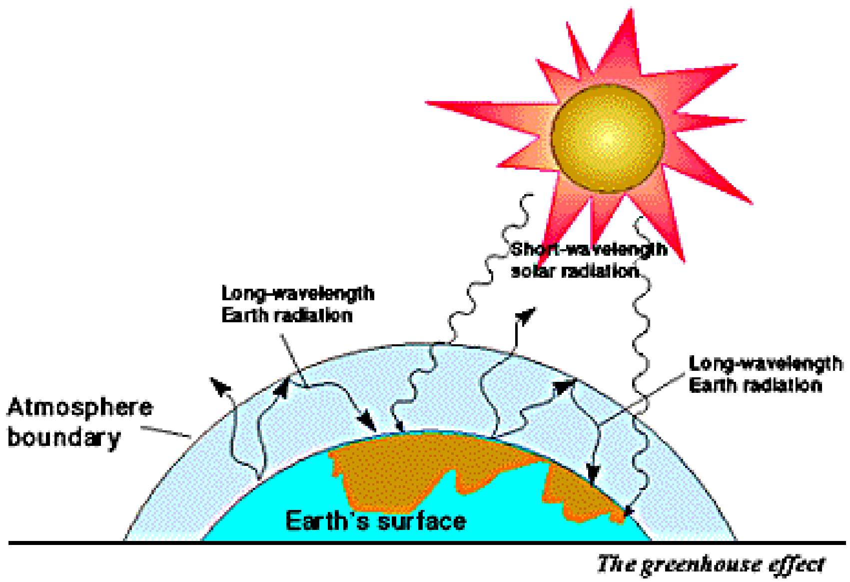
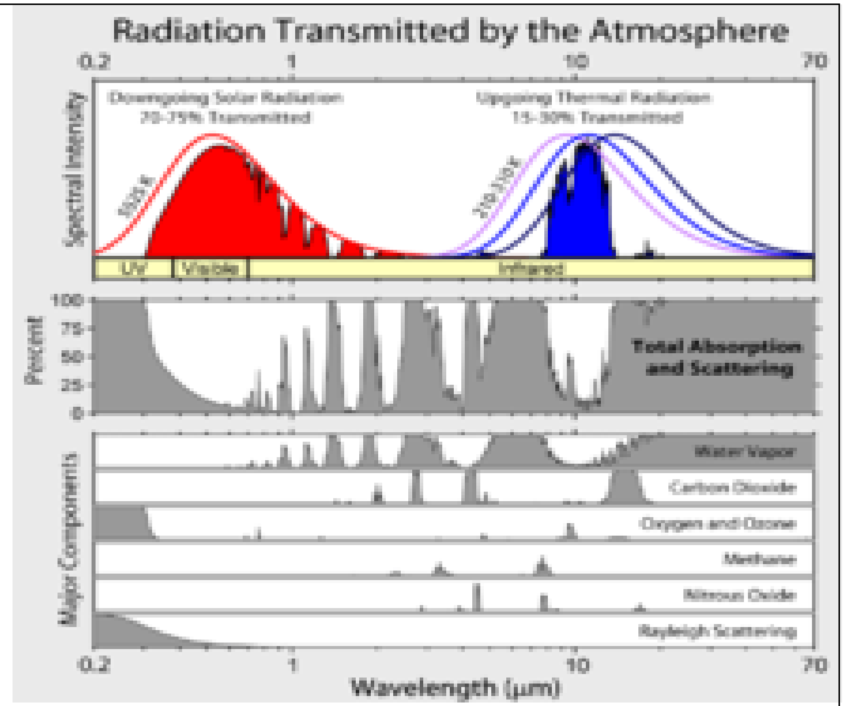
Greenhouse Effect

The Greenhouse Effect

Greenhouse gases let short-wavelength radiation come into the Earth's atmosphere from the sun. However, they absorb and re-radiate Earth's long-wavelength radiation back towards to Earth's surface keeping the temperature on Earth warm enough to inhabit.



The Earth's atmosphere is largely transparent to visible wavelengths. Sunlight which warms the Earth's surface in the daytime is reradiated at night at longer infrared wavelengths.



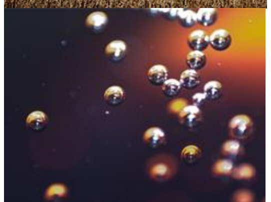
Greenhouse gases in the Earth's atmosphere absorb and scatter radiation at differing wavelengths. Notice the largest absorption band for carbon dioxide is in the infrared.

