10 questions and answers about methane, a short-lived greenhouse gas

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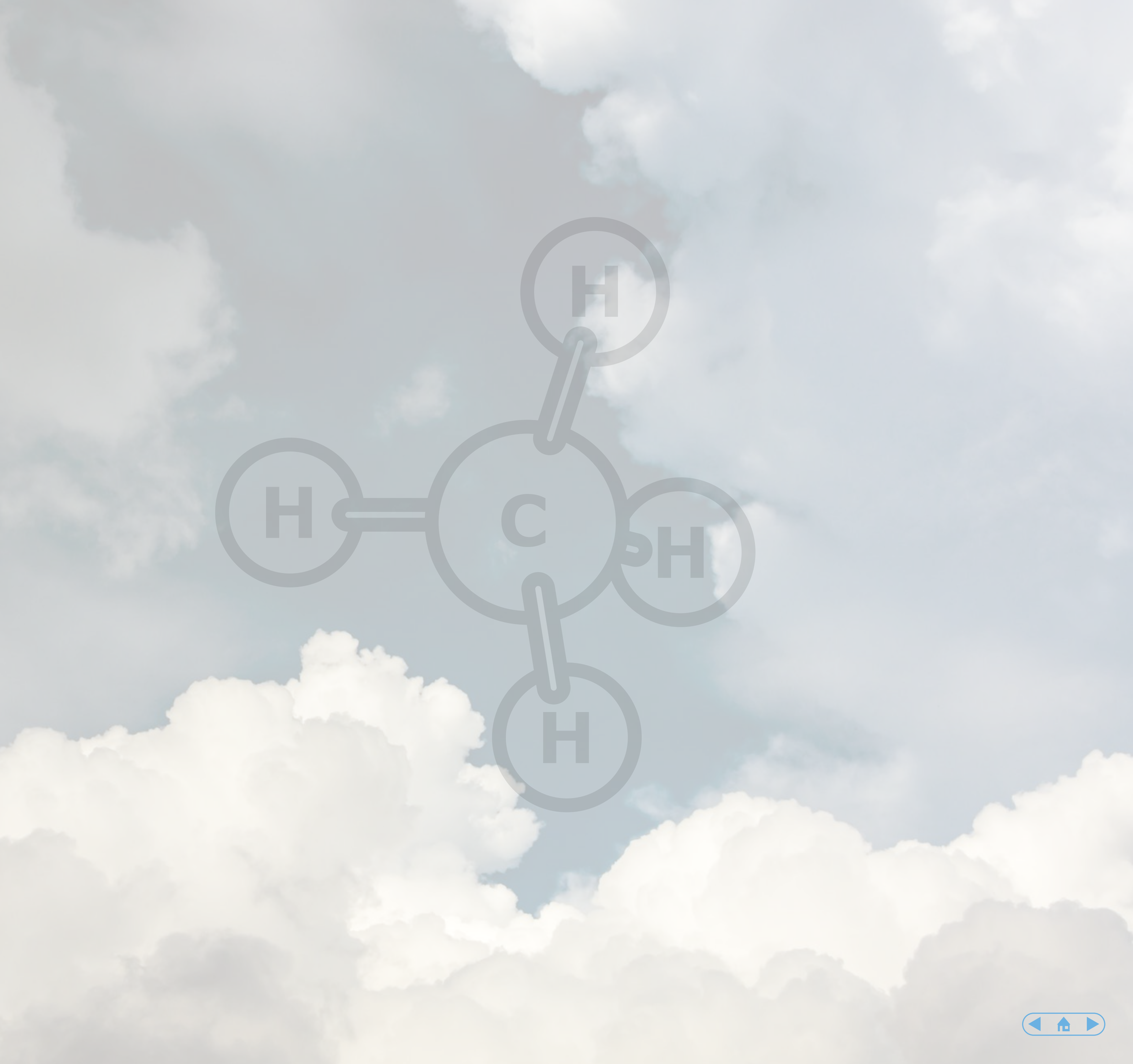

Inhoudsopgave

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What is methane and where does it come from?

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Methane (CH_4) is a very simple substance that consists of one carbon atom and four hydrogen atoms. It is also called 'natural gas'. Methane is created when organic matter decomposes and there is very little or no oxygen present. Organic matter comes from plant and animal material or from micro-organisms, and 90–100% of it consists of C (carbon), H (hydrogen) and O (oxygen) atoms. The other 0–10% is made of minerals, which are important for our nutrition and health. Some important minerals are nitrogen, phosphorus, calcium and iron.

In agriculture, organic matter can decompose without oxygen. This happens in:

a) The digestive processes of ruminants (cattle, sheep and goats);
b) Manure storage of all farm animals;
c) Wet rice cultivation.

Natural sources of CH_4 include thawing permafrost in the north of Russia and Canada. Due to climate change, the thawing of the permafrost is accelerating, which is releasing a lot of methane. Marshes and wet peat soils are the second largest natural source.

Slightly over half of all emissions, 51%, are made up of CH_4 created by humans. The extraction of fossil fuels and livestock farming are the main sources of this (see Figure 1), but our waste contributes to the formation of CH_4 too.

The total global emissions of CH_4 are estimated at an annual 750 megatons (Jackson et al., 2020), of which 115 megatons are created by livestock farming, based on Figure 1. Dutch livestock farming emits around 0.6 megatons of methane annually (van Bruggen et al., 2021). This is less than 1% of the total worldwide methane emissions from livestock farming.

The distribution of the total worldwide methane emissions across the various sources.

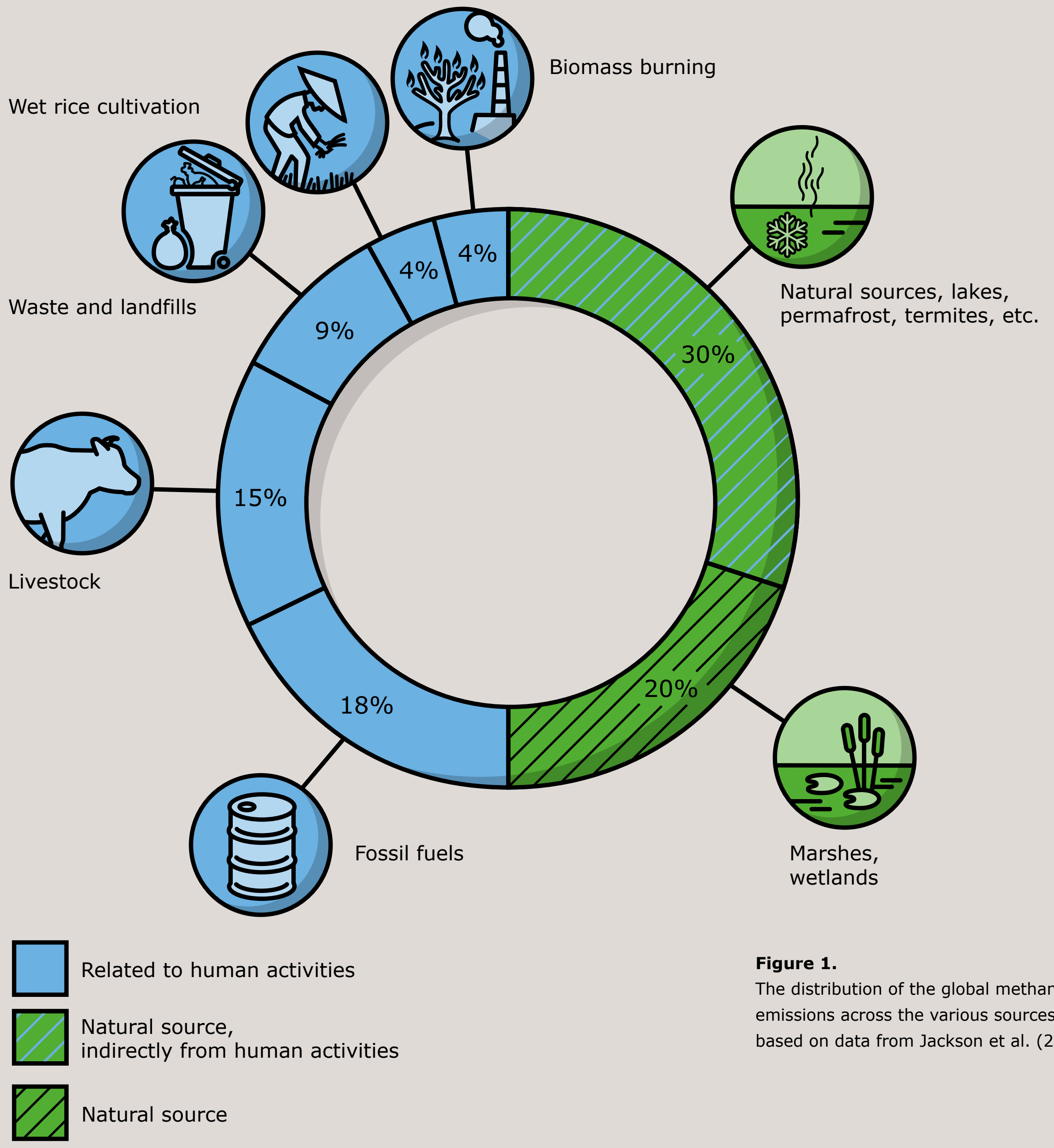

Figure 1.
The distribution of the global methane emissions across the various sources. Figure based on data from Jackson et al. (2020).

