Methane pollution: impact on the environment, health, and solutions

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k Written by the **Marketing & Communication Team**

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Methane leaks into the atmosphere are accelerating global warming, with recent scientific findings revealing a **record-breaking increase** in the past five years. As Inger Andersen, Executive Director of the UNEP, states, "Governments and oil and gas companies must stop paying lip service to this challenge [of methane leaks], as the **solutions are right in front of them**. Instead, they should recognize the enormous opportunity this represents and start acting on the warnings by plugging the leaks that release methane into the atmosphere and heat up the climate. The tools are at their disposal, **the goals are clear**. It's time to act now!"

Methane (CH_4) is an **essential gas on Earth**, found in the atmosphere, aquatic environments, and underground. As a hydrocarbon, its **simple structure gives it unique properties**, consisting of a carbon atom bonded to four hydrogen atoms. This bonding makes it a valuable **energy resource** but also poses an **environmental challenge** as a potent greenhouse gas due to **its ability to trap heat**. It has a detrimental impact on the atmosphere and living organisms, **contributing to over 25% of current global warming**.

This article explores the composition of methane, its impact on air pollution, and its contribution to climate change. It focuses on strategies to reduce methane emissions and the **urgent need for global action** to detect and reduce methane in the atmosphere, mitigating its impact to achieve climate goals.

The use of **advanced technology for monitoring methane emissions** allows for detection and subsequent reduction efforts, which are priorities for mitigating **climate change**. This will improve **air quality**, saving hundreds of thousands of lives, and preserving **ecosystems** for a sustainable future on our planet.

NASA Models Methane Sources and Movement Around the Glol
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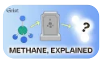
More videos 

What is methane and why is it so important?

The simplest **hydrocarbon**, composed solely of **carbon and hydrogen molecules** (alkane hydrocarbons), is **methane**. It exists in the atmosphere as a **gas**, primarily originating from **human activities** such as livestock farming, the **fossil fuel industry**, and **landfills**, as well as from **natural sources** like wetlands through decomposition in **anaerobic environments** and volcanic activity.

Understanding how **methane** forms and identifying its **emission sources** is crucial for developing effective strategies to detect and control its presence. This helps mitigate its **environmental impact** while harnessing its potential as an **energy source**.

Basics of methane: composition and characteristics

Under the **temperature and pressure** conditions of the atmosphere, methane typically exists as a **gas**, giving it the unique property of contributing to the **transparency of the atmosphere**. This allows the **sun's natural energy** to reach the Earth as **ultraviolet radiation**, making the planet **habitable**.

Methane forms naturally through the **anaerobic decomposition** of organic matter. This process occurs in **human-generated waste**, **wetlands** like swamps and lakes, **marine sediments**, and the intestines of **ruminant animals** (and their manure). This process generates what is called **natural methane**.

The **biological process** of methane formation is known as **methanogenesis**, carried out by microorganisms called **methanogenic archaea**. These microorganisms break down organic matter in **oxygen-free (anaerobic) environments**, producing methane as a byproduct.

Geological processes also contribute to methane formation in the **subsoil**, producing **natural gas** through the **thermal decomposition** of organic matter buried underground.

Anthropogenic methane originates from activities such as **agriculture**, **livestock farming**, **solid waste**, **wastewater**, and the **production and distribution of fossil fuels**.

The **anaerobic decomposition** of organic waste also generates **biogas**, where methane (CH_4) comprises **50-70%** of its composition. When biogas undergoes **purification** to remove **carbon dioxide (CO_2)** and other contaminants, it becomes nearly pure **biomethane**, with broad applications as a **fuel**.

Although methane is a **colourless, odourless, and insoluble gas**, it can become dangerous. At **high concentrations**, it is highly **flammable** when combined with air. Additionally, in **confined spaces**, elevated methane levels displace **oxygen**, creating a **toxic environment** that can cause **asphyxiation**.

Methane pollution facts

Methane remains in the atmosphere for **10–12 years**, a significantly shorter time than **CO_2** (which lasts **thousands of years**). However, methane has an **80 times greater impact** on the atmosphere than CO_2 over a **20-year period**, as it traps **infrared radiation** emitted from the Earth's surface. Methane also has **25 times the global warming potential** of CO_2 over a **100-year horizon**.

> The atmospheric concentration of methane has more than doubled over the past 200 years. Scientists estimate that this increase accounts for 20-30% of climate warming since the Industrial Revolution (which began in 1750). Climate NASA.

To combat methane pollution, the global community must leverage **advances in air quality technology** to **monitor and control** methane **emissions**. By acting **collectively**, we can still take responsibility and achieve **global climate goals**, thereby protecting **life on Earth**.

How methane contributes to climate change

Methane's behaviour in the atmosphere acts as a **barrier to thermal infrared energy** generated at the Earth's surface. This trapped heat leads to the **greenhouse effect**, accelerating **global warming**.

Since the **Industrial Revolution**, methane concentrations in the atmosphere have significantly increased. The rise of **machines** and their role in advancing human activities has driven **social, economic, and industrial development** without limits. This increase is alarming and presents a **global challenge** requiring **international collaboration** to safeguard life on Earth.

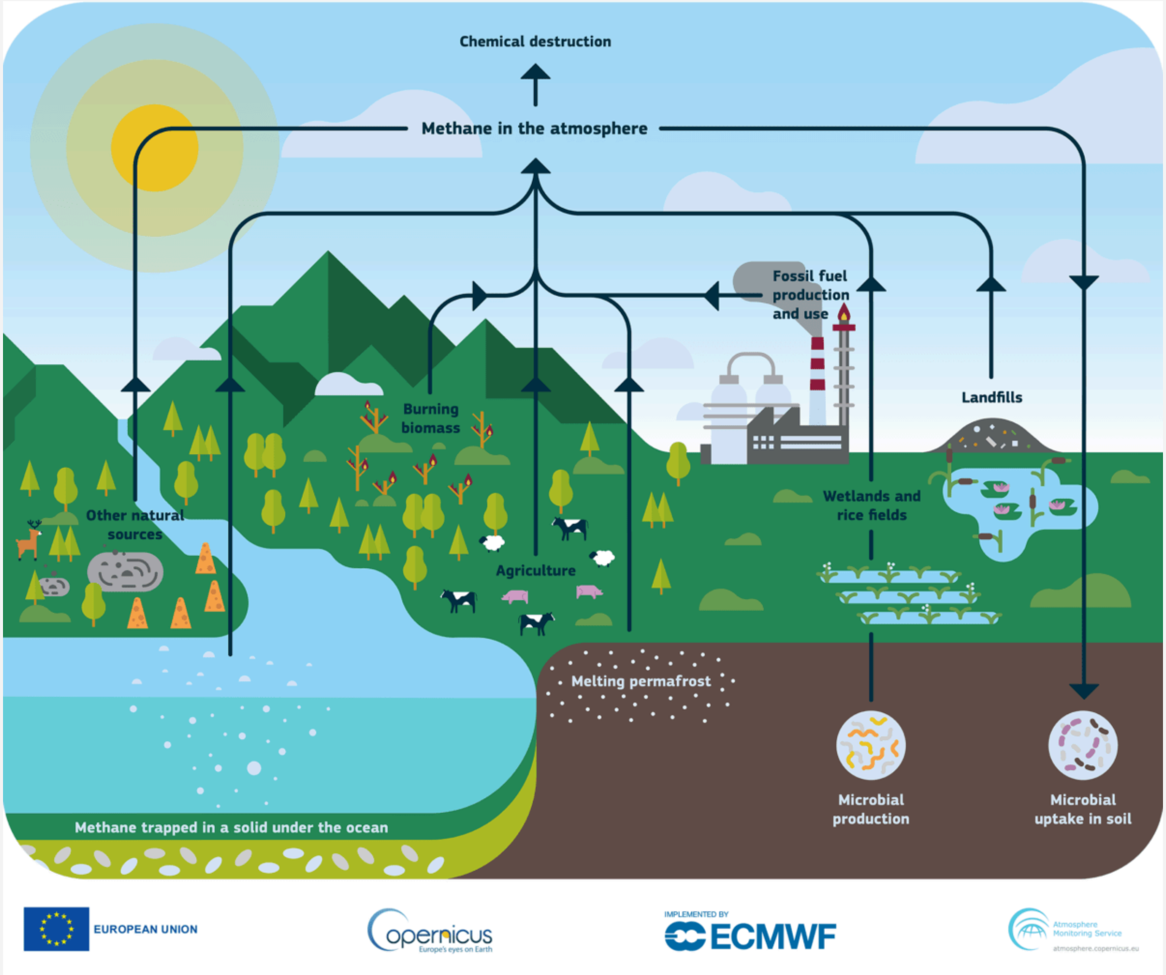
While **CO_2** is the primary **greenhouse gas** responsible for driving global warming, **methane** in the atmosphere is far more **damaging** in its effects.