DID YOU KNOW? The greenhouse effect is not necessarily a bad thing. In the absence of Earth's greenhouse gases the Earth's climate would be on average 33˚ C colder, mostly frozen and uninhabitable. The recent concern about greenhouse warming is based on abnormal levels of greenhouse gases leading to climate changes unseen in human history.

Overview of Greenhouse Gases

In order, Earth's most abundant greenhouse gases are:

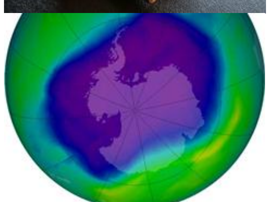
1) water vapor (H_2O)



2) carbon dioxide (CO_2)

3) atmospheric methane (CH_4)

4) nitrous oxide (N_2O)



5) ozone (O_3)

6) chlorofluorocarbons (CFC)

Greenhouse gas

Definition: A gas contributes to the greenhouse effect based on both its characteristics and abundance.

For example, methane is about twenty to sixty times stronger as a greenhouse gas than carbon dioxide (depending on timescale of interest), but it is present in much smaller concentrations. Therefore, methane's contribution to the greenhouse effect is smaller than carbon dioxide.

When greenhouse gases are ranked according to their contribution to the greenhouse effect, the order of importance is:

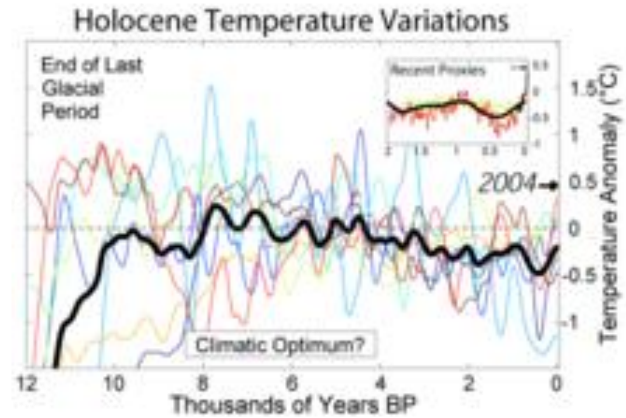
1) water vapor
2) carbon dioxide
3) methane
4) ozone

Historical Context

The Earth has been both warmer and colder than at present, having had both more and less greenhouse gases in the atmosphere through purely natural processes.

Millions of years ago various proxies and modeling show that CO_2 levels were very different than now. At times they were 10 times higher than present, while at other times they were very low. For example, in the Precambrian, a 200-million year period of intermittent, widespread glaciation extended close to the equator. Scientists have termed this period as Snowball Earth.

Snowball Earth appears to have been ended by a colossal volcanic outgassing which was not balanced by weathering of rock and deposition of carbon on the sea floor. This raised the CO_2 concentration of the atmosphere abruptly to 12%, about 350 times modern levels. No volcanic carbon dioxide emission of comparable scale has occurred since.