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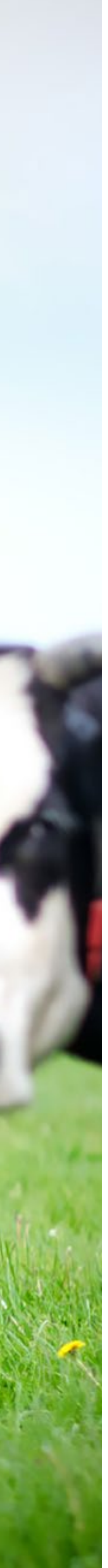
What is the difference between biogenic and fossil methane?



What is the difference between biogenic and fossil methane?

The CH_4 in all of the categories in Chapter 1 reaches the atmosphere in one of two different ways: a) as fossil CH_4 that has been stored in the Earth's crust for a long time, such as natural gas and from thawing permafrost, and b) as biogenic CH_4 created by biological processes. Fossil CH_4 is part of the long carbon cycle (see Frame 1 and Figure 2). The CH_4 from agriculture is part of the short carbon cycle (See Frame 2 and Figure 2), and it is created when organic matter decomposes in anaerobic conditions. This occurs in cows' rumen and in slurry storage. From a chemical point of view, there is no difference between both types of methane. Irrespective the origin of methane, biogenic or fossil, in both occasions it is a strong greenhouse gas and thus contributes to global warming. This is further explained in chapter 6.

Why is there a difference between biogenic and fossil methane? Methane (biogenic and fossil) is degraded over a period of about 60 years into CO_2 and other chemical components (See chapter 5). In the case of fossil methane, the C of CO_2 originates from deep in the earth crust and is now a contribution to the atmosphere. In the case of biogenic methane, the C originates from plant material and before that, from the atmosphere. So, when biogenic methane is degraded to, amongst others, CO_2, the circle is closed. That CO_2 is not considered as a contribution to the atmosphere.

The difference between fossil and biogenic methane, and related to it, the long and short carbon cycle, only refers to the question whether the CO_2 after degradation of methane should be considered as a contribution to the atmosphere. It has no meaning for the impact for methane itself.
Chapter 6 describes the radiation forcing of ethane compared to CO_2 and over a time period of 100 years. For biogenic methane, it is a factor of 34, including the so called carbon feedback. For fossil methane it is about 36, because the extra CO_2 has to be taken into account.

Frame 1
Long carbon cycle explained
The long carbon cycle is about fossil fuels, like oil, natural gas and charcoal. However, organic matter in the soil also plays a part in it. Strictly speaking, these fuels all come from plant materials, but they are plant materials from a long time ago, sometimes millions of years back. The methane is released by the soil and not from biomass that has just been produced using CO_2 from the atmosphere of today. In short: the long carbon cycle always involves the soil and it focuses on carbon from many years ago.

Frame 2
Short carbon cycle explained
The cycle in which CO_2 from the air is converted into plants and then back into CO_2 through food for humans and animals is called the 'short carbon cycle'. Animal products are also part of the cycle thanks to the feed that animals eat. We drink milk and eat meat, then convert it back into CO_2. Manure is also part of the cycle because the organic matter in manure is also converted into CO_2. The CO_2 people and animals exhale does not contribute to global warming, so it is not included in greenhouse gas emissions. It is only withdrawn from the atmosphere briefly. For the same reason, produced biomass – such as grass, potatoes and vegetables – is not considered as carbon sequestration. There are a lot of calculations you can do on it but, in the end, the calculation for CO_2 always ends up at zero, even with the "detour" via methane. But during the time when methane is present, it is a strong greenhouse gas. The short carbon cycle takes place above ground, over a period of days to years but doesn't mean anything for the radiation forcing of methane.

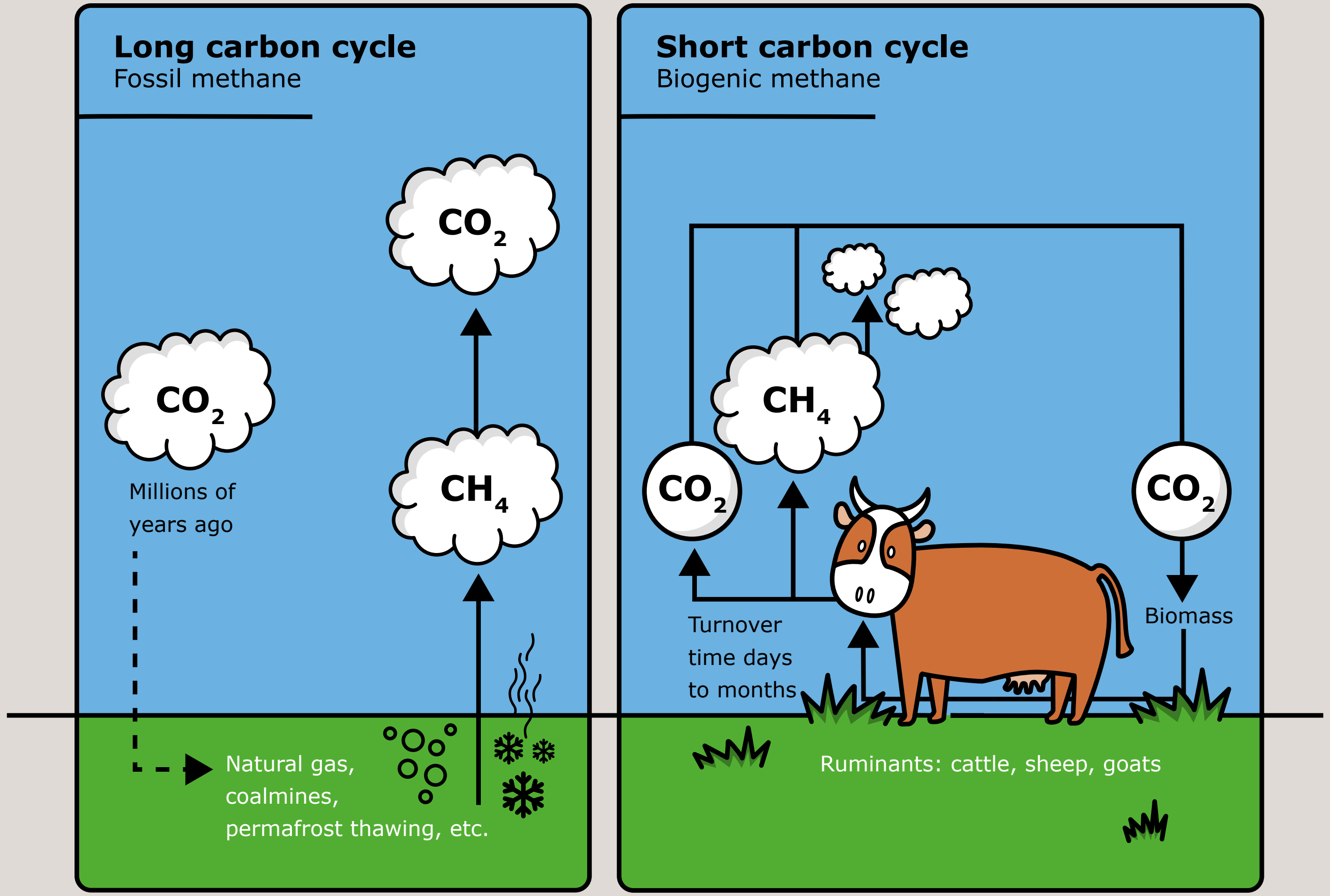


Figure 2.
Representation of the long carbon cycle with fossil methane (left) and the short carbon cycle with biogenic methane (right). The gases in the clouds contribute to the greenhouse effect. Methane contributes to global warming in both cases, CO_2 coming from methane degradation only in the case of the long carbon cycle.

What is the total amount of methane in the atmosphere?

What is the total amount of methane in the atmosphere?

Since the beginning of the Industrial Revolution (around 1750, also see Figure 3), the concentration of CH_4 has increased from about 250 ppb (parts per billion, so 250 methane molecules per billion air particles) to the current level of about 1,900 ppb.

A more detailed picture of the last 35 years is provided in Figure 4. In recent decades, the concentration of CH_4 in the atmosphere has continued to increase, caused by a global increase in methane emissions.

The extraction of shale gas (a form of natural gas) as a source of CH_4 has contributed to an increase in the concentration of methane in the atmosphere. However, livestock farming is making an increasing contribution to methane emissions. The reason for this is the number of cattle and buffalo in the world is still increasing (Figure 5).