Controlling **anthropogenic methane sources**, along with reducing the use of **fossil fuels** such as **oil**, **coal**, and **natural gas**, are **priority actions** to lower methane emissions.

> Reducing methane emissions by 45% by 2030 could help achieve the Paris Agreement's goal of limiting global warming to 1.5°C. (Source: UN Environment Programme)

How methane is produced

The concentration of methane gas in the atmosphere has skyrocketed in recent decades due to **industrial development**, reaching **exceptional levels**. This increase is primarily driven by **human activities**, including **agriculture**, **livestock farming**, **energy production**, and **waste management**.



Methane Cycle – Copernicus Atmosphere Monitoring Service, ECMWF – Kunak

While less significant than human sources, **natural methane emissions** also play an important role in atmospheric pollution. The main natural sources of methane emissions include:

Wetlands

Wetlands are the **largest natural source** of methane. In these ecosystems, microorganisms break down organic matter under **anaerobic conditions**, releasing methane. Wetlands account for approximately **30% of global methane emissions** into the atmosphere.

Thawing permafrost

The rising temperatures caused by **global warming** are thawing the **permafrost**—permanently frozen soil in the Arctic. This process releases **methane trapped** in the subsurface for thousands of years.

This phenomenon is occurring most notably in Arctic regions such as **Siberia** and **Alaska**. The process accelerates a **feedback loop**: as temperatures rise, more methane is released from the permafrost, further intensifying global warming.

Geological sources

Natural methane emissions originating from **Earth's processes**, unrelated to human activities, are known as **geological sources**.

Though less understood than anthropogenic sources, they play a crucial role in the **global methane cycle**. Methane can escape from the depths of the subsurface via fractures in the **Earth's crust**, **geological faults**, or surface cracks. **Underwater volcanoes** and tectonic activity also contribute to methane emissions, such as in the **Gulf of Mexico**.

Natural gas deposits, of which methane is a primary component, can also emit methane into the atmosphere through cracks or tectonic movements.

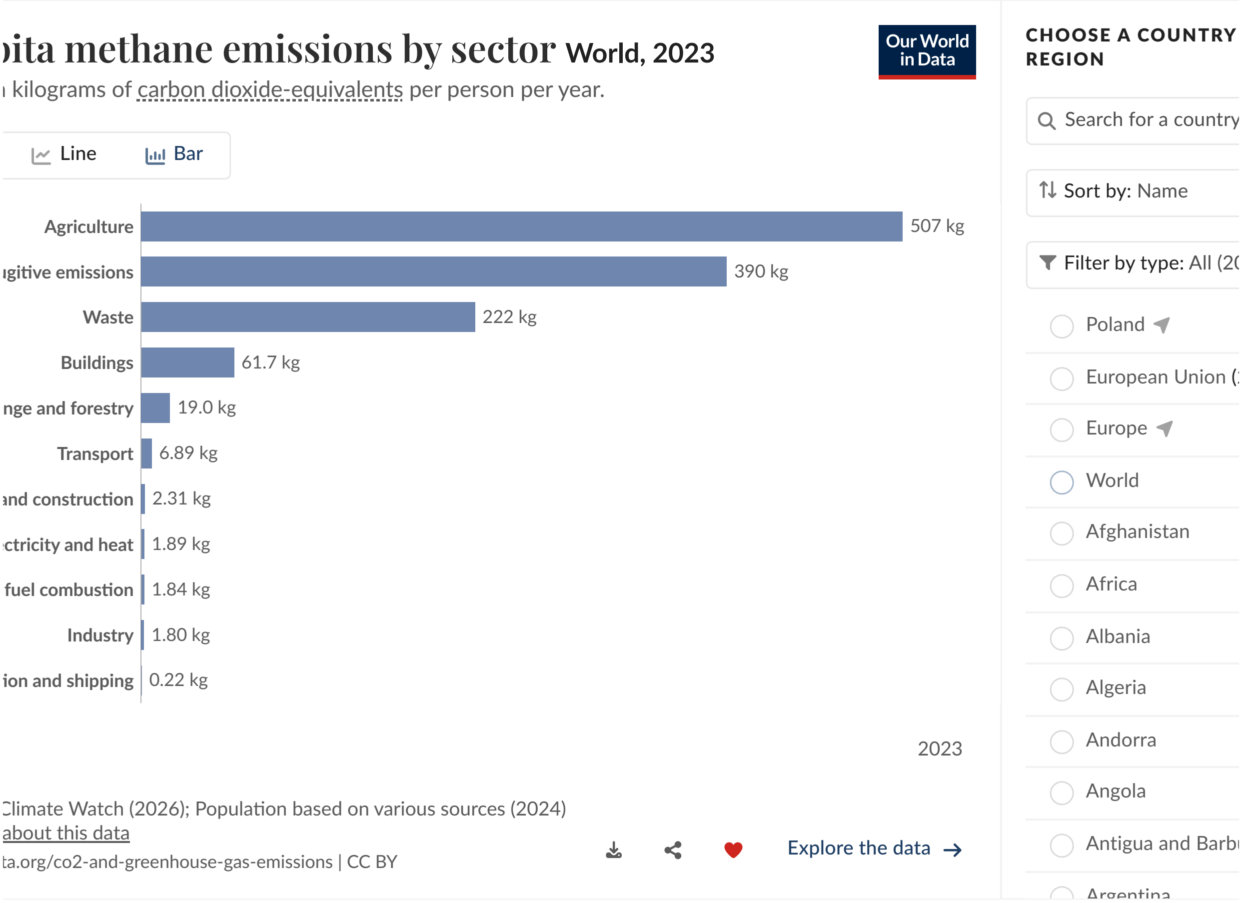
Additionally, the **seafloor** contains areas where methane ascends from **hydrocarbon deposits** deep within the seabed. **Methanotrophic bacteria** in the water consume part of this methane before it reaches the atmosphere. This phenomenon occurs on a large scale in the **East Siberian Sea**.

Wildlife

Methane emissions from **wild animals**, such as **ruminants**, occur naturally due to their **herbivorous diet**. These animals possess a specialised digestive process for breaking down **plant matter** and **cellulose**, which produces methane as a by-product.

Although wild ruminants emit less methane than domesticated livestock, both contribute to the **natural presence of methane** in the atmosphere.

Human activities responsible for methane emissions



A significant portion of the **methane gas** present in the atmosphere originates from **human activities**, known as **anthropogenic methane**. The primary sources are:

Agriculture and livestock

The **digestion process** of ruminant animals in the livestock industry generates methane gas. Similarly, the decomposition of agricultural residues under **anaerobic conditions** produces large quantities of methane. **Rice paddies**, during their flooded periods, create ideal anaerobic conditions for microbes to break down organic matter, releasing methane in the process.

Production and use of fossil fuels

The use of **fossil fuels**, such as **oil**, **coal**, and **natural gas**, generates substantial methane emissions at various stages, from **extraction** to **distribution** and **storage systems**. During these processes, **fugitive methane emissions** escape into the air through activities like extraction, refining, and transportation via distribution networks.

Methane leaks from **fossil fuels** represent a major threat to the **global climate**. While less visible than **CO_2**, methane's **climatic impact** is significant due to its **higher global warming potential**. **Monitoring leaks**, reducing emissions, and **capturing methane** in the fossil fuel industry are crucial actions to mitigate its impact on **climate change**.

> A study by the Global Carbon Project estimated that “methane leaks from the oil and gas industry in 2020 reached around **70 million metric tons**, equivalent to **2.1 gigatonnes of CO_2** in terms of climate impact”.

Landfill management – image credit Powerknot – Kunak

Landfills and waste management

Landfills are one of the largest **anthropogenic sources** of **methane emissions**, due to the **anaerobic decomposition** of organic matter. However, implementing **biogas capture systems**, **composting**, **anaerobic digestion**, and **waste reduction** can help mitigate these emissions and utilise methane as a source of **renewable energy**, contributing to the fight against **climate change**.

Biomass burning

This process involves the **combustion of organic material**, such as **wood**, **agricultural residues**, or **vegetation**. Depending on the **conditions**, the **type of biomass**, and the **environment**, it can directly or indirectly contribute to methane production.

