonnes			



Additional details can be found on a NASA website (3). Wikipedia gives a more detailed account at (4).

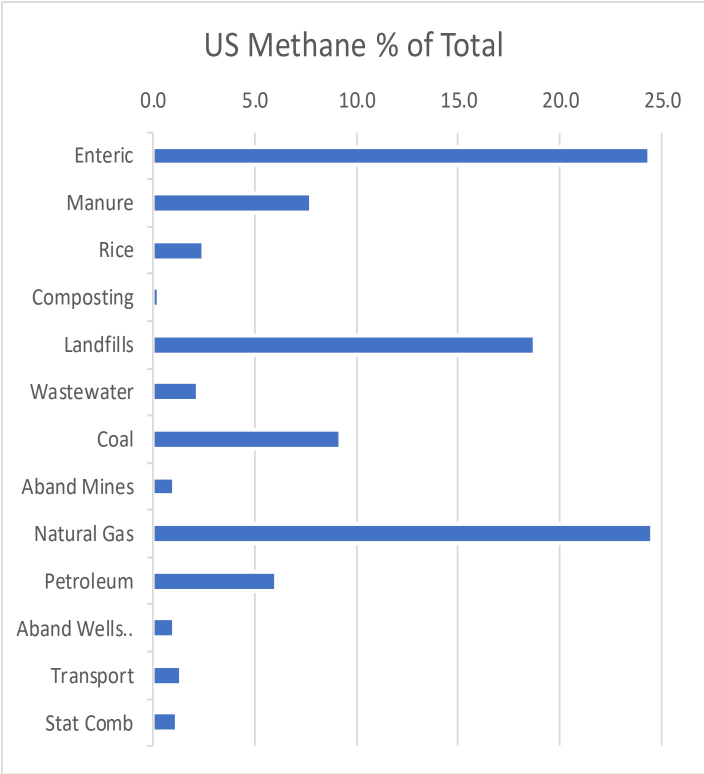
Wikipedia quotes a research paper (Lelieveld et al) to the effect that as of 1992, total emissions of methane were about 0.6 Gt (Gigatonnes) by mass, slightly more than in the table above (0.5 Gt). Anthropogenic methane emissions were about 0.33 Gt mass per year (55%), of which the agricultural sector, mainly ruminants, provided 0.12 Gt (20%). Natural emissions were about 0.27 Gt (45%). This roughly agrees with the table above.

6. US Methane Emission Details

The EPA gives a large amount of detail in a report (5).

Here we give a summary of the estimates for 2005, as used in the flow chart. Note that the amounts and percentages do not change much from year to year so the 2005 estimates are quite typical. The EPA uses GWP=25 which we convert to GWP=34 for the flow chart.

Source	**GWP-25**	**GWP-34**	**%**
	Gte	**Gte**	**Total**
Enteric (ruminant)	0.170	0.231	24.4
Manure	0.054	0.073	7.7
Rice	0.017	0.023	2.4
Composting	0.002	0.003	0.3
Landfills	0.131	0.178	18.8
Wastewater	0.015	0.020	2.2
Coal	0.064	0.087	9.2
Abandoned Mines	0.007	0.010	1.0
Natural Gas	0.171	0.233	24.5
Petroleum	0.042	0.057	6.0
Abandoned Wells..	0.007	0.010	1.0
Transport	0.010	0.013	1.4
Static Combust	0.008	0.011	1.1
Sum	0.697	0.948	100



Note that if these numbers are accurate, the US produces relatively little methane (0.95Gte or .027 Gt by mass) compared to the estimated world anthropogenic numbers (10.9 Gte or 0.32 Gt by mass).