Greenhouse gas concentrations from the year 0 to 2005

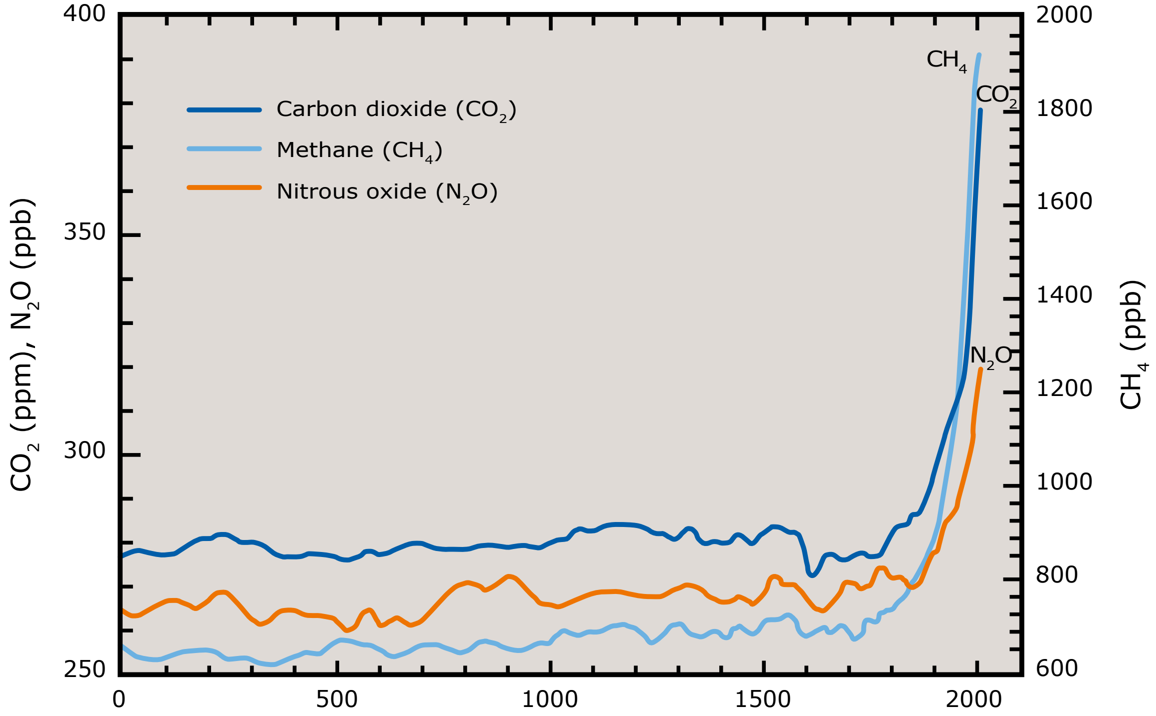


Figure 3.
Concentrations of the most important greenhouse gases over the last 2,000 years. The increase since 1750 is attributed to human activities in the industrial era. Concentrations are expressed as parts per million (ppm, CO_2) and parts per billion (ppb, CH_4 and N_2O). ppm and ppb reflect the number of molecules of a certain gas per million respectively billion air molecules.
Source: https://www.ipcc.ch/site/assets/uploads/2018/02/ar4-wg1-chapter2-1.pdf.

Global monthly average CH_4 concentration

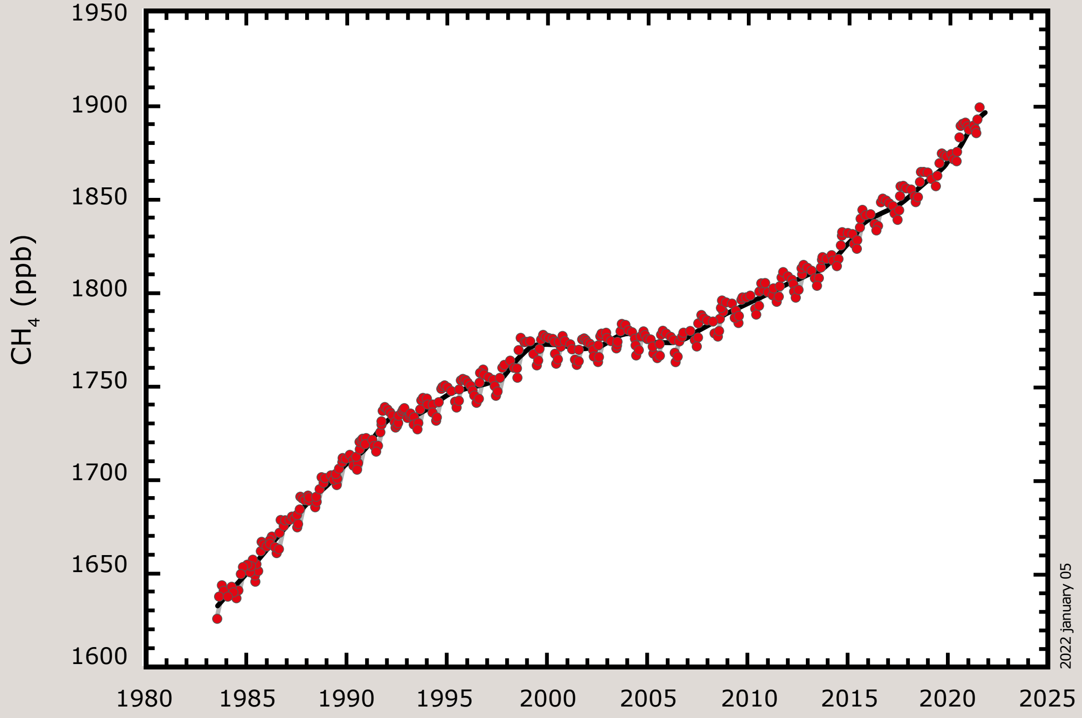


Figure 4.
Concentration of methane in the atmosphere between 1984 and 2020. The red dots around the black line indicate seasonal variation. Source: Ed Dlugokencky, NOAA/GML (gml.noaa.gov/ccgg/trends_ch4/)

Cattle and buffalo

global numbers

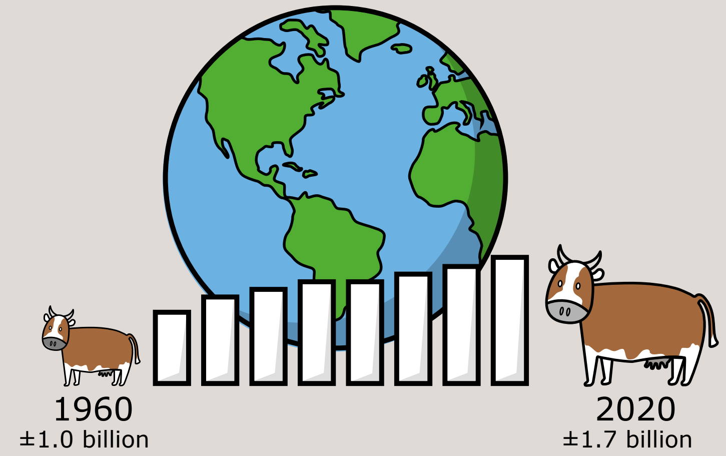


Figure 5.
Number of cattle and buffalo in the world between 1960 and 2020. Source: FAOstat database

What is methane's life span in the atmosphere?

What is methane's life span in the atmosphere?

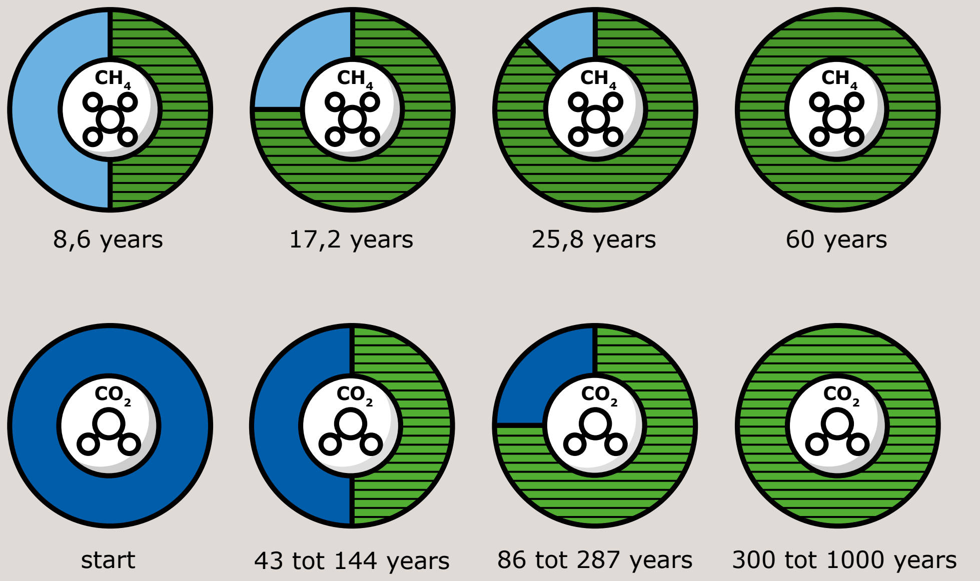
The lifespan of greenhouse gases is referred to as 'half-life', which is the time it takes for half of them to degrade. The half-life of CH_4 is 8.6 years. This means that if you release a kilogram of CH_4 into the air, it will take 8.6 years for half of it (50%) to break down. It then takes another 8.6 years before half of the previously remaining half has broken down (total 75%). After 25.8 years, 87.5% will have broken down, and so on.

Figure 6 shows what happens if you release one kilogram of CH_4 and one kilogram of CO_2 into the air at the same time (at 0). After 60 years, almost the entire kilogram of CH_4 will have disappeared owing to chemical degradation. CO_2 disappears in three ways: through plants absorbing CO_2 and converting it into biomass, by sequestration into the soil and by oceans absorbing it. The residence time of CO_2 can vary from 300 to 1,000 years (https://climate.nasa.gov/news/2915/the-atmosphere-getting-a-handle-on-carbon-dioxide/), so it remains in the atmosphere for a long time. You can also see this in Figure 6: if the CH_4 has completely disappeared after 60 years, 87% of the original kilogram of CO_2 will still be in the air.

You can imagine that if you release CO_2 and CH_4 into the air not once but continuously, as you actually do, these amounts accumulate because more greenhouse gases are supplied than are broken down or absorbed, especially if CO_2 is involved since it has such a long residence time.