Biomass burning occurs in two main contexts:

- **Natural burning**, such as **wildfires** in forests, savannahs, grasslands, and peatlands.
- **Anthropogenic burning**, which includes controlled burning of crops, agricultural residues, or the use of biomass as a fuel source for **cooking**, **heating**, or **energy generation**.

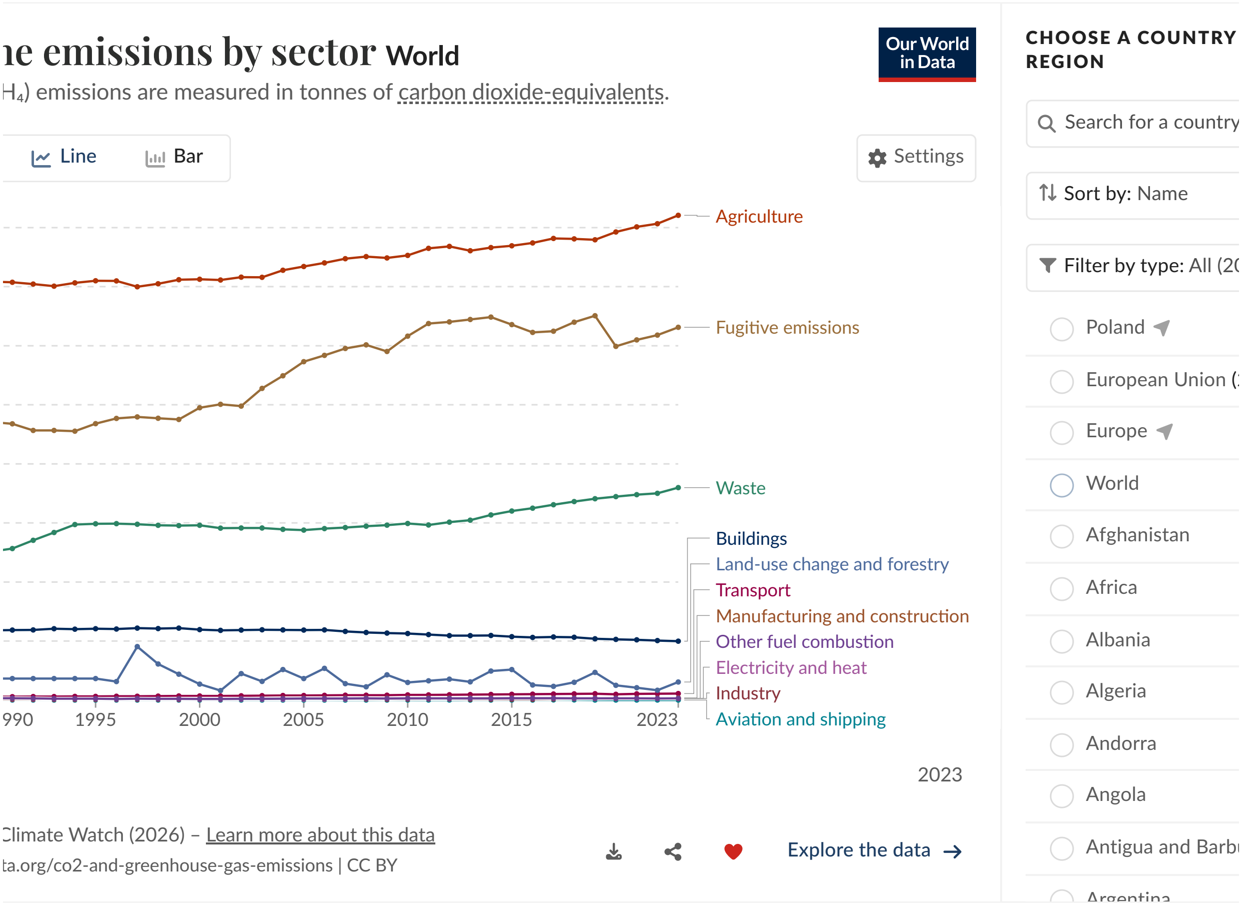
When biomass burning is **complete**, it predominantly produces **carbon dioxide** and **water**. However, **incomplete combustion** results in the formation of other gases and particles, including **methane**, carbon monoxide (CO), and **black carbon**.

Methane gas emissions by source

Urbanisation and the growth of cities have multiplied the sources of **anthropogenic methane**, driven by the increased generation of **solid waste and wastewater** and a higher global demand for **energy and food**.

Methane emissions from the **agriculture and livestock sectors** are of **significant global concern** due to their large share of global emissions and the challenges associated with mitigating them. **Monitoring methane levels** in the air through specialised **sensors** is a vital resource for achieving **climate objectives**, given the **high global warming potential** of methane.

> According to the World Bank, methane accounts for approximately 19% of global greenhouse gas emissions. Of this, rice production contributes 8%, livestock accounts for 32%, and waste represents 18% of all human-caused methane emissions.



Methane emissions in agriculture

According to the **World Bank**, methane emissions from agricultural activities constitute around **41% of anthropogenic methane**, primarily stemming from **rice cultivation** and the **burning of agricultural residues**.

Methane emissions in livestock

Domesticated ruminants, such as **cows and sheep**, produce methane through a digestive process called **enteric fermentation**, which releases methane directly within their intestines and during **manure management**.

Methane emissions in oil and natural gas extraction

Industrial activities related to **fossil fuels** are a significant source of methane emissions into the atmosphere. These emissions occur during the **extraction, processing, storage, transportation, and distribution of natural gas**. In the case of crude oil, methane emissions arise during **production, refining, and storage**.

Methane pollution in the fossil fuel industry primarily stems from **leaks** during these processes. Collectively, these activities are responsible for approximately **25-30% of global anthropogenic methane emissions**. As a result, the **energy sector** is investing in **emission monitoring technologies** and new methods to reduce methane emissions, aiming to mitigate their **environmental impact**.

Methane emissions in landfills

The **storage and management of human-generated waste** is the third-largest global source of methane emissions. Methane production occurs during the **management and treatment of urban wastewater**, as a result of the **anaerobic decomposition of organic waste**.

According to the **Global Methane Initiative**, most developed countries rely on **centralised aerobic treatment systems** that collect and treat wastewater, producing small amounts of methane. However, these systems also generate large quantities of biosolids that could lead to **high levels of methane emissions**.

In contrast, developing countries often lack adequate **wastewater collection and treatment systems**. When such systems are in place, they tend to be **anaerobic**, leading to an **increase in methane emissions** into the atmosphere.

Methane emissions in industry

The industrial sector also contributes to methane emissions, particularly through processes that either use or produce methane as a **by-product**. For instance, the production of **methanol and**

ammonia, among other chemical compounds, can release methane into the environment. Similarly, **coal mining** emits methane as a by-product during mineral extraction.

Emissions from biogas combustion

The burning of **biogas or biomethane** emits both **CO_2** and methane derived from **natural gas reservoirs**. However, unlike fossil-derived methane, biogas is **biological in origin**. Although it shares the same chemical composition as fossil methane, biogas originates from the **controlled decomposition of organic matter**, which is already part of the **natural carbon cycle**.

During the formation of this organic matter, **plants absorb CO_2** from the atmosphere. When these plant remains decompose in **landfills** or **waste treatment plants**, they produce biogas, which can later be used as a fuel. When energy is generated from biogas, the CO_2 previously absorbed by the plants is released back into the atmosphere in the same proportion.

This process can occur continuously without adding additional CO_2 to the atmosphere, provided that **CO_2 emissions** are **monitored and controlled** to ensure a **net-zero balance**. Over time, it is essential to **equate the CO_2 absorption by raw materials** with the **combustion of biogas** and the **release of an equivalent amount of CO_2** to prevent any increase in this potent greenhouse gas.

