

What Is Methane?

- Methane is an odorless, colorless, tasteless gas that is lighter than air.
- It is the main component in natural gas and is also present in many coal formations. When methane burns it produces a great amount of heat, which makes it very useful as a fuel source.
- Methane is a chemical compound with the molecular formula CH₄ (one carbon atom bound to four hydrogen atoms).
- In sufficient amounts of oxygen, methane burns to give off carbon dioxide and water.

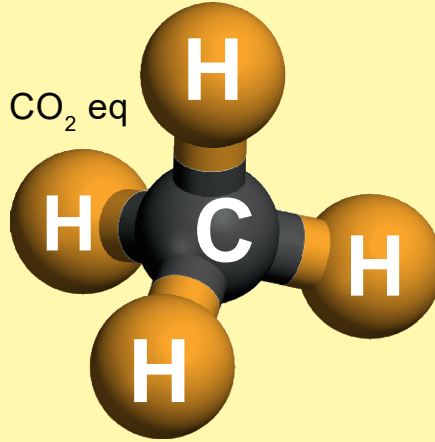
Methane As A Greenhouse Gas

Atmospheric methane is an important greenhouse gas with an ability to trap infrared radiation that is 28 times greater than carbon dioxide on a 100-year timescale

- Since the Industrial Revolution, methane concentrations in the atmosphere have more than doubled.

Methane (CH₄)