Figure 7 shows what happens if we release one kilogram of CO_2 and one kilogram of CH_4 every year, over 100 years. You can see that the amount of CO_2 increases over the entire period. CH_4 remains constant after 50–60 years. If you then double the emissions of both gases after 100 years (left figure), you can see that the concentration of CH_4 will rise again until a new equilibrium is reached after a few decades. The concentration of CO_2 rises faster after year 101 than before. However, if you start to halve the emissions from year 101 (right figure), then something remarkable happens: the total amount of CO_2 in the air continues to increase, but at a lower rate. The warming then slows down. However, the amount of CH_4 slowly decreases, reaching a new equilibrium at t=150 years. This is because degradation depends on the amount in the atmosphere, and that amount was a result of years of emissions of one kilogram per year. Once emissions are halved, degradation is no longer fully supplemented by new CH_4. After a while, the equilibrium amount of CH_4 adjusts to the supply of half a kilogram of CH_4. The lower concentration of CH_4 reduces the warming of the atmosphere.

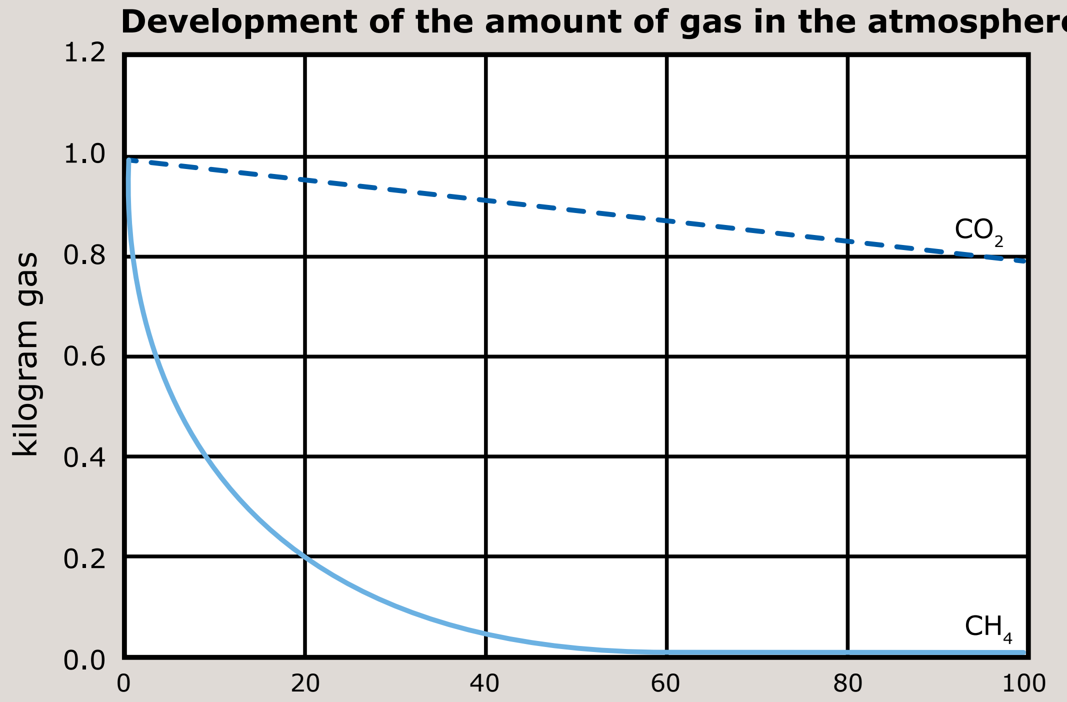
The residence time of CH_4 in the atmosphere is long enough so it is distributed across the globe via air currents, so it does not matter where it is produced. This indicates that with constant emissions, the amount of CO_2 in the atmosphere continues to increase because CO_2 disappears so slowly and the amount of CH_4 does not increase over time because CH_4 breaks down quickly.



Half-life: the time it takes to break down (CH4) or absorb (CO2).

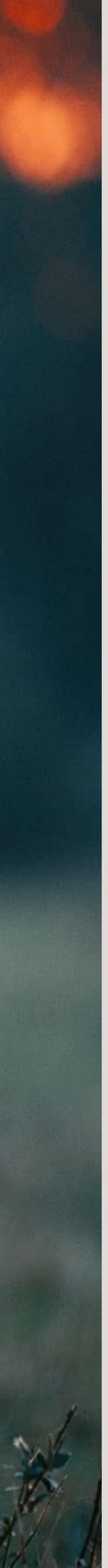
still present

Absorbed or broken down



CH4
CO2

Figure 6.
Course of amounts of CH_4 and CO_2 over time, if at t=0 1 kg of CH_4 or CO_2 enter the atmosphere.



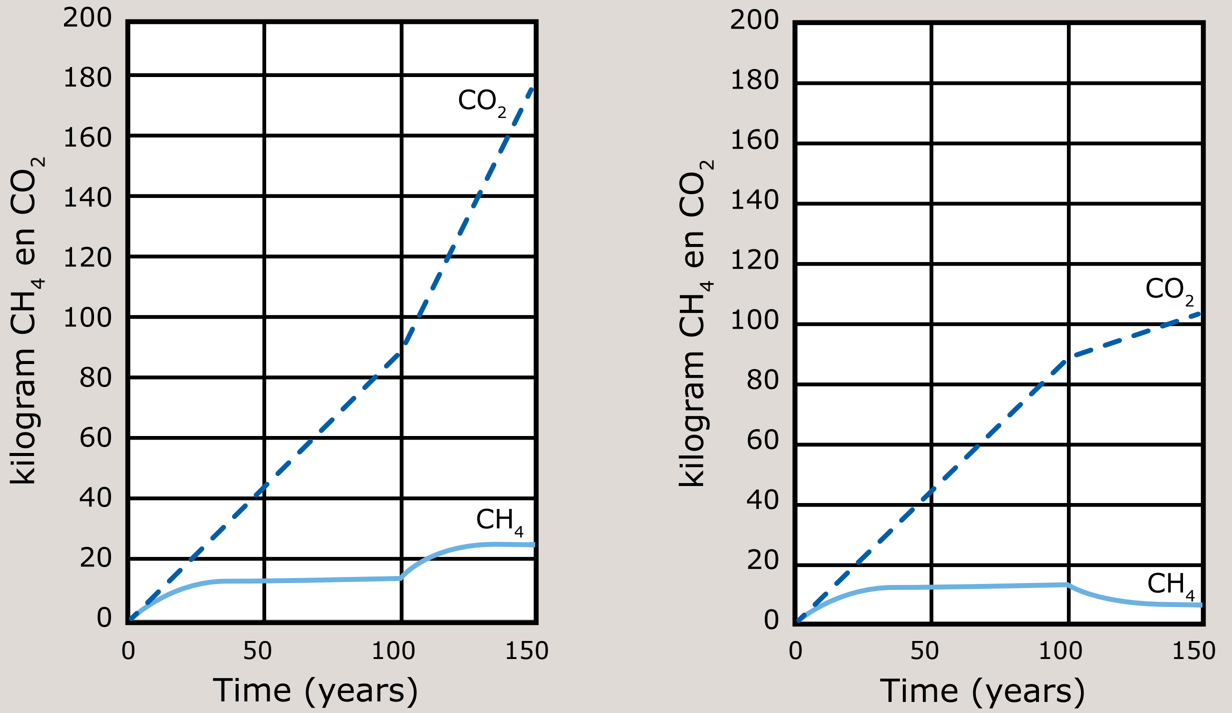
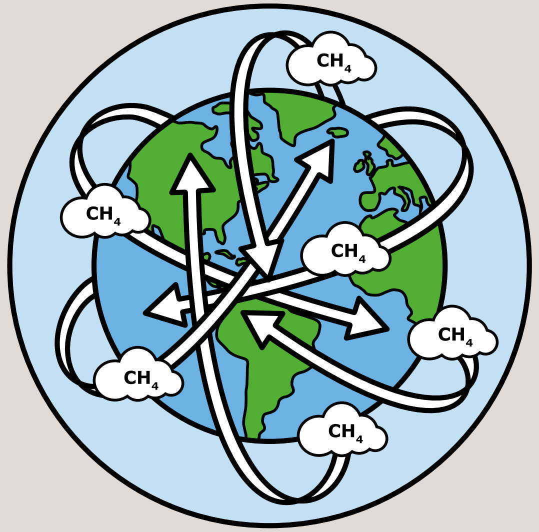


Figure 7.
The development of the total amount of CH_4 and CO_2 if an amount of 1 kg is released into the atmosphere annually in the period from t=1 to 100 years.
Left figure; from year 101, 2 kg of both gases are emitted;
right figure: from year 101, 0.5 kg of both gases are emitted.



Distribution of CH_4 in the atmosphere
Due to a decomposition time of ±60 years, it does not matter where in the world methane is emitted; air currents in the atmosphere spread it all around the world.

How does **methane** **disappear** from the atmosphere?

How does methane disappear from the atmosphere?

Methane is broken down in the atmosphere in different ways:

1. The most important is way is by so-called 'OH radicals' (84%). OH radicals are the cleaners of the atmosphere;
2. Degradation via chlorine radicals (4%) also occurs;
3. Some is transported to and oxidised in the stratosphere (8%), and
4. Oxidation in the soil occurs too (4%).

The breakdown of CH_4 to CO_2 is not a simple oxidation as occurs during combustion. It is a complex process in which OH radicals play an important role. Tie et al. (1992) describe this process in detail and discuss how the methane oxidation chain has a large number of intermediates. The breakdown of CH_4 with OH radicals ultimately leads to the formation of CO_2 (carbon dioxide), CO (carbon monoxide), H_2O (water vapor) and O_3 (ozone). Water vapour in the atmosphere also contributes to the greenhouse effect. An average of 1.15 molecules of ozone are formed per broken down molecule of CH_4 (Tie et al., 1992). The concentration of ozone through methane breakdown has doubled over the past 100 years. Methane may disappear from the atmosphere, but it leaves traces in the form of ozone (see Frame 3).