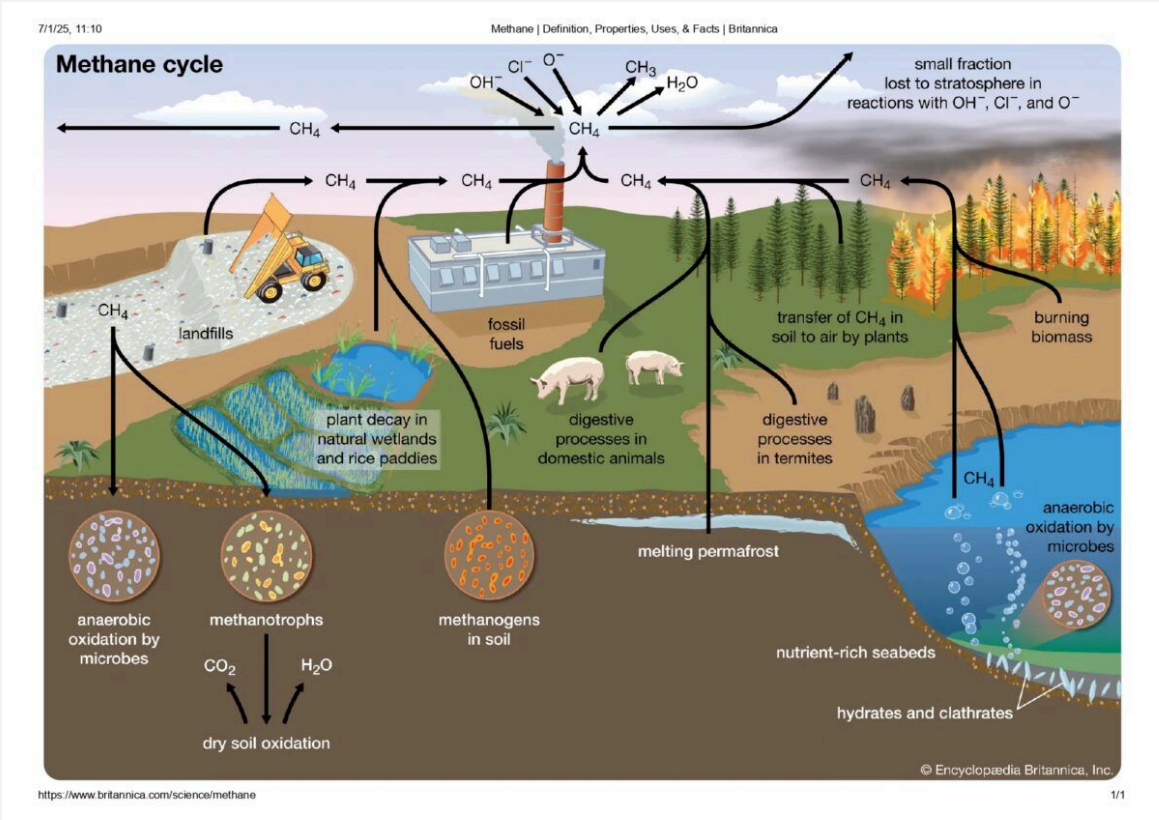
In this balance, consideration must also be given to the **different organic materials** from which the biomass, and subsequently biogas, is derived. Using **waste organic matter**, such as **manure, wood residues**, and **sludge from water treatment plants**, is not the same as cultivating crops like **sugarcane, maize, sorghum, clover, alfalfa, and palm**, which are grown exclusively for biomass production.

If these crops are not grown on **marginal lands**, they may lead to changes in **agricultural land use**, creating a **significant social equity challenge** by displacing food crops. Additionally, the establishment of these crops poses **environmental risks** to ecosystems and biodiversity, which play a crucial role in capturing atmospheric carbon. The demand for larger biomass production areas may result in the **destruction of fertile lands**, leading to the **loss of biodiversity** and essential **ecosystem services** while significantly increasing greenhouse gas emissions.

The combustion of biomethane not only produces **CO_2** but also other atmospheric pollutants, such as **NO_x** (which contributes to **acid rain** and **tropospheric ozone formation**), **PM_{10} and $PM_{2.5}$** (which cause severe **respiratory health problems**), and **carbon monoxide (CO)** in cases of incomplete combustion.

However, while biomethane as a fuel emits these pollutants, the levels are significantly **lower** than those produced by **traditional fossil fuels**.

In contrast, using natural gas as an energy source releases not only these pollutants but also **new CO_2 molecules** into the atmosphere, further contributing to the rise in this **potent greenhouse gas**.



Methane Cycle – Encyclopaedia Britannica

Effects of methane pollution

The **critical role** that **methane** plays in atmospheric pollution stems from its status as one of the most **potent greenhouse gases**. While less abundant than **CO_2**, its ability to trap heat in the atmosphere—**over 25 times more powerful than carbon dioxide over a 100-year period**—makes it a **dangerous driver** of **global warming**.

Methane also contributes to a **devastating environmental impact** by aiding in the formation of **tropospheric ozone** or **smog**, harming both humans and ecosystems.

Addressing the **global challenge** of reducing **methane emissions** requires **urgent monitoring**. Detecting its emissions and reducing its presence is essential to advancing **climate goals** and protecting **human health** and ecosystems.

Effects of methane pollution on the atmosphere

Due to its capacity to **absorb more thermal energy** than **CO_2**, **methane** significantly influences **global warming**. Even though its atmospheric lifespan is relatively short (around **10–12 years**), its impact during this time is **intense**.

Timely detection of methane through **air quality monitoring** is critical. Methane emissions, when interacting with other atmospheric pollutants like **nitrogen oxides (NO_x)** or volatile organic compounds (VOCs), accelerate the formation of **tropospheric ozone**. This harmful ozone at ground level directly affects **human health** and **crop yields**.

Additionally, **methane** disrupts the **chemical balance** of the atmosphere by altering **hydroxyl radicals (OH)**, which are essential for breaking down other atmospheric pollutants.

Effects of methane pollution on humans

While **methane in outdoor air** is not toxic to humans, it plays a **triggering role** in the formation of **tropospheric ozone**, contributing to **public health issues** such as **respiratory** and **cardiovascular diseases**.

By contributing to **global warming**, methane emissions exacerbate **extreme weather events** such as **wildfires**, **heatwaves**, **droughts**, and **torrential rains**, which impact both the environment and **human well-being**.

Short-term health effects of methane

Methane-induced **tropospheric ozone** can irritate the **respiratory system** and cause **eye and nasal congestion**. Breathing in ozone-rich environments increases the risk of developing **asthma**, **bronchitis**, and other **respiratory conditions**. Even those without pre-existing conditions may experience **difficulty breathing** outdoors.

Long-term health effects of methane

Prolonged exposure to environments with high levels of **tropospheric ozone** increases the risk of **chronic respiratory diseases**, such as **emphysema** and **chronic obstructive pulmonary disease (COPD)**.

Research has also linked elevated levels of **atmospheric pollutants**, caused by methane, to increased **heart attacks** and **cardiovascular incidents**.

For children living in **chronically polluted areas**, exposure to **poor air quality** can hinder proper **lung development**, leaving them more vulnerable to **respiratory illnesses** throughout their lives.

Methane’s role in global warming and climate systems

As already mentioned, methane emissions contribute to the **greenhouse effect** by over **25%**. This is due to the **methane’s powerful ability** to enhance the **warming of the atmosphere** by absorbing **infrared radiation**, preventing heat produced at the Earth’s surface from escaping into space. This phenomenon accelerates **polar ice melting**, which in turn releases the **methane trapped in the ice**.

This further accelerates **climate change** and promotes the consequent **sea-level rise**, along with the **human welfare** damages it implies.

The **increase in global temperature**, driven by the **activating effect** of methane emissions, fosters more **intense** and **frequent extreme weather events**. **Droughts** and **torrential rainfall** become more severe and frequent, linked to shifts in **climate patterns**.

In summary, the presence of **methane** in the atmosphere must be addressed **globally** and effectively, and **timely detection** of methane is essential. Methane sensors that monitor the air facilitate precise actions to **reduce** and **prevent** its presence in the atmosphere.

Reducing **global methane emissions**, with a particular focus on the **key sectors** where it is most prevalent, will mitigate the **dangerous climate change-accelerating effect** of the gas. It will also improve **air quality** by preventing the formation of other harmful **atmospheric pollutants**, such as **ground-level ozone**, which jeopardises **human health**, especially for the most vulnerable (children, the elderly, and pregnant women), and deteriorates the **natural conditions** of ecosystems.

Global and regional perspectives on methane pollution

The pollution caused by methane emissions is a **global issue** that requires urgent action due to its **powerful impact** on **climate change**. Methane emissions, both from **natural sources** and **anthropogenic activities**, significantly contribute to the increase of **greenhouse gases**, driving substantial **climate changes** on a planetary level.

Depending on the activities predominant in each region (such as **industrial processes**, **agricultural practices**, **fossil fuel use**, **livestock farming**, and **solid and liquid waste management systems**), **methane emissions** are increasing worldwide.