91 Mt CO₂ eq



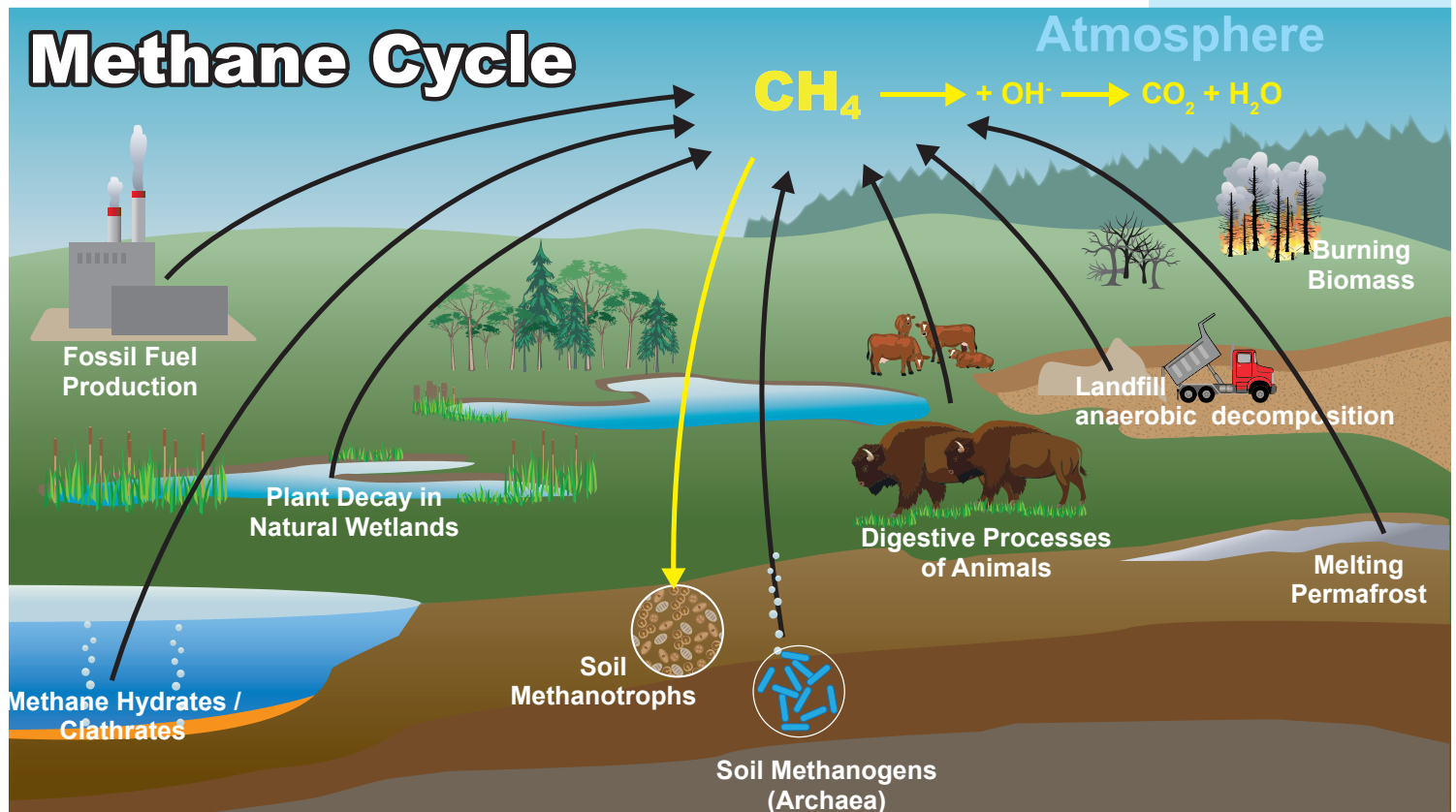
Greenplanet Energy Analytics

- It is about 200 times less concentrated in the atmosphere than carbon dioxide.
- About 20 percent of the warming our planet has experienced can be attributed to the methane.

(Also see Fact Sheets on Greenhouse Effect, Greenhouse Gases and Climate Change.)

Methane is an important greenhouse gas with an ability to trap infrared radiation that is 28 times greater than carbon dioxide.

Methane Cycle



Greenplanet Energy Analytics

How Is Methane Produced?

Some methane is produced by geological processes (abiotic), but most of Earth's methane is biogenic - produced by living organisms and one kind in particular.

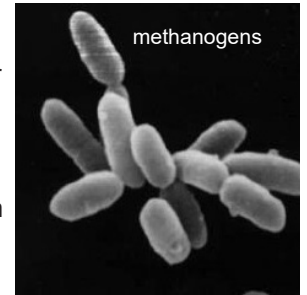
- Methane is produced by some members of the Domain Archaea (ar-KEE-ə) - single celled organisms which are similar to bacteria. Since they produce methane, they are called methanogens.
- Methanogens use a form of anaerobic respiration - in other words they produce energy without oxygen.
- This process is called methanogenesis: $\text{CO}_2 + 4 \text{H}_2 \rightarrow \text{CH}_4 + 2 \text{H}_2\text{O} + \text{energy}$
- Methanogens occupy many habitats from wetlands to sediments below the seafloor, to the digestive tracts of ruminants, termites and some people. Oxygen inhibits the growth of methanogens, so this limits their habitats.

Importance in the carbon cycle (Also see *Fact Sheet on The Carbon Cycle*.)

- Methanogenesis is the final step in the decay of organic matter.
- Without methanogenesis, a great deal of carbon would accumulate in anaerobic environments.

The Methane Cycle

- There are many sources that release methane (CH_4) into the atmosphere. There are also sinks, or ways that methane is trapped or destroyed.
- Methane concentrations have more than doubled over the past 200 years
- About 60% of the current methane released from land to the atmosphere is the result of human activities, including livestock handling, cultivating rice paddies, fossil fuel use, biomass burning and landfill use.
- In an ideal world, methane sources would be balanced with methane sinks, as with carbon dioxide. However, global atmospheric methane concentrations are rising as a result of human activities - faster than natural sinks can offset it.
- Scientists are worried because as the planet warms, even more methane will to be released from soils or other sources, adding to the global warming problem.