Frame 3.
The harmful effects of ozone

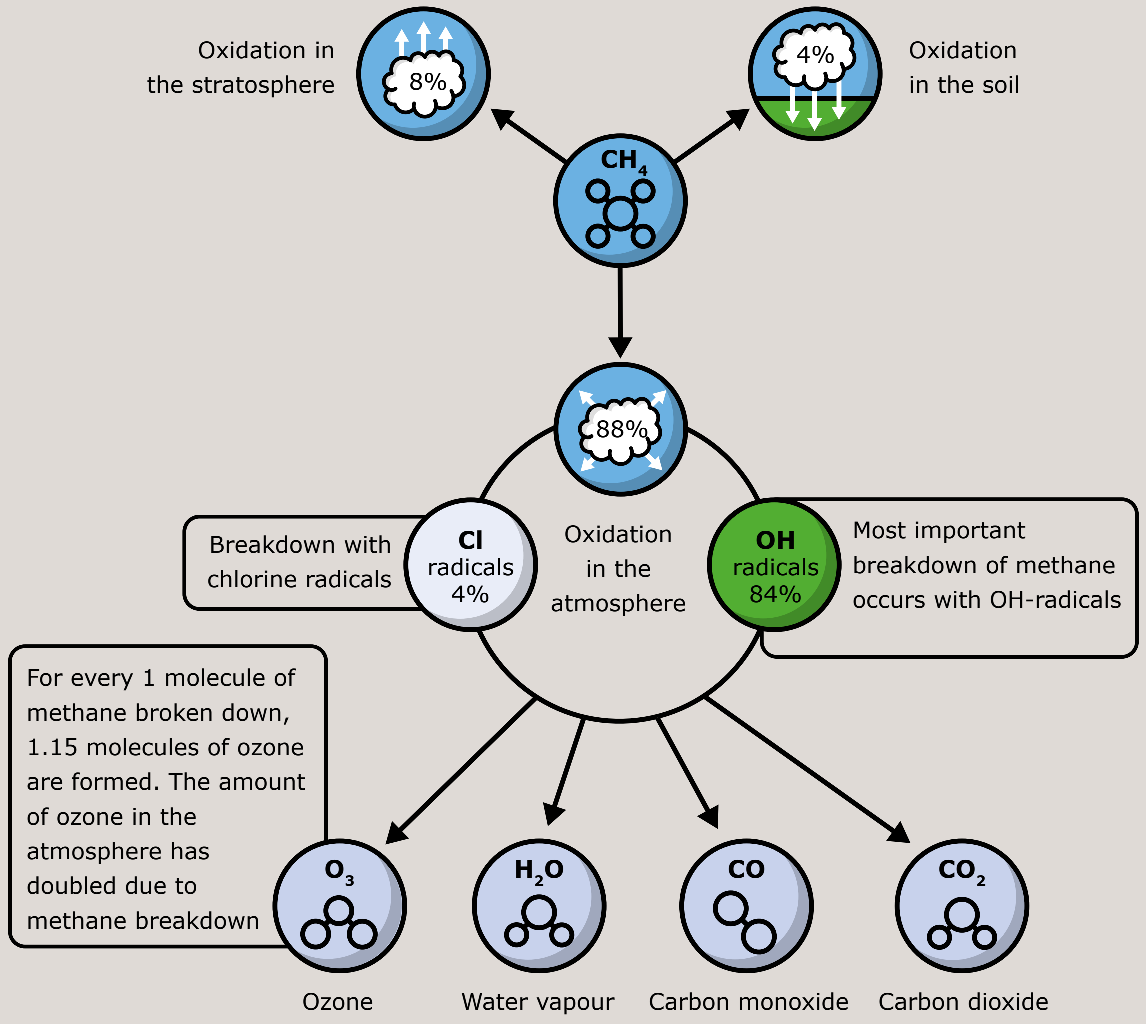
Ozone is an oxygen compound (O_3) with a characteristic pungent odour that you sometimes smell during thunderstorms. Ozone affects the lungs and mucous membranes. Van Dingenen et al. (2018) estimate that, worldwide, 0.3 to 1.2 million people per year die prematurely due to higher ozone concentrations. Higher ozone concentrations also reduce crop production. Mills et al. (2018) calculate a yield decline of 4 to 12% for the most important crops in the world. The total drop in yield in the world is calculated at 227 megaton product per year. To give an impression of how much that actually is, in 2020, 119 megatons of wheat were produced across the entirety of the European Union's 28 countries.

Table 1.
The yield decline due to ozone concentrations in the period 2002–2012 compared to ozone concentrations during the pre-industrial period. Source: Mills et al. (2018).

Crop	calculated yield reduction (%)
Soy	12.4
Wheat	7.1
Rice	4.4
Corn	6.1

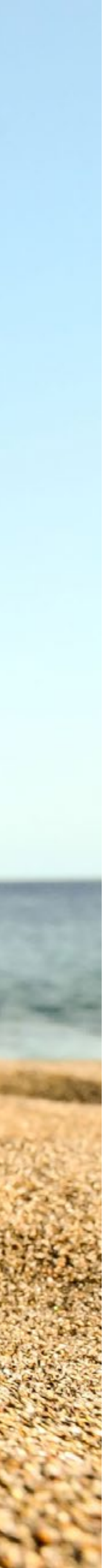
For soy, the effects are strongest in North and South America; wheat is the most affected in India and China; rice in China, Bangladesh, India and Indonesia, and maize (corn) mainly in China and the US. Accordingly, researchers also highlight the importance of reducing methane emissions because of the effect on the world's food supply.

Breakdown CH_4
methane oxidation chain



6

Do carbon dioxide and methane retain the same amount of heat?



Do carbon dioxide and methane retain the same amount of heat?

The sun transfers light and heat to the earth through electromagnetic radiation. We refer to this as ‘thermal radiation’. This thermal radiation is partly reflected back into space and partly absorbed by greenhouse gases. This is quite a good arrangement because if all the heat was reflected back into space, it would be too cold to live on Earth. However, greenhouse gas concentrations are too high, and the atmosphere is warming more than it used to. We call this the ‘enhanced greenhouse effect’. Greenhouse gases all contribute to retaining thermal radiation while they are in the atmosphere. However, some gases do perform ‘better’ than others: carbon dioxide and methane are different.

Per molecule, CH_4 is a stronger greenhouse gas than CO_2 because it absorbs thermal radiation from the Earth better. How well molecules absorb thermal radiation compared to CO_2 is expressed as Global Warming Potential (GWP). This can be seen in the left-hand graph of Figure 8. When a kilogram of CH_4 is released into the air, the warming effect of CH_4 is many times greater than that of CO_2 especially at the beginning.

Over the first 20 years, it is approximately 86 times greater (GWP20 = 86). After several years, however, the total retained heat no longer increases, simply because there is no more CH_4. It has decayed and becomes CO_2 as part of the short carbon cycle in the case of biogenic methane (see Frame 2, question 2). The CO_2 still retains heat, as shown by the slowly rising line in Figure 8, left. After a period of 100 years, the CH_4 is 28 times as strong as CO_2 (GWP100 = 28). This is shown in the right figure.

The values for GWP20 and GWP100 come from the fifth IPCC report (Assessment Report 5, abbreviated to AR5).

The AR5 also mentions a higher value of 34 for the GWP100, so over a period of 100 years CH_4 is 34 times stronger than CO_2. The difference is due to the so-called ‘carbon feedback’, a subsequent effect of degradation processes in the atmosphere. Due to the rising temperature, the capacity of seawater to absorb CO_2 decreases. Vegetation is also affected, as is the amount of water vapor in the air and the clouds. These side effects are all included in ‘carbon feedback’, which means that the GWP is another 6 units higher, so it is actually 34 instead of 28. In Figure 8, the effect of the CO_2 produced during the breakdown of CH_4 has deliberately not been included because it was biogenic CH_4. This is not the case for the CO_2 created after the breakdown of fossil CH_4. The GWP values for fossil CH_4 are therefore slightly higher, at 36, because the additional CO_2 in the atmosphere must also be taken into account.