While countries like the **USA**, where **livestock farming** is one of the main sources of global methane emissions, contribute significantly, regions like the **Middle East** and **Russia** see substantial methane emissions from the significant number of **industries** involved in the **processing**, **storage**, and **transportation of fossil fuels**.

These disparities in methane source origin are key to developing strategic actions that enable **methane sensors** in **air quality monitoring stations** to detect precisely when methane emissions occur or when their levels exceed established thresholds. Only through **international cooperation**, aligning **methane reduction policies**, will it be possible to adequately assess the proportion of methane reaching the atmosphere and implement **global strategies** to meet objectives aimed at **mitigating global warming**.

This is a **priority action** due to the **global environmental alert** it represents, requiring collective efforts from not only the **productive sectors** but also **governments** and **communities**. Technological innovations, such as **advanced methane leak detection sensors** (like those offered by **Kunak**) and technologies for its capture, make initiatives like the **Global Methane Pledge (GMP)** viable. This pledge aims for a **30% reduction** in methane emissions by 2030, which would result in a **0.2°C decrease** in global temperature by 2050.

> According to the Global Methane Assessment by the **Climate and Clean Air Coalition (CCAC)** and the **United Nations Environment Programme (UNEP)** achieving the temperature reduction target would prevent over 200,000 premature deaths, hundreds of thousands of asthma-related emergency visits, and more than 20 million tonnes of crop losses per year by 2030.

The Global Methane Pledge (GMP) was launched during **COP26 in 2021** by the Climate and Clean Air Coalition (CCAC) of the **United States** and the **European Commission**. The GMP now has over **155 countries** signed up, representing **80% of the global economy** and nations capable of controlling approximately **50% of anthropogenic methane emissions** worldwide.

Methane emissions in the United States

The main sources of methane emissions in the United States are the **energy production and distribution**, **agriculture**, and **wastewater and solid waste treatment** sectors.

Methane emissions in India

In India, there is **significant concern regarding methane emissions** due to the country's agricultural-based economy, which is a major contributor of methane, especially from **rice cultivation**. **Livestock farming** also contributes to methane emissions, as India has the largest livestock sector in the world. Additionally, India's **inadequate waste management infrastructure** adds to the global methane balance, given the limited resources available for waste treatment.

India also significantly contributes to global methane levels due to its **mining activity**, being one of the **world's largest coal producers**. Methane is released from the underground coal mines. As a natural gas producer, although India's output is smaller, methane is also emitted during extraction and distribution.

Methane emissions in Europe

Methane emissions in Europe primarily originate from the **agriculture**, **waste management**, and **energy** sectors.

> According to the **European Environment Agency**, 53% of methane emissions in the EU come from agriculture, 26% from waste management, and 19% from energy resources such as the production and distribution of fossil fuels and underground coal mining.

Global trends in methane pollution

Many countries and international organizations are implementing **strict policies** to control and reduce both natural and anthropogenic methane emissions. Monitoring and reducing methane is a strategic goal to mitigate short-term climate change.

The global trend shows **continuous increase in methane emissions**. In 2021, atmospheric methane concentrations reached **record levels**, exceeding 1,900 parts per billion (ppb), a significant rise from pre-industrial levels (~720 ppb).

> According to the **Global Methane Budget**, methane emissions have been steadily increasing since the early 21st century.

Methane emissions 2023

Methane (CH_4) emissions are measured in tonnes of carbon dioxide-equivalents. Emissions from fossil fuels, industry, agriculture, and land-use change are included.

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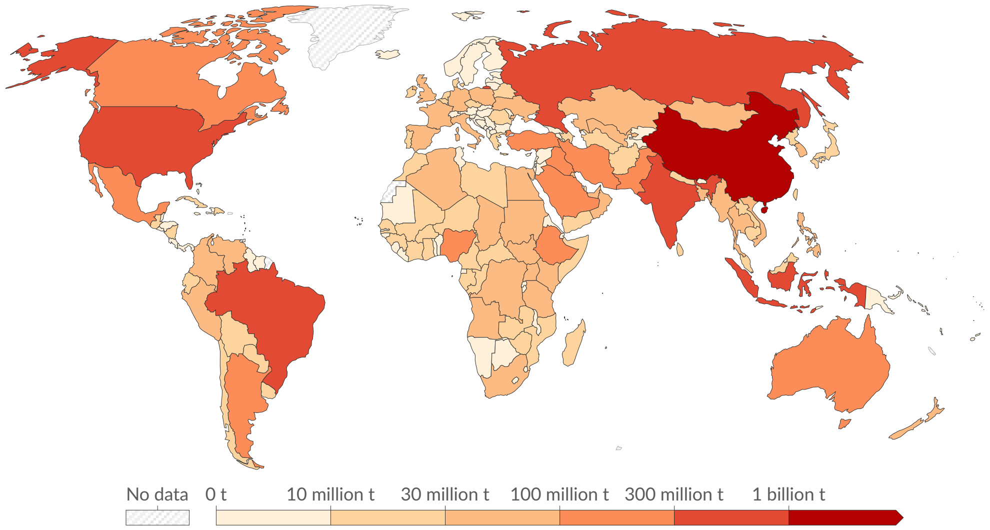


1850 2024

Data source: Jones et al. (2025) – Learn more about this data

Explore the data →

The primary causes driving the alarming increase in methane emissions include the expansion of **intensive agriculture and livestock farming**, driven by the demand for food, increased production of **fossil fuels**, leading to methane leaks. Additionally, **climate pattern changes** that accelerate global warming contribute directly to **permafrost thawing** and intensified methane emissions from wetlands.

Solutions to methane pollution

The difficulty in detecting **methane leaks** and regulating them, because it is challenging to quantify—given that they are generally **fugitive emissions** like those arising from **fossil fuel production**—is the true challenge of **methane pollution**.

However, reducing **methane emissions** is an urgent issue due to the significant role this pollutant plays in **climate change**.

Efforts are focused on improving the efficiency of **agricultural practices**, updating **wastewater** and **solid waste treatment systems**, and implementing stricter **regulatory measures** in the **fossil fuel** industries. Only through a **joint approach**, considering both **natural** and **anthropogenic methane sources**, is it possible to measure and properly regulate methane levels.

> Reducing the proportion of methane in the atmosphere will benefit air quality and contribute to preserving a healthy and sustainable environment.

If the anthropogenic activities generating methane continue as they are today, the increase in methane will not only threaten **climate stability** but also life on Earth. On the other hand, methane's relatively short atmospheric lifetime (a maximum of 12 years) offers an exceptional opportunity to act quickly in **climate change mitigation** through its precise and monitored regulation.

Through a **global approach** and **international commitment**, it will be possible to reduce emissions from essential productive sectors like **agriculture** and **energy production**. Proper management, through monitoring and controlling emissions in **waste treatment systems**, alongside the use of **advanced methane measurement** and **capture technology** in the air, supported by stricter policies, will reduce global methane emissions and ensure a future for life on the planet.

How to reduce methane emissions in agriculture

Reducing methane emissions in agriculture will lead to significant progress in controlling the gas, as this sector accounts for approximately **40% of global anthropogenic methane emissions**, primarily due to **enteric fermentation** in livestock and **manure management**.

Among the most developed measures to reduce these methane emissions is targeting livestock digestion (**enteric fermentation**) through dietary improvements. Feeds are introduced that inhibit methane-producing bacteria (**methanogenic bacteria**). Along with reducing fiber and increasing healthy plant-based fats, these feeds become more digestible, requiring less fermentation in ruminant digestive systems.

Genetic improvements in livestock will contribute to long-term methane reduction, as will **improvements in grazing systems** with rotational practices and the planting of more nutritious foods like certain legumes (**clover** and **alfalfa**).