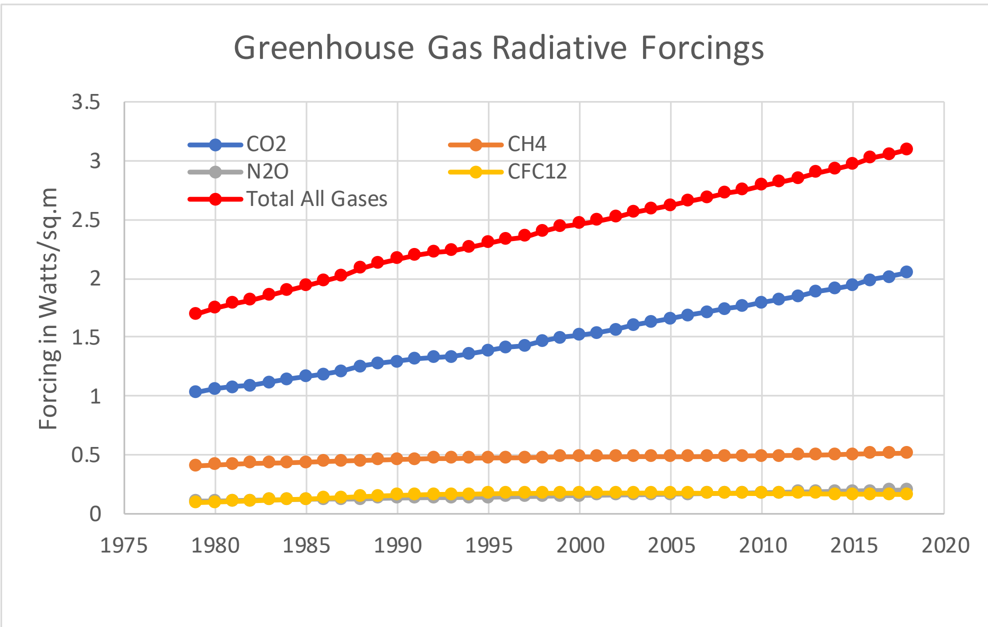
While these numbers are not very accurate, the implication is that 'steady state' meat and dairy production produce less than 10% of effective US greenhouse emissions. The biggest global agricultural problem is land clearance for meat and dairy production.

7. Greenhouse Gas Relative Importance

The importance of a greenhouse gas is sometimes estimated from its radiative forcing relative to 1750, that is, the increased amount of energy reaching the ground because of the additional gas. This additional energy is measured in Watts per square meter. For example, CO2 now has a forcing of approximately 2 watts per square meter. This means that, relative to 1750, CO2 results in an extra 2 watts arriving on every square meter of the earth, or about 1% of the energy from the sun which falls on every square meter.

The amount due to methane is between a quarter and a third of this.

The forcing of a greenhouse gas is calculated in two steps. First the greenhouse gases are measured at many global locations well separated from 'point-sources', so that the gases are 'well-mixed' into the usual atmospheric gases. Then standard theories from physics are used to calculate the forcing. The plot below shows the results for the major gases as given by NOAA as of 02/18/20 (6).



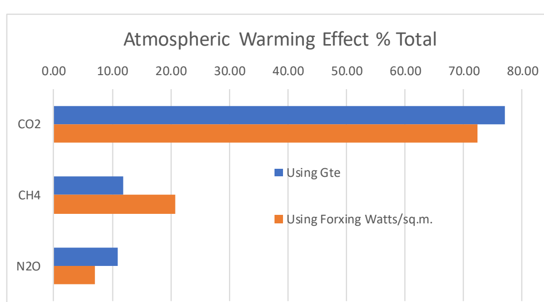
Annual Greenhouse Gas Index - NOAA

The plot shows that CO2 is the most important greenhouse gas, and its effect is increasing at around 2.5% per year. The effects of the other gases are increasing at a much lower rate. As of 2005, the percentage contributions to the total forcing were:

CO2: 72%   CH4: 21 %   N2O: 7%

The table and plot below compare the use of forcing to the use of Gte to estimate the importance of a greenhouse gas in the atmosphere.

	Gte	Forcing
Gas	**% Total**	**% Total**
CO2	77.18	72.35
CH4	11.84	20.70
N2O	10.98	6.96