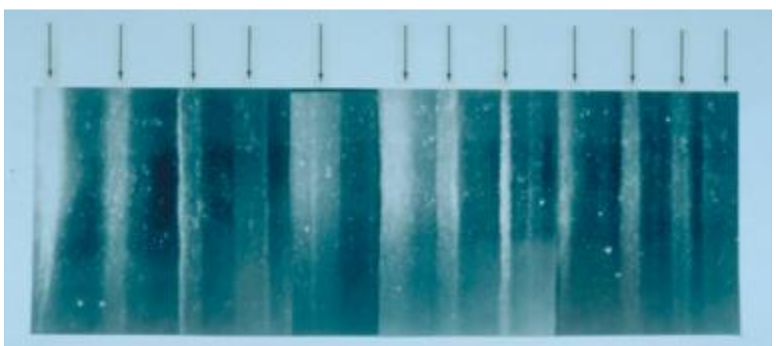


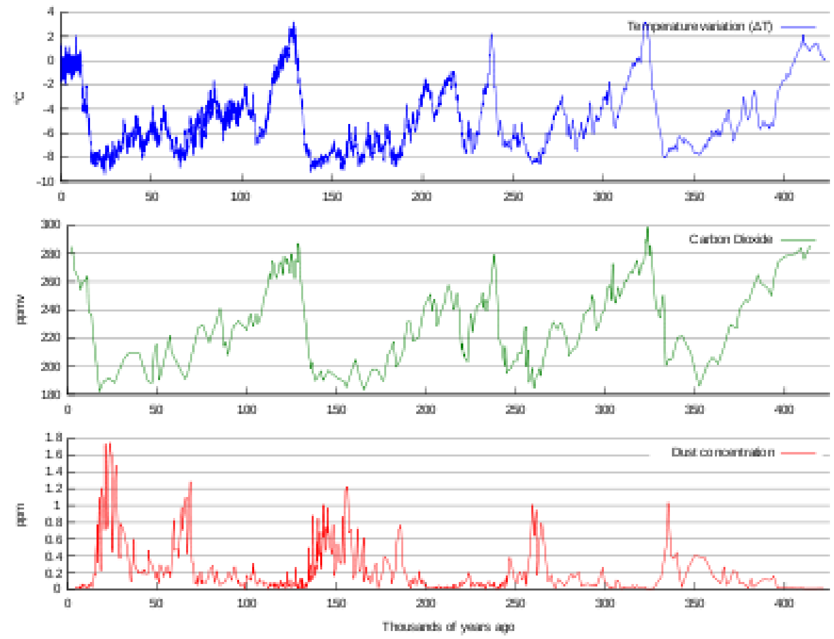
During the last 10,000 years, human civilization developed during the relatively steady atmospheric composition and climate of the Holocene. In the modern era, emissions to the atmosphere from volcanoes are balanced by deposition of sediments on the sea floor and subsequent subduction.

Collecting and Analyzing Data on Greenhouse Gases

Scientists have been collecting data about changes in atmospheric concentrations of greenhouse gases. Observations of conditions over the 1st century indicate that we are heading for conditions never before seen by modern man.

Scientists get information about the past atmospheric gas concentrations from a variety of sources. Ice cores provide evidence for variation in greenhouse gas concentrations over the past 800,000 years.



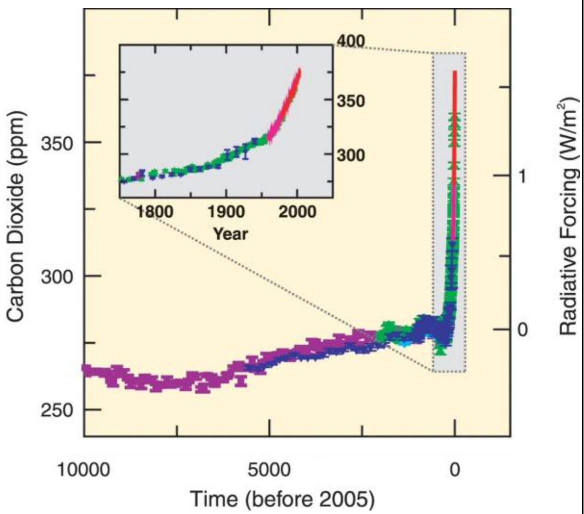


Both carbon dioxide and methane vary between glacial and interglacial phases, and concentrations of these gases correlate strongly with temperature.

Temperatures are Increasing

Concentrations of greenhouse gases were roughly constant for the last 10,000 years, until the industrial era began in the mid-1800's. Now, greenhouse gas concentrations are rising rapidly. The current rates of temperature increases make it difficult for many species to evolve or migrate in response to today's rapid environmental change, which involve not only temperature, but precipitation patterns, storm tracks, ice cover, and ocean chemistry.