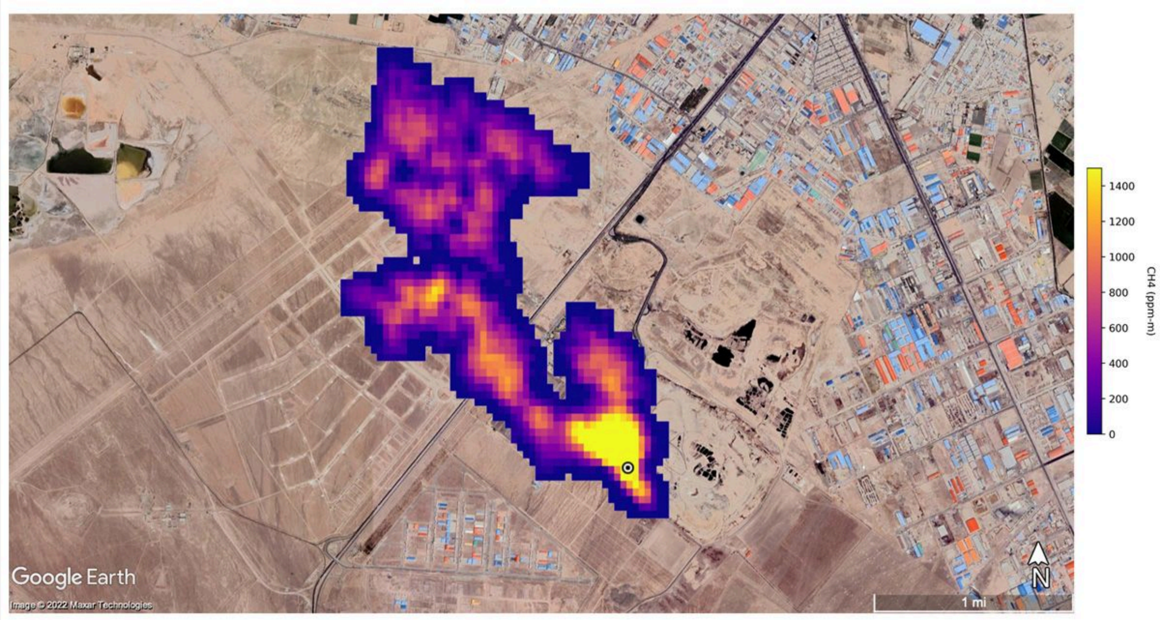
In manure management, apart from **aerobic composting** and **solid separation** which reduce methane emissions, methane is captured using **anaerobic digesters** that convert it into **biogas**, thus preventing the release of 60% of methane into the atmosphere.

Rice cultivation improvements, with reduced methane emissions from flooded fields, include optimizing water management through **intermittent irrigation** and **early drainage**, as well as the inclusion of **genetically improved rice varieties**. Other techniques, such as the application of **methanotrophic microorganisms**, which consume methane present in the soil, also contribute to reducing methane levels in the atmosphere.

Advanced **methane control technology**, such as **air monitoring sensors**, allows both **leaks** and **high methane emission points** to be detected in real-time at agricultural facilities. Data collected from these monitoring systems detects emissions and analyzes their patterns to optimize agricultural practices, reducing their environmental impact.

How to reduce methane emissions in the fossil fuel industry

Reducing methane emissions from the **fossil fuel industry** is a key factor regarding the presence of methane in the atmosphere, as it accounts for **35% of anthropogenic methane emissions**.



A methane plume at least 3 miles (4.8 kilometers) long billows into the atmosphere south of Tehran, Iran. The plume, detected by NASA's Earth Surface Mineral Dust Source Investigation mission, comes from a major landfill, where methane is a byproduct of decomposition.

Credits: NASA/JPL-Caltech

The **oil and gas industry**, in particular, is a major source of methane pollution, as **leaks** and **venting** from wells, pipelines, and storage facilities release large quantities of methane into the air. These emissions not only contribute to **global warming** but also degrade **air quality** by increasing levels of **volatile organic compounds** and **nitrogen oxides**, both precursors to **tropospheric ozone**.

Actions should focus on **oil extraction** and **processing**, as this is where most fugitive methane emissions occur. The **transport of oil and natural gas** via pipelines, compression stations, and storage is another significant source of fugitive emissions.

Advanced monitoring technologies using **methane sensors** at facilities enable the implementation of regular **leak detection and repair programs** to identify and seal fugitive emissions. Their efficiency allows for a **reduction of emissions by up to 90%** at facilities experiencing recurring leaks, along with cost savings from anomaly detection in processes.

Leak Detection and Repair Systems (LDAR) rely on **infrared sensors** to detect methane leaks in real-time. Satellites such as **GHGSat** and **MethaneSAT** are designed to monitor greenhouse gas emissions, including methane, from space. These advanced tools are revolutionising the way methane emissions are detected, identified, and managed, thus contributing to **climate change** mitigation.

Among the **emerging technologies** is the **modernisation** of **oil refinery flares** and **flaring** (efficient burners) through the combustion of non-recoverable methane, converting it into carbon dioxide and thereby reducing the impact of methane on **climate change**.

Regarding **methane recovery**, technologies are focused on the **capture** and **reuse** of methane, alongside carbon dioxide, in **industrial facilities**. The implementation of these technological improvements and best practices available for the optimisation of the **fossil fuel industry**, supported by **strict regulations**, could reduce methane emissions by up to **80%**. This improvement will primarily affect **energy efficiency**, with **low carbon emissions**, and its value chain; globally contributing to the **mitigation of climate change**.

How to improve waste management techniques to reduce methane emissions

Waste management is a significant source of methane emissions due to the **anaerobic decomposition** of organic materials that occurs in landfills and the **improper management** of wastewater. Reducing these emissions requires the adoption of advanced practices that promote the **capture**, **reuse**, and **minimisation** of organic waste.

Separation and recycling is key to reducing the presence of organic waste in landfills. This waste is treated through **composting** and **biodigestion** processes instead of being sent to landfills. Furthermore, this processing enhances the **value chain** as it is used to produce **fertilisers**, **animal feed**, or converted into **reusable materials**.

Landfills already capture and utilise **biogas** generated by waste, which is then used as a **renewable energy source**, whether for generating **electricity**, **heat**, or **fuel**. Inactive landfills must be properly sealed to limit **anaerobic conditions** and methane leaks.

As **wastewater treatment plants** and **septic tanks** generate significant amounts of methane, it is essential to **modernise** these facilities and use **biodigesters** that capture methane, converting it into **biogas**.

Landfill sealing with advanced membranes – Photo credit Genap – Kunak

In all these **waste facilities**, **methane gas sensors** are essential. This **advanced technology** detects and measures this pollutant in real time to improve waste management, as demonstrated by the Cerro Patacón landfill near **Panama City**, thanks to **Kunak technology**. The data provided by the sensors allows for the analysis of emissions and the optimisation of control operations by capturing and managing them according to the amount and origin of the landfill waste.

Improvements in waste treatment practices can reduce methane emissions by **70%**. Additionally, it **produces renewable energy** through **biogas generation**, improves **air quality**, reduces **bad odours**, and promotes the **circular economy**.

What are the innovations in methane capture and utilisation

The **capture** and **utilisation** of methane have notably advanced, supported by **technological**, **scientific**, and **operational innovations**. With these advancements, not only can methane emissions to the atmosphere be reduced, but this gas can also be turned into a valuable source of energy. These solutions are being applied to sectors such as **oil**, **gas**, **agriculture**, **landfills**, and **wastewater treatment**.

The key step involves developing **efficient technologies** that are adaptable to each productive sector to prevent this potent **greenhouse gas** from reaching the atmosphere. This ranges from the **detection of methane** at the source of production, using **methane sensors** that detect **fugitive emissions** from industrial plants, pipelines, and landfills, to **satellite systems** that monitor methane from space, identifying emission sources precisely.

Modern **capture technology** is based on **innovative materials** that can collect methane on-site through **collection pipes** installed in landfills. These technologies are also employed in the **sealing of coal mines** for systems that capture the methane released inside.

Innovations in the **utilisation** of methane focus on converting it into useful products or **renewable energy**, while also generating **economic value**.

Methane conversion through technology can be used to produce **blue hydrogen**, which simultaneously captures **carbon dioxide emissions** in the process.

Methane can also be converted into **chemicals** such as **methanol**, which is used in the production of **plastics** and **biofuels**. The most modern technologies have made it possible to transform methane into **ammonia**, leading to a compound essential for **fertilisers**. The **biological conversion** of methane, through **methanotrophic microorganisms** that ingest methane as a source of carbon and energy, results in **biomass** rich in **proteins**, **bioplastics**, and other **sustainable products**.

Methane emission regulations

Reducing **methane emissions**, one of the most significant **greenhouse gases**, benefits the **climate** but also life on the planet, as it will improve **air quality**. Additionally, it contributes to the achievement of international **climate goals** set out in the **Global Methane Pledge**.

Methane regulations in Europe

The **European Union** has adopted an **ambitious approach** to regulate and reduce **methane emissions**, establishing specific measures within the framework of the **European Green Deal** and other international commitments, such as the **Global Methane Pledge**, which aims to reduce emissions by **30% by 2030**. These measures not only serve to improve the climate and optimise **air quality** but also contribute to boosting the **EU's energy sovereignty**.

