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What are greenhouse gas emissions?

The release of certain gases into the Earthâ€™s atmosphere can create a â€œgreenhouse effectâ€, in which heat becomes trapped and global temperatures rise. While emissions can result from natural causes, they are primarily the result of human activities, especially the burning of fossil fuels for energy and transportation.

What are greenhouse gases?

As sun rays hit Earth, they generate heatâ€”consider the temperature difference on a sunny day versus a cloudy one. However, when greenhouse gases (GHGs) are released into the Earthâ€™s atmosphere, they can create a layer of insulation that prevents that heat from escaping back into space. Similar to how a greenhouse fosters a warmer environment for the plants that it houses, these greenhouse gases trap heat within our atmosphere.Â

This greenhouse effect is essential; without it, the planet would become too cold to sustain life.Â But since the Industrial Revolution, human activities have significantly increased the amount of greenhouse gas emissions in our atmosphere.Â As they remain for years or even centuries, they amplify theÂ greenhouse effect and cause global temperatures to rise, making greenhouse gas emissions a leading cause of global climate change.

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What are the main types of greenhouse gases?

Experts consider carbon dioxide (CO_2) the primary driver of the greenhouse effect, but it isnâ€™t the only contributor. The impacts of other greenhouse gases, including methane (CH_4),Â nitrous oxide (N_2O) and fluorinated gases such as chlorofluorocarbons, are measured in terms of carbon dioxide equivalents (CO_2e). CO_2e measurements help to show the overall impact of all greenhouse gases, not just CO_2.Â

The impact of each type of greenhouse gas is collectively measured in terms of its global warming potential (GWP). This metric compares the heat-trapping ability of a gas to that ofÂ CO_2 over a particular periodâ€”for instance, over 20, 100 or 500 years. For example, the 100-year GWP of CH_4Â is approximately 28â€“36 times that of CO_2.

Carbon dioxide

The most abundant of the GHGs,Â CO_2 emissions represent three-quarters of all human-caused GHG emissions. The primary source of CO_2 emissions is the burning of fossil fuels such as coal, oil and natural gas for energy and transportation. CO_2 is also released through deforestation and other land-use changes. Before the Industrial Revolution, the global CO_2 concentration was about 280 parts per million (ppm)â€”in May 2023, according to the National Oceanic and Atmospheric Administration Global Monitoring Lab, it reached a record level of 424 ppm.[1]

Methane

CH_4, a key component of natural gas, is less abundant than CO_2Â but more than 25 times as effective at trapping heat in the atmosphere. This is largely the result of agricultural practices and livestock emissions (a cow emits 220 pounds of CH_4Â each year[2]). But animals arenâ€™t the only source: CH_4Â emissions also occur as organic waste decays in landfills, and through rice harvesting practices, wetland habitats and the production and transport of fossil fuels.

Nitrous oxide

N_2O originates from agricultural activities, industrial processes and the combustion of fossil fuels. It is less prevalent than CO_2 and CH_4Â but remains a potent contributor to global warming. Agricultural practices, particularly the use of synthetic fertilizers, are the leading source ofÂ N_2O emissions.

Fluorinated gases

Synthetic, human-made gasesâ€”including hydrofluorocarbons, perfluorocarbons, chlorofluorocarbons, sulfur hexafluorideÂ and nitrogen trifluorideâ€”are used in processes like refrigeration, air conditioning and electronics manufacturing. Though less common than CO_2, CH_4Â and N_2O, fluorinated gases are among the most effective at trapping heat and can potentially persist in the atmosphere for thousands of years.

Where do greenhouse gas emissions come from?

Total greenhouse gas emissions come from several sources. Some result from natural processes; for example, volcanic eruptions and wildfires releaseÂ CO_2 and other gases into the atmosphere, while the decomposition of plants and animals releases CH_4. But most global greenhouse gas emissions come from anthropogenic sourcesâ€”meaning they result from human activity, such as:

Burning fossil fuels

Three-quarters of human-made GHG emissions result from the combustion of fossil fuels, including coal, oil and natural gas. As they are burned to generate energy or to fuel transportation, they release large amounts ofÂ CO_2 into the atmosphere. For example, cars and other vehicles powered by gasoline and diesel emit CO_2 as those fuels are combusted in the engine. Airplanes are major contributors: the burning of jet fuel emitsÂ CO_2 and other GHGs at high altitudes, where they have a stronger impact on the atmosphere. Many power plants use coal, oil or natural gas to produce electricity, as do heating and cooling systems for homes and buildings.