Carbon Dioxide

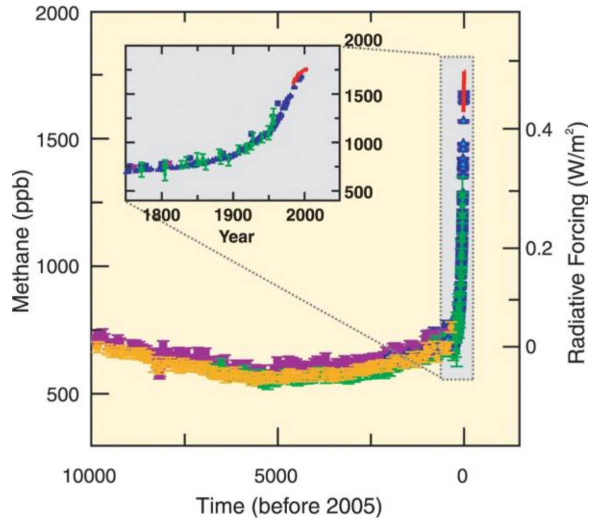


Preindustrial Level: 280 parts per million

Current Level (mid-2010): 388 ppm

Increase since 1750: 108 ppm

Methane

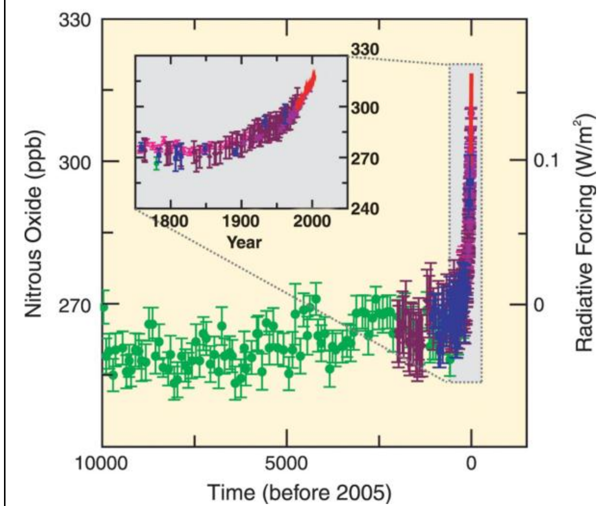


Preindustrial Level: 700 parts per billion

Current Level: 1745 ppb

Increase since 1750: 1045 ppb

Nitrous Oxide



Preindustrial Level: 270 parts per billion

Current Level: 314 ppb

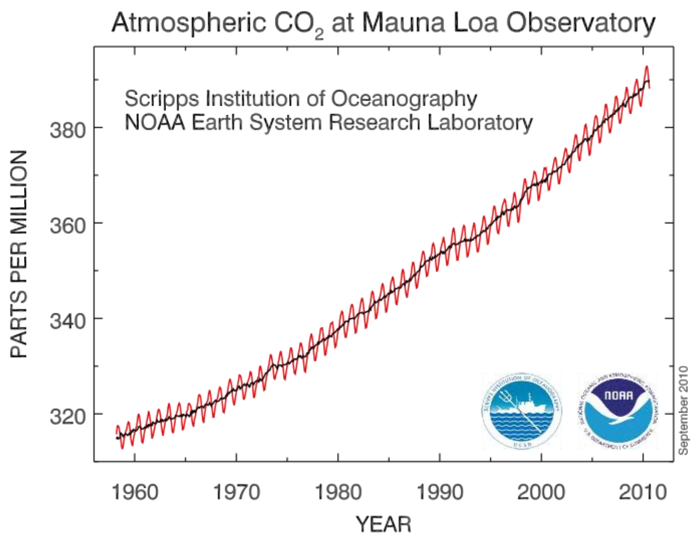
Increase since 1750: 44 ppb

DID YOU KNOW?

Water vapor is an important greenhouse gas. It is difficult to affect, or even measure global water vapor at a given moment in time. However, warmer air can hold more moisture than colder air, so a positive feedback occurs. When the air is warmed by the greenhouse effect of additional carbon dioxide, this enables more water to be held in the air, which adds to the warming, which then adds to the water, which produces further warming. As such, carbon dioxide can be considered a trigger of additional greenhouse warming by water vapor.

Human-Caused Gas Increases

Most greenhouse gases have both natural and anthropogenic (human-caused) sources, but since the beginning of the industrial revolution, human sources have dominated the observed increase in atmospheric carbon dioxide concentration.



This graph clearly shows an increase in atmospheric carbon dioxide concentration in the last 50 years. The annual oscillation in the graph is explained by a decrease in atmospheric CO2 during the vegetative growing season in the Northern hemisphere and an increase in the winter months when plants are dormant and natural and anthropogenic carbon dioxide contributions to the atmosphere continue.

The main sources of greenhouse gases due to human activity are:

Burning fossil fuels adds substantial levels of carbon dioxide to the atmosphere and industrial emissions also add chlorofluorocarbons and other gases to the atmosphere.

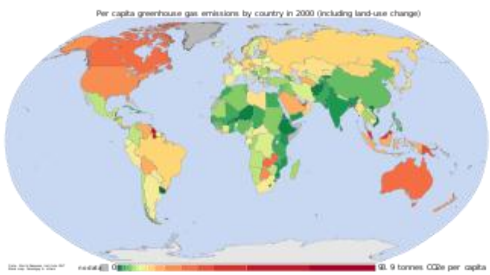
Land use changes add carbon dioxide to the atmosphere by removing natural vegetation. Deforestation removes a carbon dioxide sink which means more stored carbon from the soil goes into the atmosphere.

Livestock digestion and manure add methane to the atmosphere.