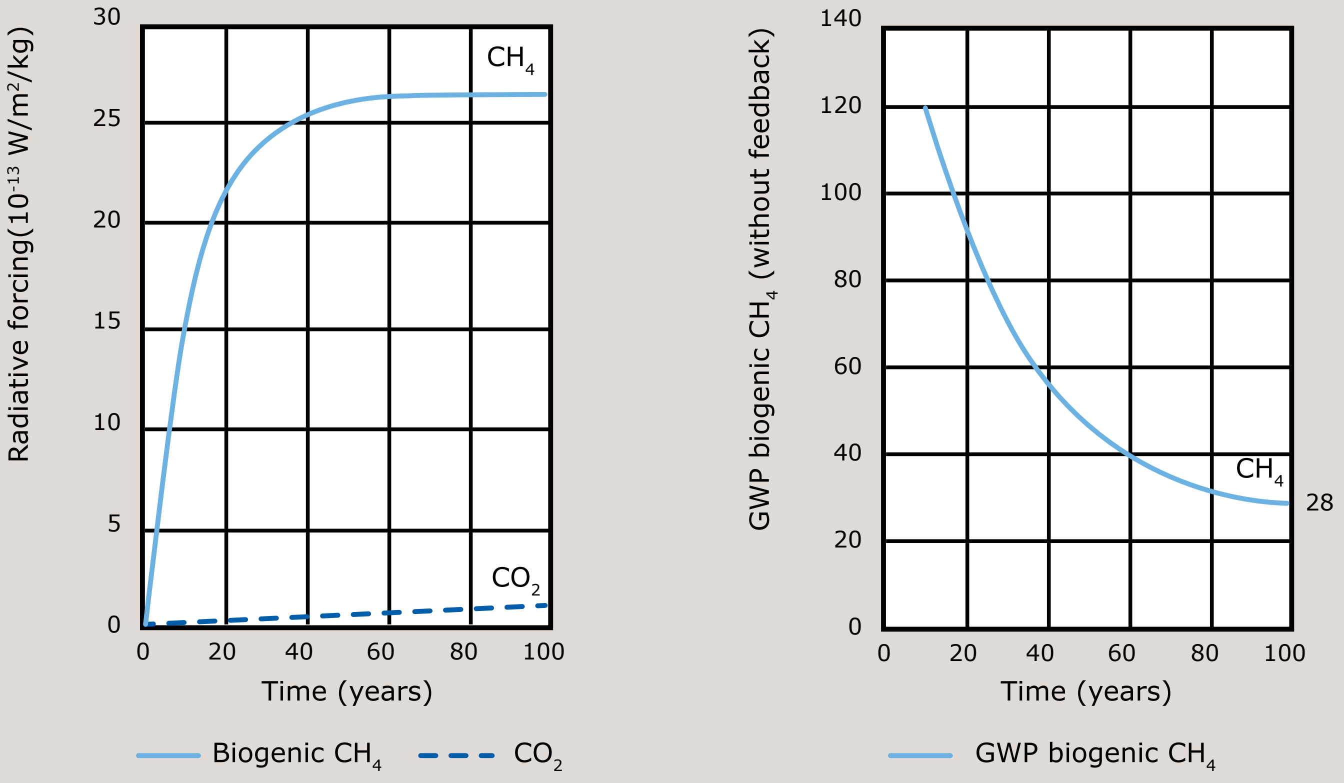
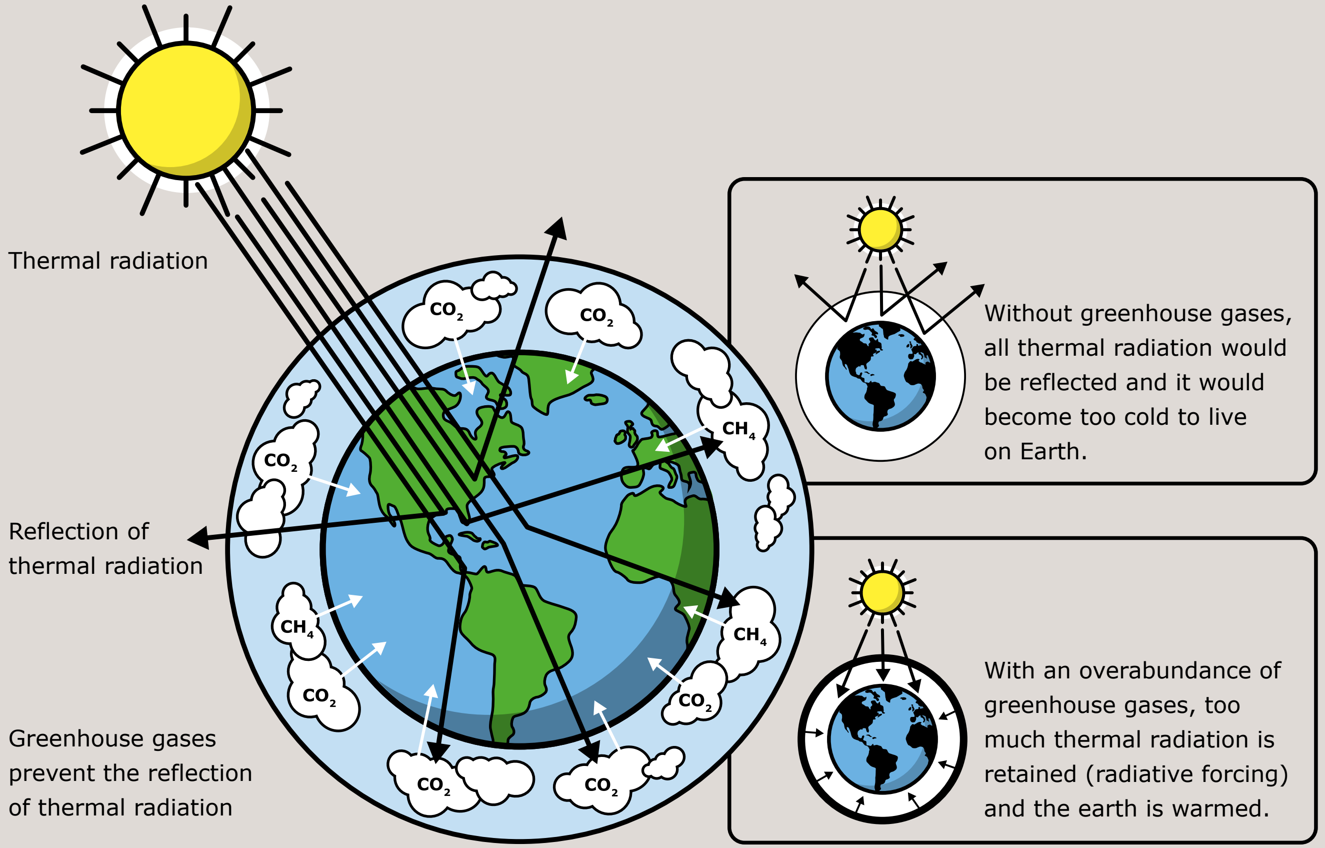
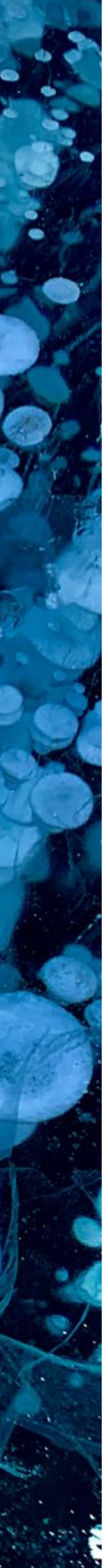


Figure 8.
Left: the cumulative retained thermal radiation (radiative forcing) of CO_2 and CH_4 expressed in 10^{-13} Watt/m²/kg.
Right: the ratio between the retained heat of 1kg CH_4 compared to 1kg CO_2.
Source: IPCC 5th Assessment Report, Chapter 8: the physical background.

Operation of greenhouse gases, including CH_4 and CO_2



How is the total greenhouse gas effect calculated if the effect of gases is so different?



How is the total greenhouse gas effect calculated if the effect of gases is so different?

To be able to compare and visualise the greenhouse effect of every gas together, you have to be able to add their effects up. Because the effects of CH_4 and CO_2 are not the same, this is not quite as simple as it first seems.

There are several ways to add warming effects up. The most commonly used calculation methods are GWP20, GWP100 and GWP*. They all express the warming effect of CH_4 relative to CO_2.

GWP20 and GWP100 represent the ratio of the total retained thermal radiation of CH_4 to CO_2 over a period of 20 and 100 years, respectively. These values can be read in the right-hand graph of Figure 8 (question 6). Because the GWP is a conversion from CH_4 to CO_2, it is expressed in 'CO_2 equivalents'.

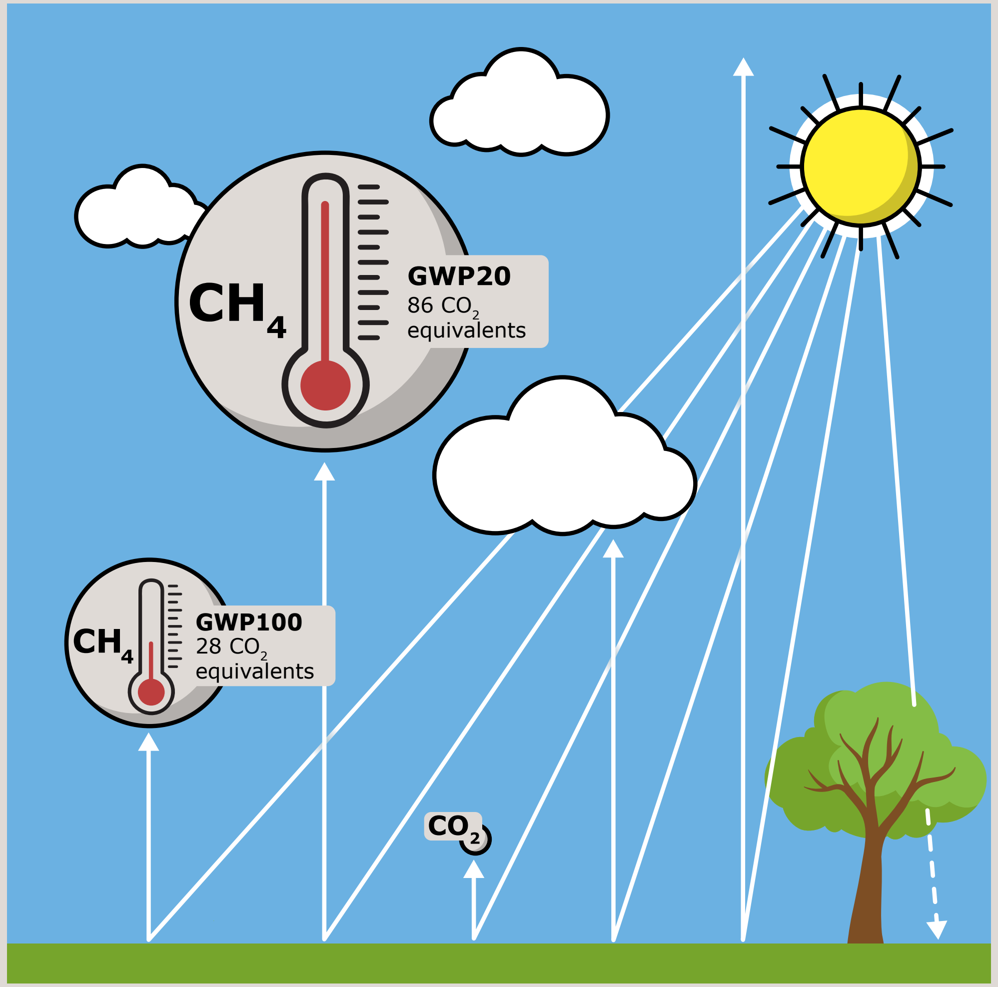
The GWP100 therefore indicates how the emission of a quantity of CH_4 must be settled over a period of 100 years. A comparable settlement over a period of 20 years applies to the GWP20.