Agriculture

Livestock, especially cows, produce CH_4Â during digestion, which is then released into the atmosphere. When large herds are raised for meat production, the collectiveÂ CH_4 emissions can be substantial. Rice paddies also emitÂ CH_4 during cultivation. As rice fields are flooded, they create the anaerobic conditions for bacteria to feed on decomposing natural materialsâ€”and releaseÂ CH_4 in the process.

Deforestation

Forests are important carbon sinks, meaning they pullÂ CO_2 out of the atmosphere. When forests are cut down or burned, the trees again release the carbon they stored. Demand for agricultural products often drive deforestation, which leads to the clearing of land for cash crops and livestock ranching.

Industrial processes

Certain manufacturing processes release GHGs. As raw materials are heated to high temperatures, they can generate CO_2; for example, CO_2 is a byproduct of the chemical reactions that turn limestone into clinker when producing cement. In the chemical manufacturing industry, the production of synthetic chemicals, plastics and other products can result in CH_4,Â N_2O and CO_2.

Why are greenhouse gas emissions a problem?

Greenhouse gases are necessary to maintain a livable temperature on Earth. But as greenhouse gas concentrations grow, they trap more heat in the atmosphere and the consequences for the global climate and environment become more severe. These consequences include:

Global warming

GHG emissions are a primary contributor to global warming. They increase the greenhouse effect, leading to rising global temperatures. Recent years have been among the hottest on record.Â According to the United Nations' Intergovernmental Panel on Climate Change assessment report, each of the last four decades has been successively warmerÂ than any decade that preceded it since 1850.[3] This increased heat can result in more frequent and severe weather events like hurricanes, floods, heatwaves and droughts.

Rising sea levels

Warmer temperatures help accelerate the melting of polar ice and glaciers. This contributes to rising sea levels, posing a significant threat to coastal communities and low-lying regions.

Ocean acidification

MoreÂ CO_2 in the atmosphere leads to higher levels of CO_2 in the world's oceans. This causes ocean acidification, which can harm marine life, including coral reefs and shellfish.

Disrupted ecosystems

Climate change can result in a loss of biodiversity as species struggle to adapt to changes or face extinction. Rising temperatures can affect the migration patterns of birds or lead to an influx of invasive species. These changes can wreak havoc on the complex food chains that power an ecosystem, impacting every level.

Poor air quality

Some GHGs contribute to poor air quality, which can lead to respiratory problems and other health issues in humans. Climate change-driven weather conditions, such as droughts and wildfires, can lead to an increase in ground-level ozone, dust, smoke and other pollutants. It can also lead to a spread or increase in the level of allergens in the air.

Economic impact

The disruption to the environment can hurt a wide range of industries and businesses as it impacts supply chains and access to resources. Climate change can have a devastating impact on the agricultural sector, as extreme weather, changes in temperature and water access, and poor air quality disrupt the growth and harvesting of crops. Tourism and

other industries that depend on the weather are at risk; for example, ski resorts might close as warming temperatures reduce snow levels.

What helps reduce greenhouse gas emissions?

Because of their immense contribution to global warming, reducing greenhouse gas emissions is key to mitigating climate change. To achieve this, individuals, corporations and government institutions are uniting in their efforts to lower emissions, aiming for the ultimate goal of net zeroâ€”the point at which the amount of greenhouse gases emitted equals the amount removed from the atmosphere, effectively bringing human-caused emissions as close to zero as possible.

Strategies that might help reduce greenhouse gas emissions include:

Renewable energy

One of the most effective ways to reduce CO_2 emissions is to transition from fossil fuels to renewable energy sources such as solar, wind and hydropower. This shift to renewable sources reduces reliance on emissions-heavy fossil fuel combustion and therefore lowers emissions from electricity generation and transportation.