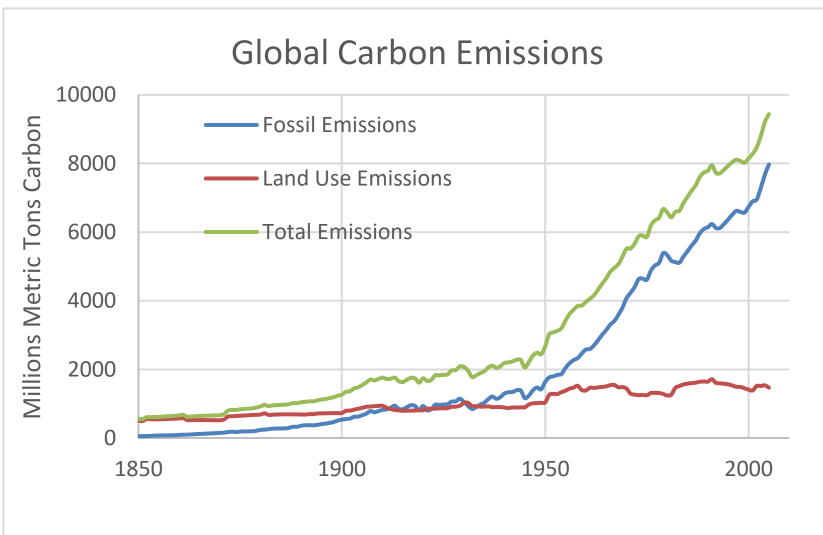
It is evident that the forcing due to methane is almost twice what would be expected using Gte, and this implies that the value of methane's GWP is higher than that usually used. The reason for this is that the usual value is computed as an average over 100 years. This is probably not appropriate in the case of methane because the atmospheric level of methane increased very rapidly after the industrial revolution.

8. Fossil Fuel CO2 Emissions

Fossil fuels (and cement) are the primary source of net human emissions of carbon, that is emissions which have no automatic offsets (as often happens with natural emissions). To find the mass of CO2 we multiply the mass of carbon by 3.7 to take into account the mass of oxygen combined with carbon.

According to NASA, in 2011 human fossil fuel carbon emissions amounted to approximately 9 GT of carbon which is equivalent to 33.3 Gt of CO2. The result was 2 Gt carbon absorbed in the ocean, 4 Gt stored in the atmosphere as 14.8 Gt of CO2, while 3 Gt returned to plant biomass and soil carbon via photosynthesis. Note that these numbers are approximate. The NASA diagram is given at the end of this note (section 11).

Marland and others (6) have estimated the global amount of carbon emitted to the atmosphere from fossil fuel use and from land changes such as forest clearance (note: CO2 mass is 3.7 x carbon mass). The plot below shows their historical estimate.

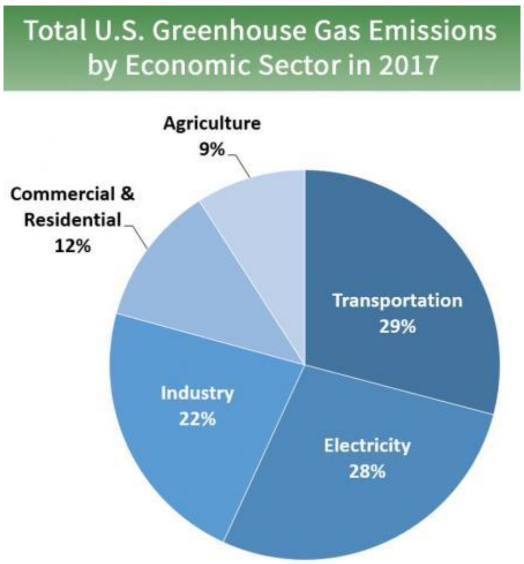


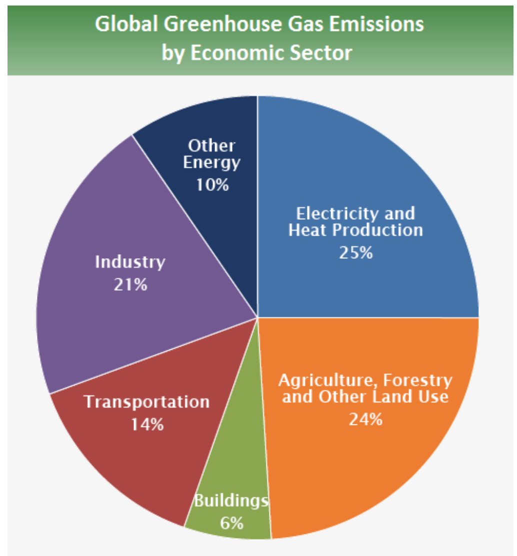
Fossil emissions includes cement and concrete, which are about 10% of the fossil emissions.

Marland's numbers suggest that land use emissions amount to 14% of the total emissions as of 2005, which is less than the number given above by the EPA. The EPA's number comes from an IPCC (Intergovernmental Panel of Climate Change). It may be that the IPCC's use of 'economic sectors' led them to include some fossil emissions in the agricultural category. Assuming that the 14% primarily refers to CO2, then the mass of CO2 emitted due to land use is 4.7 Gt.