The **European Union** has implemented a comprehensive strategy to reduce **methane emissions**, which includes measures to improve the efficiency of **natural gas operations**. This is achieved through the **detection and repair of methane leaks (LDAR)**, banning **unplanned flaring and venting**, and capturing and reusing methane released from **coal mining**.

In **agriculture**, sustainable agricultural practices are promoted through the **Common Agricultural Policy (CAP)**. One of the key points to reduce methane emissions is the management of **manure**, which can be converted into **biogas** using **biodigesters**. Additionally, livestock **feeding practices** are being improved to reduce **enteric fermentation** in ruminants.

Strict **regulatory measures**, increasingly widespread in **Member States**, have been established for **landfills**, encouraging biodegradable organic waste to be kept out of landfills. If this is not possible, landfill operators are required to **capture the methane emitted** and **reuse** it.

Improving **methane gas measurement systems** through **advanced sensor technology** and accurately monitoring emissions in key sectors such as **energy**, **agriculture**, and **waste management** will enable Member States to provide more precise data on emissions from diffuse sources, such as **agriculture** and **methane leaks**. Once analysed, this data will allow for effective actions through the development of **best practices**, such as **capture and reuse**, to minimise global methane emissions.

Methane regulations in the United States

The **Environmental Protection Agency (EPA)** is responsible for regulating methane emissions in the United States through the **Clean Air Act**.

Its regulations have been updated to include rules that involve the use of the most **advanced technologies**, such as **precise and continuous monitoring** to provide accurate **methane gas measurements**. Special emphasis has been placed on measuring methane sources in **energy industries**, particularly **oil** and **gas**, with continuous monitoring of facilities and the reduction of

venting and flaring of methane gas. In addition, federal measures implemented by each state enhance efforts, such as those developed in **Colorado** to control methane leaks in the gas industry.

In the **agricultural sector**, regulation falls under the **U.S. Department of Agriculture (USDA)**, which is implementing the inclusion of **additives** to reduce **enteric fermentation** in livestock digestion and the capture of methane during **manure management** using **biodigesters**.
The control of **landfills** is regulated by the **EPA** and the **Clean Air Act**. As a result, some **waste treatment plants** are already implementing methane capture and conversion into **biogas**.
The United States, through the **EPA**, actively participates in the **Global Methane Initiative**, an international coalition aimed at reducing methane emissions through cooperation and **technology exchange**. Similarly, through laws such as the **Inflation Reduction Act**, the U.S. is making investments accompanied by **economic incentives** to reduce methane emissions in key sectors and capture the methane produced.

Methane regulations in India

To regulate and mitigate methane emissions to the atmosphere, the Indian government follows the **Clean Development Mechanism (CDM)** framework established under the **Kyoto Protocol**. This includes sustainable agricultural practices such as **Alternate Wetting and Drying (AWD)** rice planting, which reduces the flooding duration of fields and minimizes methane emissions. Additionally, **voluntary programmes** are in place that promote the use of **biodigesters** to capture methane from **manure** and convert it into **biogas**. There are also ongoing initiatives to modify livestock **diets** with supplements that reduce **enteric fermentation** in ruminant digestion.

Regulatory advances in **landfills** for waste management, though limited in India, have resulted in several cities implementing **waste treatment plants** with methane capture systems from the **anaerobic decomposition** of waste, and developing **biogas production** projects.

Within India's **energy sector**, **coal** and **natural gas production**, as well as its transportation, are the main concerns regarding methane emissions. As such, projects are being developed, driven by the **Global Methane Initiative**, to capture methane from **underground mines** and use it as fuel. Similarly, existing infrastructure is being expanded and monitored to detect and reduce **methane leaks** in **natural gas networks**.

India is one of the countries that has joined the **Global Methane Pledge**, committing to reduce methane emissions by **30% by 2030** compared to 2020 levels.
Nationally, India is developing the **National Biogas and Manure Management Program (NBMMP)**, which promotes the use of **biodigesters** to convert agricultural waste and manure into **biogas**.

Kunak Solutions for Methane Pollution

Kunak's advanced solutions for environmental monitoring also include the **precise and real-time detection** of methane emissions.

Methane monitoring with precision using Kunak technology

Kunak's technology enables the detection of methane emissions with **high precision** through **high-sensitivity sensors**. These sensors are capable of identifying and measuring **low concentrations of methane**, ensuring the detection of methane emissions even at **minimal and specific levels**.

The **advanced calibration** of Kunak devices ensures they maintain their **accuracy** under a wide range of environmental conditions, without compromising the **reliable and real-time data** that guarantees effective environmental monitoring.

The data collected, integrated with the analysis software, is analyzed on the **web platform**, allowing for **detailed visualization**, study, and analysis of the emissions produced, thereby facilitating **informed decision-making**.

A Kunak AIR Pro air quality station installed at a landfill site in Portugal to monitor methane emissions and other pollutant gases.

Methane emission monitoring with Kunak AIR Pro

Kunak has developed air quality monitoring stations, such as the **Kunak AIR Pro**, which enable **precise measurement** of various pollutants, including **methane**.

Through the use of **smart cartridges** that integrate specific sensors for measuring methane emissions, **accurate and reliable** measurements of **CH_4 levels** are obtained, even under **varied environmental conditions** and in **real-time**.

The cartridges are equipped with **patented GasPlug technology**, which ensures precision in gas detection, allowing for a **fast and reliable response** to changes in methane concentrations.

Global success stories of Kunak Solutions

Entre las soluciones que Kunak ha implementado en proyectos internacionales para la detección de gas metano emitido a la atmósfera destacan:

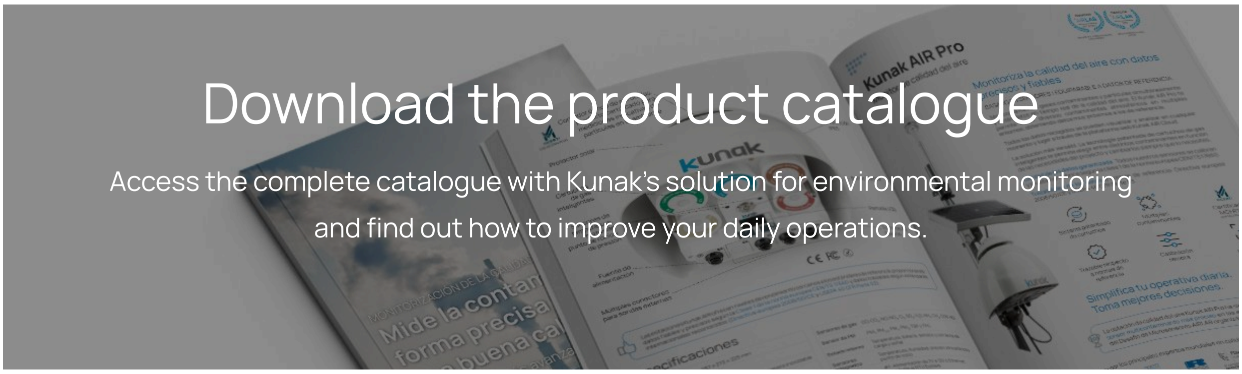
Among the solutions Kunak has implemented in international projects for detecting methane gas emissions to the atmosphere, the following stand out:

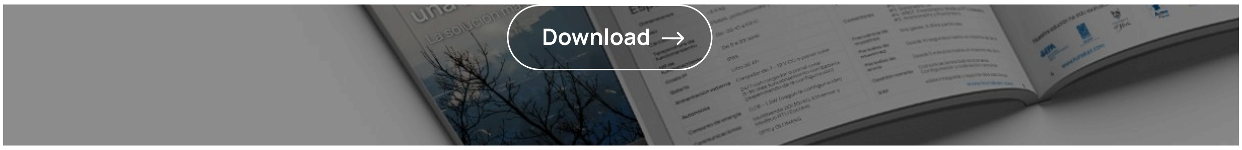
- **Control air quality at Idaho's largest landfill, Ada County (USA)**: **Advanced real-time environmental monitoring strategy** implemented with Envirosuite to manage **emissions** more efficiently and address the challenges of urban sprawl. Using innovative systems, such as state-of-the-art Kunak AIR Pro sensors and digital platforms, **air quality** is constantly monitored and **mitigation strategies** are put in place to protect both the environment and neighbouring communities.