Energy efficiency

Enhancing energy efficiency in homes, buildings and industrial spaces reduces energy consumption and, as a result, GHG emissions. This change in energy use can be achieved through building insulation, energy-efficient appliances and sustainable design practices. At a corporate and industrial level, new technologies that allow for better energy management can help companies reduce their carbon footprint.

Sustainable transportation

Reducing emissions from the transportation sector involves switching to electric vehicles, increasing public transportation and encouraging carpooling, cycling and walking.

Sustainable agriculture and forestry

Implementing sustainable practices, such as reduced fertilizer use and responsible land management, can decreaseÂ N_2O emissions and promote soil health. Restoring and planting trees can help drawÂ CO_2 from the atmosphere.

Emerging technologies

Digitalization, artificial intelligence (AI), advanced data capture and analysis and other technological innovations can contribute to reduction efforts. For example, the use of drones and sensors can help make agricultural and industrial processes more precise, thus ensuring the most efficient use of resources. Or AI-powered sorting systems can separate recyclable materials more accurately than manual sorting, aiding waste management practices.

Individual action

On a smaller scale, individuals are taking steps to reduce their personal carbon footprints. These include recycling, switching to sustainable power sources and modes of transportation, and dietary and other lifestyle changes. People can use tools like the US Environmental Protection Agency Household Carbon Footprint calculator[4] or the United Nations Framework Convention on Climate Change Lifestyle calculator[5] to gauge their impact.

How are governments and policymakers reducing GHG emissions?

Countries worldwide are acting in accordance with the Paris Agreement, a landmark international treaty negotiated at the 2015 United Nations Climate Change Conference to limit the impact of greenhouse gas emissions.[6] Efforts include government support for renewable energy through subsidies and other incentives, fuel efficiency standards for vehicles and industrial operations, and investment in public transportation. Governments are also establishing environmental regulations and standards to limit emissions. Through carbon pricing, governments can impose carbon taxes or establish cap-and-trade systems to encourage businesses and individuals to reduce their emissions.

How are corporations and businesses reducing GHG emissions?

To achieve net zero greenhouse gas emissions, businesses are measuring their carbon emissions and identifying opportunities for mitigation of their greenhouse gas emissions.Â Corporations are targeting their Scope 1 emissions, which are produced by their own sources, and Scope 2 emissions, which are generated by power and other resources they use. They are also addressing Scope 3 emissions, also known as supply chain emissions, which result from indirect sources such as transportation, supply chain, and product use and disposal.Â Some of their options for emissions reduction through decarbonization include:

Carbon accounting

Tracking emissions through carbon accounting allows businesses to demonstrate transparency and a commitment to environmental responsibility as they set targets and measure progress.

Carbon capture and storage (CCS)

CCS technology capturesÂ CO_2 emissions from power plants and industrial processes, then stores them underground,

preventing them from entering the atmosphere.

Reducing consumption and switching to renewable energy

Reducing energy waste and increasing energy efficiency can result in improved energy use. Shifting to renewable energy sources contributes to decarbonization efforts and can also lower operational costs. Environmental, social and governance software can help companies identify opportunities for efficiency or waste reduction and measure and manage their emissions.

Supply chain management

To help reduce Scope 3 emissions, many companies are working with suppliers to reduce the overall carbon footprint of products and materials.

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Footnotes

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[1]Â Broken record: Atmospheric carbon dioxide levels jump again, National Oceanic and Atmospheric Administration, June 2023.

[2]Â Cows and climate change, University of California, Davis, June 2019.

[3]Â Climate Change 2021: The physical science basis, Intergovernmental Panel on Climate Change (IPCC), August 2021.

[4]Â Household Carbon Footprint Calculator, Environmental Protection Agency (EPA.gov), June 2023.

[5]Â Lifestyle Calculator, United Nations Framework Convention on Climate Change, September 2021.

[6]Â The Paris Agreement, United Nations, undated.