9. Emissions by Economic Sector

An EPA website gives a breakdown of 2017 US greenhouse gas emissions by sector, and also the 2010 global breakdown (7,8). Note that here methane and other gases have been included, taking into account GWP, the relative strength of their greenhouse gas effect compared to CO2. EPA numbers generally come from IPC reports (9).





Several points should be noted:

- The US percentage for agriculture (9%) is smaller than the global percentage (24%) partly because the US emits so much CO2 in other sectors, and partly because the destruction of forests boosts the CO2 emitted in less developed countries
- If we look at food production, and add transportation, refrigeration etc., then the US 9% would get a little bigger.
- Forests are expanding quite rapidly in the US, and this growth removes an amount of CO2 equivalent to about 11% of US emissions.

10. Emissions and Net Emissions of the Potato and Fossil Fuels

A growing potato plant removes CO2 from the atmosphere, and uses its carbon to construct cells. After the plant has been harvested, this carbon is emitted to the atmosphere either when the potato is eaten and used for energy, or when leftover material decomposes. This emission cycle does not change the amount of CO2 in the atmosphere.

However, if fossil fuel is used to harvest, transport or cook the potato, then there is a net emission to the atmosphere. This is usually included in the fossil fuel category. It might be better if fossil fuel emissions were split into food and non-food related categories.

11. The Cow Problem

Grass uses photosynthesis to remove CO2 from the atmosphere and create cells. Cows then eat the grass and produce milk, meat, CO2 and methane.

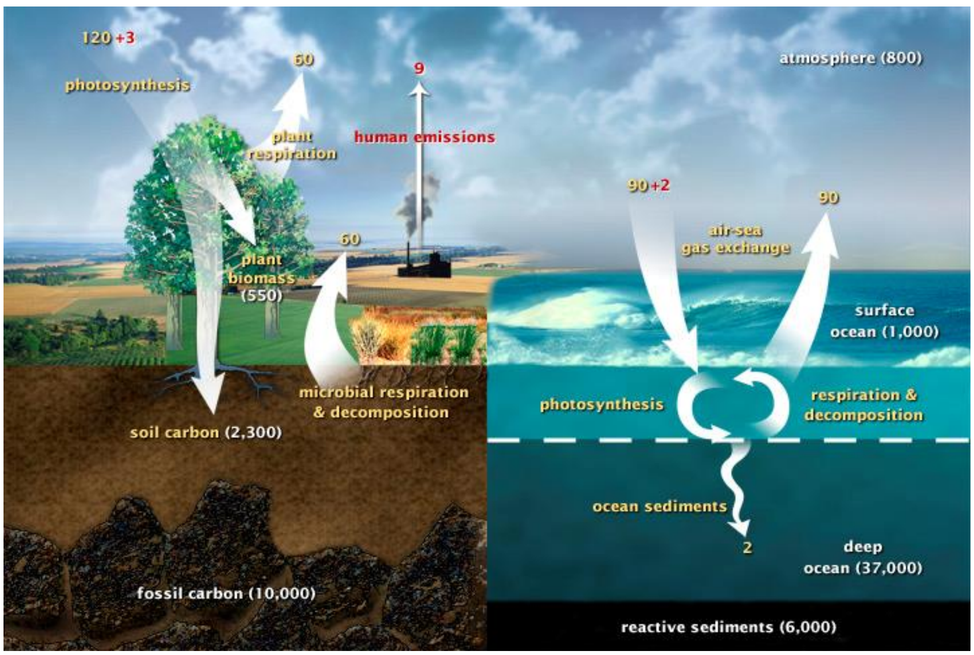
The CO2 is produced as the end result of the cow's metabolism.

The milk and meat also end up as CO2. The emitted CO2 is slightly less than the CO2 required to produce the grass. So up to here we have a net reduction in atmospheric CO2.

The methane is produced by bacteria in the cow's gut. Unfortunately, methane is a very potent greenhouse gas and is roughly estimated to be 34 times more potent than CO2 in the long-term (100 years). Fortunately it decays in the lower atmosphere, 50% disappearing in about 10 years. A small fraction (~ 10%) gets into the upper atmosphere where its half-life is about 100 years. So we have to worry about that.