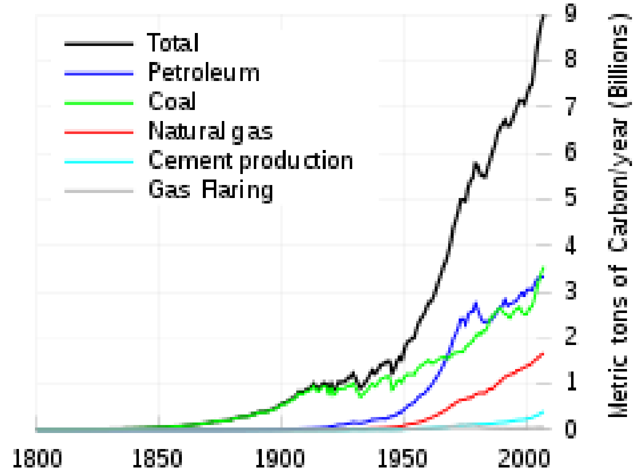
Rice farming adds methane to the atmosphere.

Greenhouse Gas Emissions

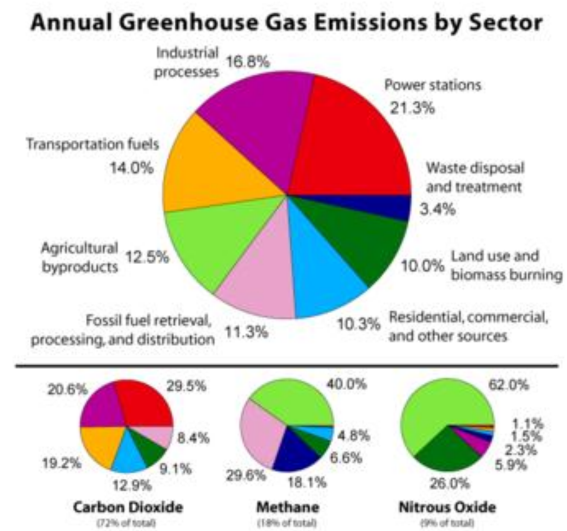
Emissions are a serious problem. The most recent Assessment Report compiled by the Intergovernmental Panel on Climate Change (IPCC) noted that "increase in anthropogenic greenhouse gas concentrations is very likely to have caused most of the increases in global average temperatures since the mid-20th century".



Greenhouse gas emissions per capita by country for 2000



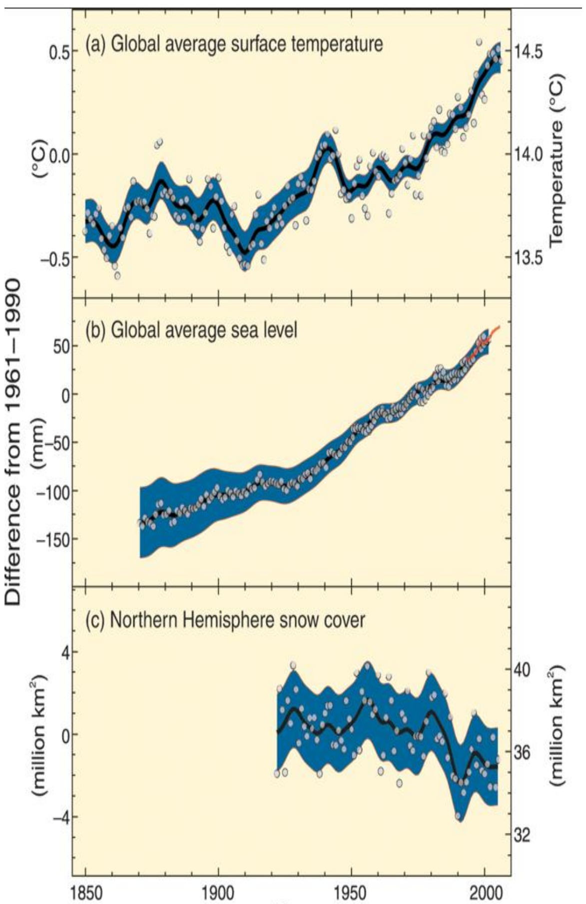
Recent year to year increase in carbon dioxide emissions by source