Methane has a relatively short greenhouse effect, but it is intense. If you spread it over a period of 100 years, the effect per year will be smaller than over a period of 20 years. For example, using GWP20, CH_4 is equal to 86 CO_2 equivalents because the stronger effects of CH_4 in relation to CO_2 are spread over a short period of time. When calculated over 100 years, however, the GWP of CH_4 is only 28 times as strong as CO_2 (28 CO_2 equivalents).

The GWP* works differently. It takes the short half life of CH_4 into account. Two things are done in the GWP*: a) the GWP* does not look at current emissions, but at the change in CH_4 emissions over a period of time because the change affects the total amount in the atmosphere, as shown in Figure 7 (question 4); and b) the GWP* takes into account the fact that CH_4 has the most effect at the beginning (Figure 8, question 6). The formula used to calculate GWP* also uses GWP100 (Lynch et al., 2020).

With increasing emissions, the GWP* calculates a strong warming effect for the first few years and a less strong effect afterwards. This means it is a completely different way of looking at the GWP20 and GWP100, which spread it equally over a period of 20 and 100 years respectively! It fits better with what can be seen in Figure 7 (question 4) and Figure 8 (question 6). Figure 7 shows that the total amount of methane increases as annual emissions increase. Figure 8, on the other hand, shows that the major effects of CH_4 occur precisely in that period of a limited number of years after the moment of emission. Conversely, the GWP* calculates a negative value with decreasing CH_4 emissions. This also fits well with the development of methane quantity in the graph on the left of Figure 7 (question 4), where the total methane quantity decreases when annual emissions fall.

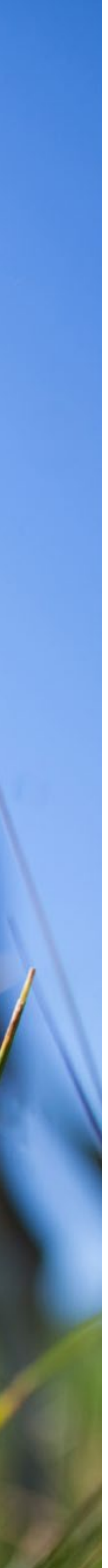
Do CH_4 and CO_2 retain the same amount of heat?



The warming effect (retention of thermal radiation, radiative forcing) of a gas is expressed in GWP (Global Warming Potential). Here, CH_4 is converted to CO_2 equivalents. In GWP, the warming effects of methane have been measured over their lifetime and distributed evenly over 20 and 100 years respectively. Methane is a very strong greenhouse gas but, fortunately, it also breaks down quickly. If you spread that strong effect over 20 years you have a GWP of 86; if you spread it over 100 years, you have a GWP of 28.

8

What do the differences between GWP100 and GWP* look like for agriculture now?



What do the differences between GWP100 and GWP* look like for agriculture now?

The left graph in Figure 9 shows the emissions from Dutch agriculture for the period 1990–2016 (the solid line) and the annual change in emissions (the dotted line). Total emissions in the Netherlands fluctuate between 450 and 600 kilotons. The changes are always in the order of 20–30 kilotons, which is only 5% of the annual amount.

The graph on the right describes what the amounts of CO_2 equivalents and CO_2 heat equivalents are when they are calculated using GWP100 and GWP*, respectively. The CO_2 equivalents (GWP100) are about 450–600 kilotons, the CO_2 heat equivalents (GWP*) are only about the 5% changes.

You can use the solid line of the left graph to calculate the CO_2 equivalents with GWP100 in the right graph, and the dotted line of the left graph to calculate the CO_2 heat equivalents with GWP* in the right graph. You can then see that the line of the CO_2 equivalents/GWP100 has a very stable course, while the line of the CO_2 heat equivalents/GWP* is much less regular.

The GWP* emphasises changes in several kilotons, while less attention is paid to the level of about 500 kilotons of CH_4 that is emitted annually. This is lot easier to understand with the solid line (GWP100), because it continues to describe the annual amount of CH_4 emitted. However, the GWP100 pays little attention to the positive effect of reducing methane emissions due to the short life of CH_4. On the other hand, the GWP* takes into account not only decreases, but increases in methane emissions too. You can see this in the right-hand graph of Figure 9 after 2003, when Dutch agriculture started to emit slightly more CH_4.

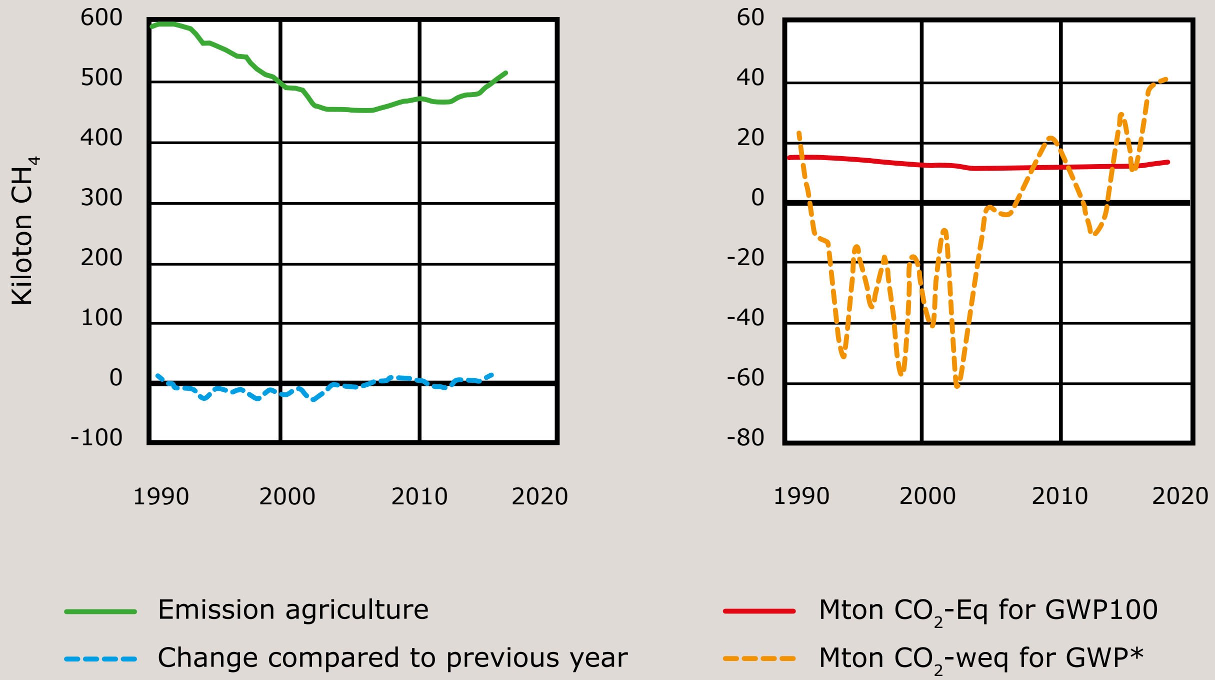


Figure 9.
The amount of methane (in kilotons) per year emitted by Dutch agriculture as a whole (left graph, solid line) and the change in the annual amount of methane (left graph, dotted line). The graph on the right shows the conversion of the annual amount of methane to CO_2 equivalents with GWP100 (solid line) and the conversion of the annual change to CO_2 heat equivalents with GWP* (dotted line). Data taken from the Dutch emission calculations.

Is GWP100 or GWP* better for measuring how much methane causes?

Is GWP100 or GWP* better for measuring how much methane causes?

There is a lot of debate in research, practice and policy about whether GWP* is a better value than GWP100 because the GWP* describes short-term effect better and takes the degradation of CH_4 into account. It also provides a much more favourable picture of the changing livestock population than the GWP100.

To put the value of GWP* into perspective: Figure 10 shows almost the same situation as Figure 9, only the annual methane emission is 400 kilotons lower, so a much lower emission rate. The annual changes remain the same in both figures. The right graph in Figure 10 shows that the GWP100 is lower than in Figure 9, but the GWP* is exactly the same. The GWP* therefore says absolutely nothing about absolute emission rates despite it being important, because high annual emissions still result in large amounts of CH_4 in the atmosphere. The GWP* says something about the **change** in annual emissions.

You can draw a parallel with cars: the GWP100 displays a speed, for example 30 or 80 km per hour. The GWP* can indicate an acceleration of 20 km per hour. The issue is, with just the information from the GWP* (the acceleration), you do not know if you are going from 30 to 50 or from 80 to 100 km per hour. If you want to know how fast you are going towards your destination, speed is particularly important!