12. NASA Carbon Cycle Estimate 2011

NASA has provided a pictorial description of the movement of carbon through the atmosphere, ocean and land. This movement is called the carbon cycle. Note that most of the carbon stored in the atmosphere, or emitted int the atmosphere, is in the form of CO2. To get the mass of CO2, multiply the mass of carbon by 3.7.



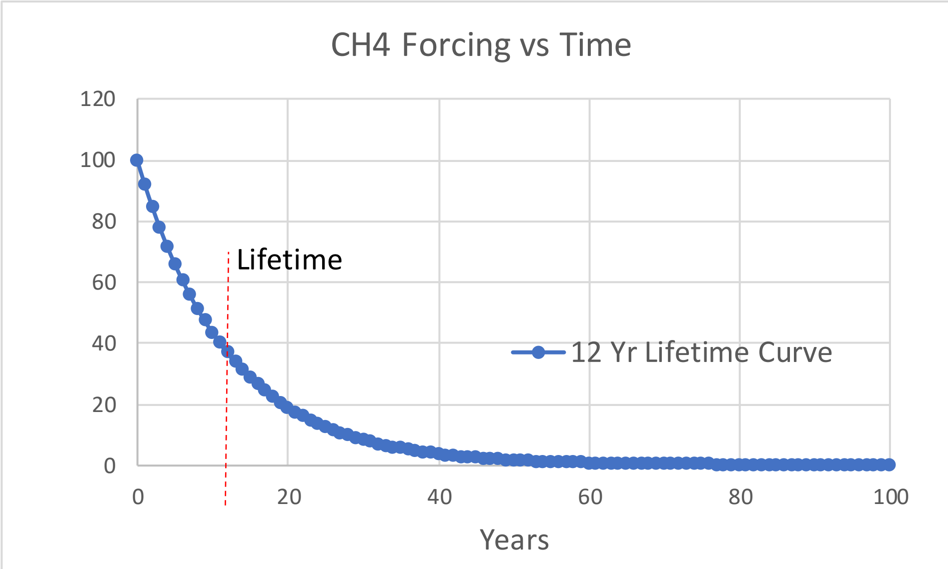
NASA Carbon Cycle Chart, 2011 (10):

- Numbers are Approximate GT carbon (multiply by 3.7 for CO2 GT or GTE)
- Red Indicates Human Responsibility
- Note that CO2 is actually accumulating in the upper waters of the oceans.

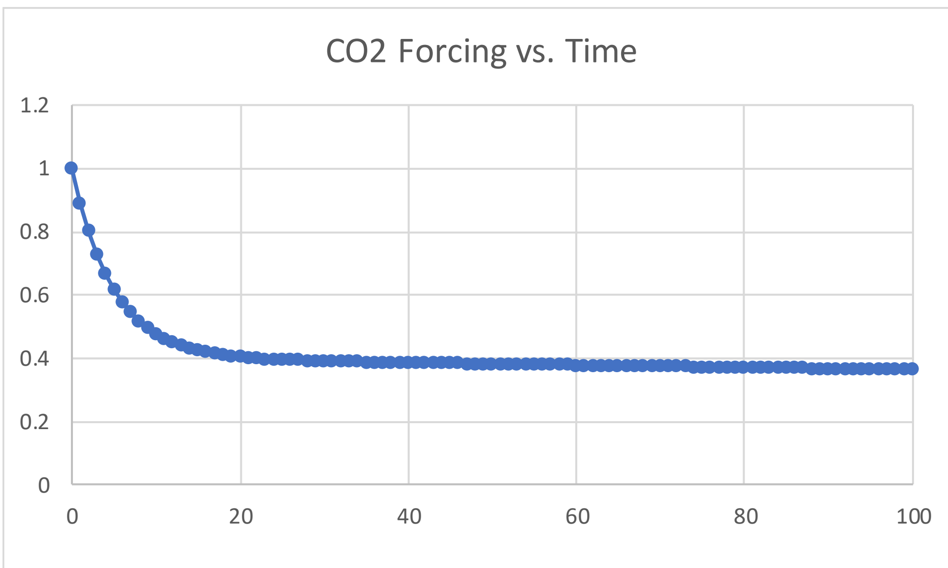
13. GWP – How It Is Calculated

Here we give a simplified account of a complicated topic. We will only consider two complications, the 'lifetime' and the 'averaging time'.