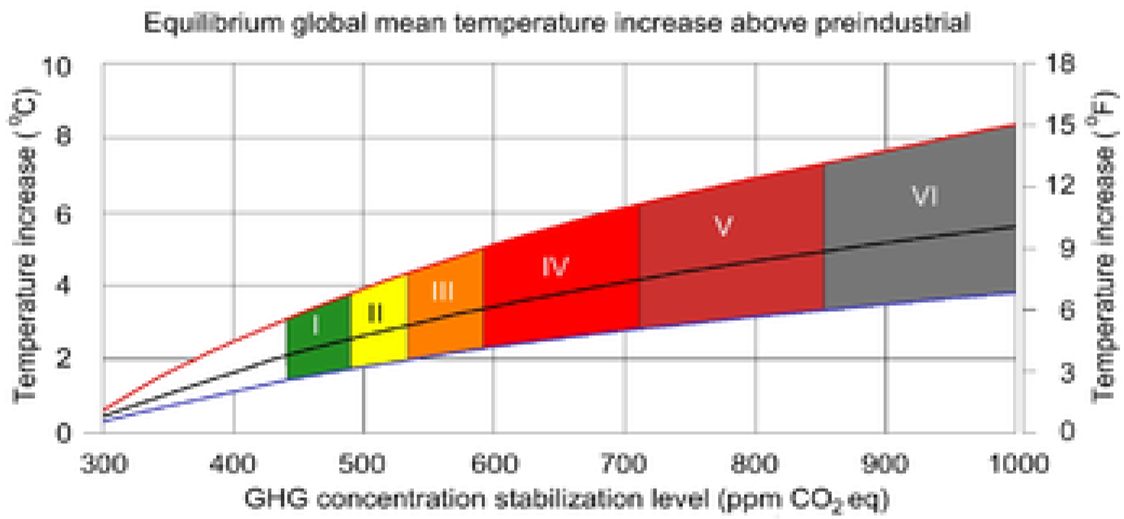


Greenhouse gas emissions by sector

The Planet is Warming – Evidence A

The Assessment Report compiled by the Intergovernmental Panel on Climate Change (IPCC) also included further evidence of global warming.





The charts to the left show environmental effects attributed to global warming including the rise in temperature and sea level and the decline in snow cover, all evidence that the planet is warming.

The above diagram shows projected temperature increase for a range of greenhouse gas stabilization scenarios (the colored bands). The black line in middle of the shaded area indicates 'best estimates'; the red and the blue lines the likely limits.

The Planet is Warming – Evidence B

These NASA Earth Observatory photo pairs show glacial retreat. As the global average temperature rises, the glaciers continue to retreat farther. Glacial melt makes the sea level rise.

Columbia Glacier c. 1980

Columbia Glacier 2005

Arapaho Glacier 1898

Arapaho Glacier 2003

Problems and Solutions

Although a lot of impact has already occurred, efforts to address climate change are underway.
There are two approaches to the problem.

The first is ***mitigation***, which focuses on ways to prevent further global warming and associated climate changes by reducing the effects of human activities on land cover, atmospheric chemistry and other Earth system characteristics. However, due to the delayed response of the climate system to greenhouse gas and other anthropogenic forcings, much of the climate impact of 20th century activity has yet to manifest. As such, we can expect to see additional climate change even if we halt all land use and emissions.

This leads to the second approach, which is ***adaptation***, which focuses on living with observed and expected climate change and reducing the negative impacts to human and natural systems. These two approaches must be considered together in any global planning for planetary management. As suggested by the Union of Concerned scientists, it will be necessary to "Avoid the unmanageable so that we can manage the unavoidable." Some efforts toward that end include emissions reductions through efficiency and carbon-free energy sources, and changes in agricultural practices.

Reservoirs-Fluxes-Global Warming Potential

Global Warming Potential (GWP) depends on the efficiency of a greenhouse gas molecule and its atmospheric lifetime. The global warming potential is measured relative to carbon dioxide and for a specific timescale. Recovery from the recent loading of the atmosphere with carbon dioxide will take tens of thousands of years. Methane has an atmospheric lifetime of 12 ± 3 years and a GWP of 72 over 20 years, 25 over 100 years and 7.6 over 500 years. The decrease in GWP at longer times is because methane is degraded to water and CO_2 through chemical reactions in the atmosphere.

Remediation-Carbon Sequestration

There is an effort currently underway to capture smokestack greenhouse gases and sequester them in underground traps. The effort is further advanced in Europe than the United States. A more difficult problem is recovering the greenhouse gases already in the atmosphere.

Political Initiatives

The Kyoto Protocol of 2005 puts restrictions on certain greenhouse gas emissions and the Montreal Protocol puts restrictions on CFC emissions. In December 2009, the US Environmental Protection Agency declared that "greenhouse gases threaten the public health and welfare of the American people".