The annual emissions for the period 1990–2020, the solid lines in Figure 9, clearly show when emissions rise or fall. At the same time, the solid lines also provide information about the absolute level of the emissions. That absolute level is important because, ultimately, its amount determines whether the methane 'blanket' is being maintained or reduced. The GWP100 shows emission rates very clearly and the change in speed a little less clearly. The GWP* pays a lot of attention to changes in emission rates, but it does not provide any information about the absolute level of methane emissions. The emphasis on the change in speed leads to an erratic course with limited changes of 3–5%. As Figure 9 illustrates, this leads to a more variable impression of the rates, and it is difficult to predict what the long-term effects will be. Have the emissions increased or decreased over a longer period of time?

The GWP* describes the dynamics of CH_4 in the atmosphere better than the GWP100. However, since the GWP* describes a change in emissions from the previous year, it cannot be added to CO_2 emissions, which are expressed in absolute annual emission rates. Then it becomes a matter of comparing the incomparable.

The best way to calculate the effect of CH_4 is to use actual amounts of methane in the atmosphere. This is also done in complex meteorological models, which do not work with GWP values. In addition, gaining an image of the methane concentration in the atmosphere is particularly helpful; figures 3 and 4 (question 3) speak for themselves. However, these meteorological models are much too complex to visualise effects per sector in a country. The GWP100 has been specifically developed to enable calculations at the national and sector level. The GWP* shows us that reducing short-lived gases is an effective strategy to slow global warming: it shows that reducing methane emissions can help slow global warming.

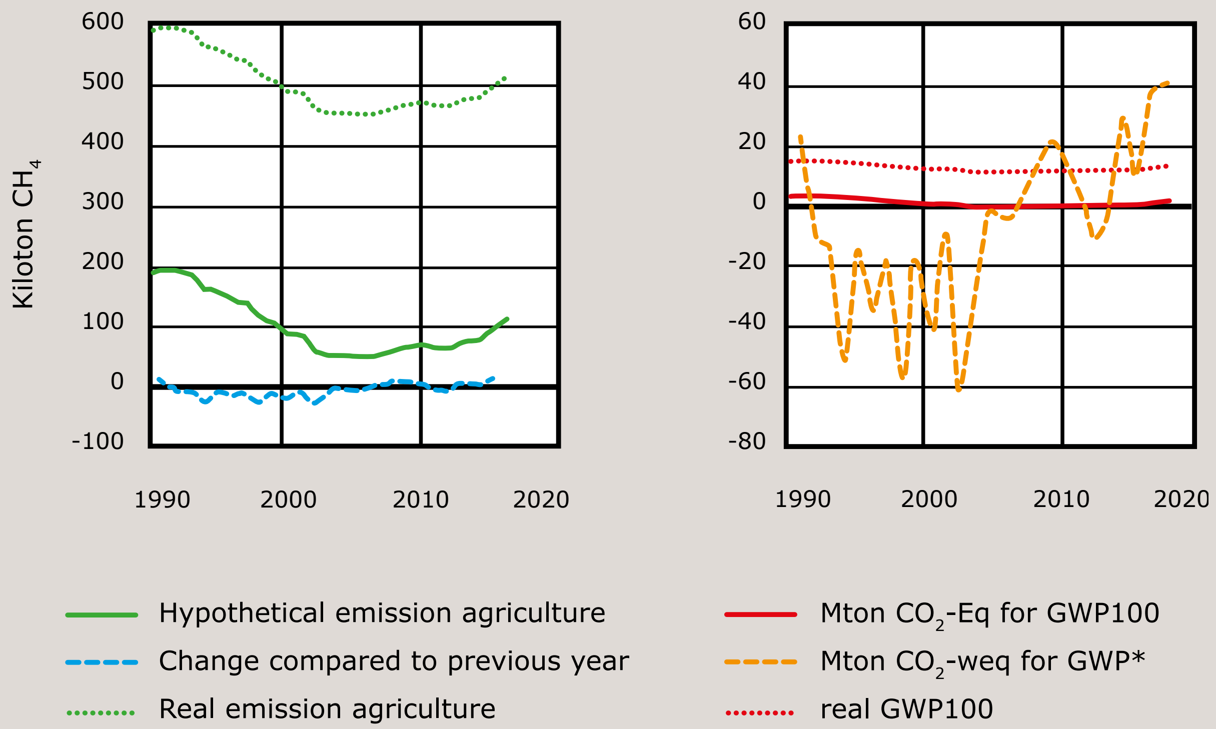


Figure 10.
A hypothetical annual methane emission, 400 kilotons lower than the actual amount of Dutch agriculture as a whole (left graph, dots: actual amount; solid line: hypothetical amount) with the same change in the annual amount of methane (left graph, dotted line). The graph on the right has the conversion of the annual amount of methane to GWP100 (dots for CO_2 equivalents of the actual and a solid line for the hypothetical amount) and the conversion of the annual change to CO_2 heat equivalents via GWP* (dotted line). Data taken from the Dutch emission calculations.

What is the best option for methane?

What is the best option for methane?

In order to reduce global warming, it is essential to bring CO_2 emissions down to net zero. Since CO_2 remains in the atmosphere for a very long time, any effects on temperature will not be visible in the short term. Methane is a short-lived gas, so a reduction will have less effect on global warming than CO_2 in the long term but, because it is a strong greenhouse gas, it can lower the global warming peak so we do not exceed 1.5–2° of warming. Reducing emissions of CH_4 is therefore a good strategy in the short term. Reducing methane emissions does not, however, mean that there is room to slow down the reduction of CO_2. Methane contributes to 16% of the total global greenhouse effect; CO_2 contributes 66%. However, methane 'decays' after about 60 years and disappears, but carbon dioxide continues to contribute to global warming for centuries. It is therefore necessary to reduce the emissions of both greenhouse gases.

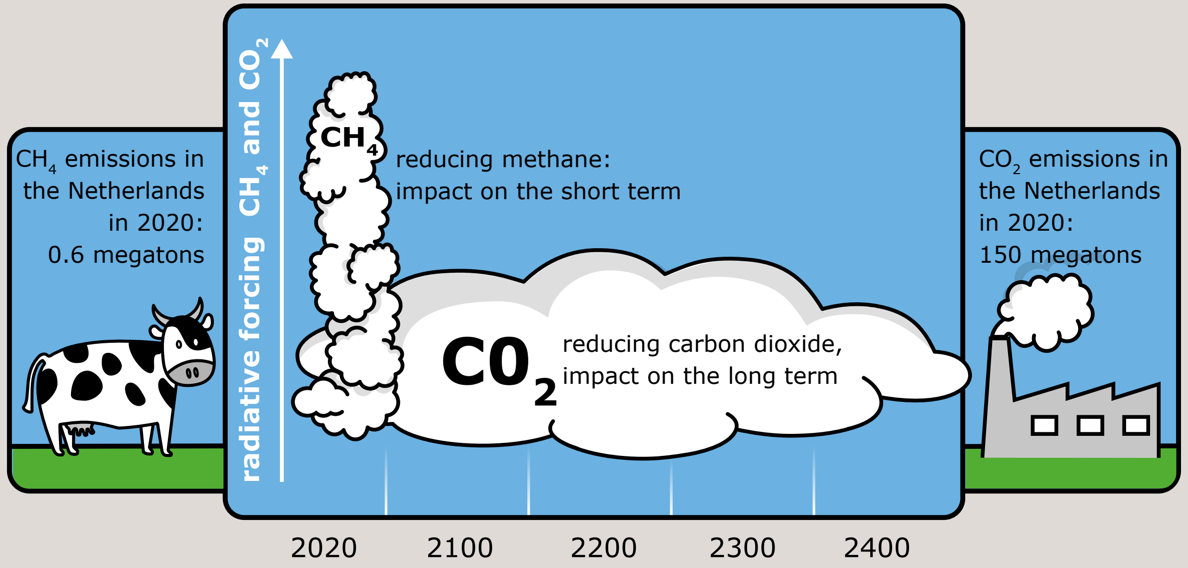
Globally, CH_4 emissions are still increasing. Methane naturally originates from marshes and peatlands, but the increase, as shown in Figure 3 and 4, is due to fossil fuel use, rice cultivation, waste processing and animal husbandry.

For the Netherlands, actions to reduce emissions in terms of livestock farming, gas extraction and gas use are important areas for attention. Emissions from waste processing and landfill have already been drastically reduced since the 1990s. The cultivation of rice plays no role in the Netherlands.

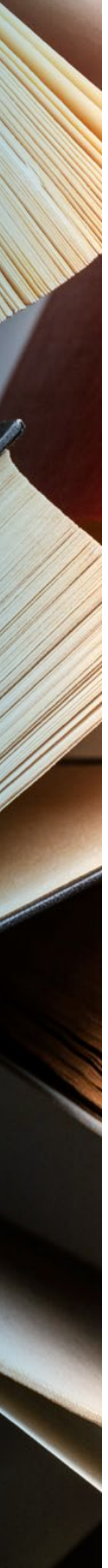
Globally, the number of cattle is increasing constantly. This increase is mainly taking place in Asia, Africa and Latin America, due to population growth, increasing prosperity and significant urbanisation. These processes took place in Europe and the US in the 19th and 20th century. In North America and Europe, the number of farm animals is either stagnant or has come to a standstill. However, these countries can be expected to reduce more than the global average due to their disproportionately high emissions per capita and their global warming legacy (Lynch and Garnett, 2021).

This shows that the issue of greenhouse gases is multidimensional, so several considerations must apply when it comes to reducing CH_4 emissions to stem global warming. These are, of course, of an environmental nature, but they also concern economic growth and social equality.

Reduce CH_4 emissions and CO_2 emissions



Literature & colophon



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Colophon

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