commons.wikimedia.org

Natural Sources – Where Methanogens Live

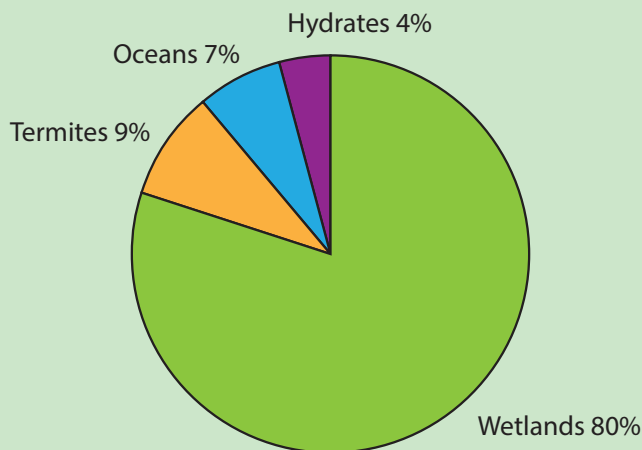
Wetlands

- Natural wetlands are responsible for approximately 80% of global methane emissions from natural sources.
- Wetlands, such as bogs, marshes, fens and permafrost provide a habitat favorable to methanogens - environments with no oxygen and plentiful organic matter for the methanogens to break down.

Other Natural Sources

All other natural sources only make up about 20% natural global emissions

Natural Sources of Methane by %



Based on information from: https://www.esr.noaa.gov/gmd/education/info_activities/pdfs/CTA_the_methane_cycle.pdf

Soil

- Methanogens in the deeper soil, where there is little or no oxygen, produce methane that bubbles up to the surface and is released into the atmosphere.
- Some research has indicated that plants are absorbing methane from the soil and then emitting it through their leaves.



pixabay.com

Digestive Tracts of Animals

Methanogens in the guts of various animals produce methane as part of their normal digestive process. This includes;

- ruminants - mammals that acquire nutrients from plant-based food by fermenting it in a specialized stomach prior to digestion. This group includes cattle, bison, caribou, deer, elk, goats, moose, sheep, and antelopes.
- humans - occurs only in some humans, resulting in flatulence.
- termites - methane from termites are estimated to be about 9% of the global emissions from natural sources.

Methanogens have been found in other animals including rats, rabbits, horses, pigs, monkeys, baboons, rhinoceroses, hippopotamuses, giant pandas, geese, turkeys and chickens.



Greenplanet Energy Analytics

Oceans & Lakes

- Methanogens in oceans and lakes contribute about 7% of the global methane emissions from natural sources.
- Anaerobic (oxygen-free) digestion in marine zooplankton and fish and methane produced in anoxic (lacking oxygen) sediments are the main sources.

Methane Hydrates

- Methane hydrates are molecules of methane produced by methanogens that are frozen into ice crystals (clathrates).
- They form in cold, oxygen poor undersea sediments. Clathrates are also trapped in permafrost, the permanently frozen soil in the arctic and subarctic.
- As global warming causes melting, this frozen methane is released and adds approximately 4% to the emissions.

Human Sources

Today, about 60 percent of the methane in the atmosphere comes from sources scientists think of as human caused.

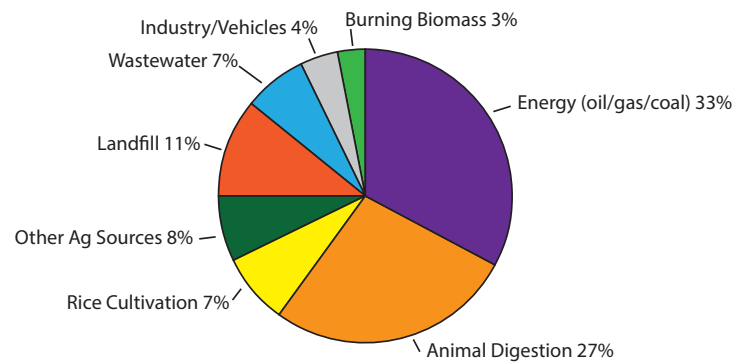
Landfills

- Methane is generated in landfills as waste decomposes by methanogens under anaerobic (oxygen-free) conditions. Landfills in regions with dry conditions do not produce as much methane as those in area with high moisture content.
- Globally, trash releases over 10 percent of all methane generated by humans
- A way to reduce landfill methane would be to reduce the amount of methane-generating materials going into landfills.
 - reducing food waste
 - turning the remaining food and yard waste into compost rather than sending it to landfills



pixabay.com

Human Sources of Methane by %



Based on information from: https://www.esrl.noaa.gov/gmd/education/info_activities/pdfs/CTA_the_methane_cycle.pdf

Fossil Fuels

- Fossil fuels were formed by natural processes of anaerobic decomposition of buried dead organisms (involving methanogens) over millions of years.
- Methane is the primary component of natural gas and can be released during the production, processing, storage, transmission, and distribution.
- Because natural gas is often found with oil and coal, the collection and combustion of these also contributes to the total methane emissions.
- The energy sector contributes about a third of the annual methane budget.