When methane is added to the atmosphere, its initial greenhouse gas forcing is roughly one hundred time the forcing of a similar amount of CO2. However, chemical reactions quickly remove CH4, and its level drops to about 37% of its initial value in around 12 years, this time being known as the 'lifetime' of methane. The graph below shows the effect on methane's greenhouse forcing.



The situation with CO_2 is unfortunately even more complicated. When CO_2 is added to the atmosphere the added mass quickly drops to about 40% of the initial value, the lifetime for this process being around 5 years. The added mass then continues to be reduced with a lifetime of around 1000 years. This is shown in the graph below.



The GWP is then defined by dividing the average methane forcing for a length of time T by the average CO_2 forcing for the length of time T:

$$GWP(T)=(\text{Average } CH_4 \text{ Forcing for Time } T)\div(\text{Average } CO_2 \text{ Forcing for Time } T)$$

It is common to use averaging times T of either 20 or 100 years. With the above numbers we have:

Methane T=20 Years GWP = 89 Methane T=100 Years GWP = 30

References

To go to the indicated website, press Ctrl button and click on the link.

(1) https://www.globalcarbonproject.org/methanebudget/16/files/MethaneInfographic2016.png

(2) https://cdiac.ess-dive.lbl.gov/GCP/methanebudget/2016/

(3) https://www.giss.nasa.gov/research/features/200409_methane/

(4) https://en.wikipedia.org/wiki/Atmospheric_methane.

(5) https://www.eia.gov/environment/emissions/ghg_report/ghg_methane.php

(6) http://cdiac.ornl.gov/GCP/

(7) https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks

(8) https://www.eia.gov/environment/emissions/ghg_report/ghg_methane.php

(9) https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data

(10) https://earthobservatory.nasa.gov/features/CarbonCycle

Glossary of Technical Terms

Anthropogenic:	Produced by human activity e.g. burning fossil fuels.
CFC's	a miscellaneous group of compounds based on methane. Methane's hydrogen atoms are replaced by chlorine and fluorine. These gases may damage the ozone layer and have been banned. Freon, or dichlorodifluoromethane (CCl_2F_2), is a typical example. It was used as a refrigerant.
Gigatonnes (Gt)	Billions of metric tons i.e. 1,000,000,000 metric tons. A metric ton is 1000 kilograms or 2240 pounds, slightly larger than the usual US 'short' ton of 2000 pounds.
Gte of a greenhouse gas	Gigatonnes of CO2 required to produce the same greenhouse effect as 1 Gt of greenhouse gas. Gases such as methane and N2O have a bigger greenhouse effect than CO2, so their mas in Gt is multiplied by an appropriate factor, the GWP, to give an equivalent amount of CO2, from a greenhouse perspective.
GWP of a gas	Global Warming Potential: ratio of the global warming effect of one Gt of greenhouse gas to 1Gt of CO2. The GWP of CO2 is 1. The GWP of methane is about 34 (EPA uses 25).
Metric tons (tonnes)	1000 Kg or very close to 2205 pounds. It is very similar to the British 'long' ton of 2240 pounds. Also a metric ton is a million grams.
Mmt	Millions of metric tons (tonnes)
ppm, ppmv	Parts per million: eg. 400 ppm CO2 means 400 molecules of CO2 in 1 million molecules of the atmosphere (mostly nitrogen and oxygen). ppmv, parts per million by volume, is effectively the same as ppm.

Radiative Forcing	An estimate of the extra energy arriving at the surface of the earth due to greenhouse gas added to the atmosphere since the beginning of the industrial revolution. In the case of CO_2, about 2 watts on every square meter of the earth, or about 1% of the energy from the sun.
Teragram (Tg)	One million million grams (10^{12} grams). Since one million grams is a metric ton, a Tg is a million metric tons (Mmt).

Author Background

Education

1958: Graduated Sir John Deane's GS, Northwich Cheshire ,UK

1961: B.Sc. Physics, University of Manchester, UK

1964: Ph.D. Mathematical Physics, University of Birmingham, UK

Main Employment

Ford Motor Company, USA, 1977-2001, primarily in Noise & Vibration Research & Development

Current Interests

- How do we know what is true?
- Philosophy of Science, Physics and why time goes one way
- Is it possible to develop a religious theory as powerful as scientific theories?
- Does my grandson Julian have a future?