  In addition to ensuring **regulatory compliance**, this initiative has improved **stakeholder relations**, fostering **environmental resilience** and long-term sustainable management. This model not only ensures a cleaner and more efficient operation, but also aligns with the challenges of **urban sprawl** and sustainable growth in the county.

- **Valdemingómez landfill, Madrid (Spain)**: A large waste treatment facility located in the southeast of Madrid. As landfills are **a major source of methane emissions**, among other gases, a network of Kunak AIR Pro sensors has been deployed to measure emissions of hydrogen sulphide (H_2S), methane (CH_4), volatile organic compounds (VOCs) and ammonia (NH_3) and alert to **potential leaks**, **optimising the environmental monitoring** of the complex.

- **Air Quality Control at Cerro Patacón Landfill (Panama)**: The **Cerro Patacón landfill** in Panama City handles a large volume of waste, coupled with poor management practices such as **intentional fires** to reduce waste volume. These practices lead to significant environmental pollution by releasing toxic gases like methane and **particulate matter**, which affect both the natural environment and the health of surrounding communities. There are **six communities** located at the base of Cerro Patacón, home to approximately **6,475 people**, whose health was constantly at risk. They are now better protected thanks to the **continuous and real-time monitoring** provided by the Kunak AIR Lite station network, which detects and prevents **pollution episodes** and **odour issues**.





Frequently Asked Questions (FAQs)

What is methane and how does it affect air quality?

Methane is a **gas** present in the atmosphere due to **natural**, **biological**, and **geological processes**, but it is primarily generated by **human activity**. While it is a valuable and useful resource as an **energy source**, it also presents an **environmental challenge**. Although methane is much less abundant in the atmosphere than **CO_2**, it absorbs **infrared radiation** from the Earth's surface much more efficiently, making it a potent **greenhouse gas**, second only to **CO_2**. This leads to a harmful effect on the atmosphere and living beings, being responsible for more than **25% of global warming**.

What is the main source of methane pollution?

The emissions from **human activities** are the major contributors to the increasing methane levels in the atmosphere. These primarily come from **intensive agriculture and livestock farming**, increased **production** and **distribution** of **fossil fuels**, as well as the extraction, transportation, and storage of **natural gas** and **coal mining**.

Among these, the **oil and gas industry** is the most problematic in methane emissions due to **leaks** in extraction, pipelines, and storage facilities, which, along with **flaring** and **venting** through chimneys, release significant amounts of methane into the atmosphere. These emissions not only cause **atmospheric disturbances** that contribute to **climate change** but also increase the levels of **volatile organic compounds (VOCs)** and **nitrogen oxides** in the air, both of which are **precursors to tropospheric ozone**.

What happens if you breathe in a lot of methane?

Inhalation of methane gas can cause **headaches**, **nausea**, **vomiting**, **eye irritation**, and **respiratory tract irritation**, leading to **coughing** and **wheezing**. In **enclosed spaces**, its presence is dangerous because it is **colourless** and **odourless**, and in high concentrations, it displaces oxygen, leading to **difficulty breathing**, **confusion** due to its effects on the **central nervous system**, **chest pain**, and **fatigue**; it can even cause **suffocation** and death.

How does methane affect health?

Methane indirectly impacts **public health** by promoting the formation of **tropospheric ozone**. Breathing in environments with high ozone levels exacerbates **respiratory diseases** such as

asthma and **bronchitis**. It can also accelerate the development of pre-existing respiratory conditions and make it difficult for anyone outdoors to breathe easily.

Prolonged exposure to high ozone levels increases the incidence and risk of **chronic lung diseases** like **emphysema** and **chronic obstructive pulmonary disease (COPD)**, as well as a higher frequency of **cardiovascular accidents** such as **heart attacks**. Methane also affects the development of children living in high ozone areas, as it impairs **proper lung development**, making them more vulnerable to respiratory diseases.

How does methane contribute to climate change?

Due to its ability to absorb **infrared radiation** from the Earth's surface, methane acts as a powerful **greenhouse gas**. It has a **global warming potential (GWP)** approximately **86 times** stronger than **CO_2** over a **20-year period** and **28 times** more powerful over **100 years**. As a result, it has a harmful impact on the atmosphere and living beings, being responsible for over **25% of global warming**.

What are the primary sources of methane emissions in the United States?

Livestock farming is the leading source of methane emissions in the United States, followed by **energy production** and **distribution**, **agriculture**, and the treatment of **solid waste** and **wastewater**.

What technologies exist to detect and monitor methane emissions?

Advanced air quality control technology includes specific **methane sensors** that allow precise monitoring in diverse locations and environmental conditions. Additionally, drones and satellites, such as **MethaneSAT**, detect and map the most concerning areas where **invisible** and **dangerous methane emissions** occur.

How is methane concentration in the air measured?

Non-dispersive infrared methane sensors detect **CH_4 leaks** in industrial processes, while **MEMS-based methane sensors** detect and measure **fugitive methane emissions** at very low concentrations. These technologies enable the detection and measurement of methane even at its **minimum levels** (from 60 ppm) or during **fugitive emissions**. They provide **timely detection** and accurate measurement data, thanks to the **automatic correction algorithm** that ensures stability over time. The data obtained is analysed on a **cloud platform**, allowing for **quick and effective action** to stop methane emissions into the air.

What methane emission regulations exist in the United States?

The **Environmental Protection Agency (EPA)** regulates methane emissions in the U.S. under the **Clean Air Act**.

Its regulations include advanced technologies for **precise and continuous air monitoring** to provide correct methane gas measurements. Emphasis has been placed on monitoring methane sources in **oil and gas industries**, such as continuous monitoring of **facilities** and the reduction of **venting** and **flaring**.

In the agricultural sector, regulation depends on the **U.S. Department of Agriculture (USDA)**, which implements additives to reduce **enteric fermentation** in livestock digestion and captures methane during **manure management** through the use of **biogas digesters**.

Landfills, under the Clean Air Act, capture methane and convert it into **biogas**.

How can industries effectively reduce methane emissions?

The capture and use of methane have significantly advanced through technological, scientific, and operational innovations. These not only reduce methane emissions into the atmosphere but also convert this gas into a valuable **energy source**.

Oil and gas industries can effectively reduce methane emissions by repairing leaks in **pipelines** and avoiding **flaring** in **oil wells**. In **underground coal mines**, carbon emissions can be captured and converted into **renewable energy**, such as **biogas**.

Modern **methane capture technology** relies on innovative materials to collect methane on-site using collection pipes installed in **coal mines** and **landfills**.

Methane can be converted into **blue hydrogen**, which simultaneously captures **CO_2 emissions** during the process.

It can also be converted into **chemicals** like **methanol**, used in the manufacture of **plastics** and **biofuels**. The latest technologies enable the conversion of methane into **ammonia**, a key component in **fertilizers**. **Biological methane conversion**, through **methanotrophic microorganisms** that consume methane as a **carbon and energy source**, results in **protein-rich biomass**, **bioplastics**, and other **sustainable products**.

What role does methane play in the formation of tropospheric ozone?

Methane emissions not only contribute to climate change but, when combined with other atmospheric pollutants, such as **nitrogen oxides** and **VOCs**, they favour the formation of

tropospheric ozone. This harmful ozone, which remains at ground level, directly affects human health by causing **respiratory issues**.

How does methane affect ecosystems and biodiversity?

In addition to its contribution to **global warming**, methane also affects **air quality** and poses a significant challenge to **global climate stability**. The rise in **earth temperatures**, to which methane contributes, leads to major environmental catastrophes, such as the **disappearance of glaciers** and polar **ice caps**, rising **sea levels**, and extreme climate events like **heatwaves**, **floods**, and **droughts**.

Methane also degrades **ecosystems** and leads to the **loss of biodiversity**. By disrupting **water resources** and their availability in ecosystems, it is already causing critical problems for wildlife species, such as **amphibians** and the **polar bear**, which depend on water and ice for their survival.

How can we reduce methane emissions?

To reduce **greenhouse gas emissions**, the application of new technologies is a major ally, especially in **agriculture** and **livestock production**. Improving **livestock feed** with more **nutritious** crops that promote better digestion, as well as enhancing human diets with more **vegetables** and alternative **protein sources**, and improving **rice cultivation**, are key steps towards reducing methane emissions and limiting global warming to **1.5°C**.

Is methane more harmful to the environment than carbon dioxide?

The ability of methane to trap more **heat** in the atmosphere than **CO_2** makes it a more damaging pollutant, with its effect being **80 times** stronger than that of **CO_2**, and this effect lasts for **20 years**.

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Written by the **Marketing & Communication Team**

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