Livestock

- Domesticated livestock produce large amounts of methane as part of their normal digestive processes.
- There are 1.4 billion cattle in the world, and that number is growing as demand for beef and dairy increases; together with other grazing animals, they contribute over a quarter of the annual methane budget.



unsplash.com

Wastewater Treatment

- Methanogens play an indispensable role in anaerobic wastewater treatments.
- When wastewater from sewage is treated to remove contaminants, methane can be produced if organic ingredients in the wastewater are treated without oxygen and if the methane produced is released to the atmosphere.

Rice Cultivation

- Methane is produced during flooded rice cultivation by the decomposition of organic matter in the soil. Flooded soils are ideal environments for methanogens because of their high levels of organic material, oxygen-poor conditions and moisture.

Biomass Burning

- Biomass burning, largely resulting from human activities, accounts for about 3% of methane emissions each year.
- Methane is released during burning as a result of incomplete combustion and huge amounts can be produced during;
 - large scale burning of woodlands and grasslands for land clearing.
 - the burning of agricultural waste due to its generally high water content.
 - wood burning for domestic fuel and for charcoal production
- Biomass burning as an alternative to traditional fossil fuels can be used effectively by avoiding incomplete combustion thereby having a much reduced net greenhouse gas impact compared to equivalent coal, oil and gas-fired power stations.



unsplash.com

Natural Sinks

Atmosphere

- The main mechanism for removal of methane from the Earth's atmosphere is oxidation, where oxygen bonded to hydrogen (called a hydroxyl radical) combine with the methane to form water vapor and CO₂.
- For this reason, OH[•] is known as the 'cleanser of the atmosphere'.
- Methane remains in the atmosphere for about 8 years until it is cycled out by oxidation.

Methanotrophs in soils

- Soil methane is also consumed by some microbes called methanotrophs.
- They use methane as a source of energy, reacting methane with oxygen and as a result producing carbon dioxide and water (methane oxidation) $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O + \text{energy}$.
- Forest soils act as good sinks for atmospheric methane because soils are optimally moist for methanotroph activity and the movement of gases between soil and atmosphere is high.
- Some methanotrophs are anaerobic (living without oxygen).
- Methanotroph habitats can also include wetlands, marshes, rice paddies, landfills, aquatic systems (lakes, oceans, streams) and more.

More Resources

Methane, Explained - National Geographic

<https://www.nationalgeographic.com/environment/global-warming/methane/>

Report on Greenhouse Gases Sources and Sinks - IPCC

https://www.ipcc.ch/site/assets/uploads/2018/05/ipcc_wg_i_1992_suppl_report_section_a1.pdf

Municipal Solid Waste And Greenhouse Gases - Government of Canada

<https://www.canada.ca/en/environment-climate-change/services/managing-reducing-waste/municipal-solid-greenhouse-gases.html>

Compost Council of Canada

<http://www.compost.org/>

Methane, Climate Change and Waste Management in Canada - Canadian Institute for Environmental Law and Policy

<http://cielap.org/pdf/Methane.pdf>

Landfills Have A Huge Greenhouse Gas Problem - Ensia / University of Minnesota's Institute on the Environment

<https://ensia.com/features/methane-landfills/>

Global Methane Emissions and Mitigation Opportunities - Global Methane Initiative

<https://www.globalmethane.org/documents/gmi-mitigation-factsheet.pdf>

Food Waste Management + Climate Action - National Zero Waste Council of Canada

<http://www.nzwc.ca/focus/food/Documents/FoodWasteClimateChange-Report.pdf>