Methane emissions

Lecture 5

GWP

- Global warming potentials (GWPs) are used to compare the abilities of different greenhouse gases to trap heat in the atmosphere. GWPs are based on the radiative efficiency (heat-absorbing ability) of each gas relative to that of carbon dioxide (CO_2), as well as the decay rate of each gas (the amount removed from the atmosphere over a given number of years) relative to that of CO_2.
- GWPs are an index for estimating relative global warming contribution due to atmospheric emission of a kg of a particular greenhouse gas compared to emission of a kg of carbon dioxide.

Global warming potentials

A ratio denoting the effect of a quantity of a greenhouse gas on climate change compared with an equal quantity of carbon dioxide.

- Usually expressed over a 100 year period
- Carbon dioxide always has a GWP of 1
- Results of applying a GWP expressed in Carbon Dioxide Equivalent (ex. t CO2e, lb CO2e)
- GWP values are periodically refined

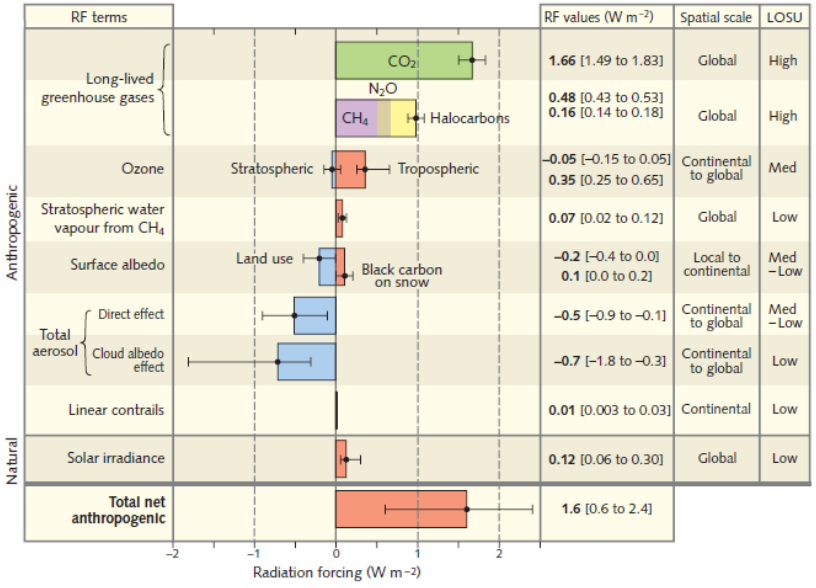
Comparison of 100-Year GWP Estimates from the IPCC's Second (1996),Third (2001) & Fourth (2007) Assessment Reports

Gas	1996 IPCC GWP[a]	2001 IPCC GWP[b]	2007 IPCC GWP[c]
Carbon Dioxide	1	1	1
Methane	21	23	25
Nitrous Oxide	310	296	298
HFC-23	11,700	12,000	14,800
HFC-125	2,800	3,400	3,500
HFC-134a	1,300	1,300	1,430
HFC-143a	3,800	4,300	4,470
HFC-152a	140	120	124
HFC-227ea	2,900	3,500	3,220
HFC-236fa	6,300	9,400	9,810
Perfluoromethane (CF_4)	6,500	5,700	7,390
Perfluoroethane (C_2F_6)	9,200	11,900	12,200
Sulfur Hexafluoride (SF_6)	23,900	22,200	22,800

Energy Consumption in 1995/96
Unit in 000 GJ

Category	Fueltype	Sector						
		Residential	Industrial	Commercial	Transport	Agricultural	Other	Grand Total
Traditional	Agr residue	10349.0	205.0	17.0	0.0	0.0	0.0	10571.0
	Animal dung	17568.0	0.0	0.0	0.0	0.0	0.0	17568.0
	Fuelwood	231109.0	3430.0	956.0	0.0	0.0	0.0	235495.0
Traditional Total		259026.0	3635.0	973.0	0.0	0.0	0.0	263634.0
Commercial	ATF	0.0	0.0	0.0	1469.2	0.0	0.0	1469.2
	Coal	15.0	2600.8	366.1	103.0	0.0	0.0	3085.0
	Electricity	1183.4	1291.2	226.5	5.2	90.3	262.2	3058.9
	Fueloil	0.0	308.2	32.6	0.0	0.0	0.0	340.9
	Gasoline	0.0	14.2	0.0	1365.3	0.0	0.0	1379.6
	HSDiesel	0.0	3294.7	0.0	5650.6	556.2	0.0	9501.5
	Kerosene	6087.0	384.3	1096.7	0.0	0.0	0.0	7568.0
	LDiesel	0.0	2.7	0.0	127.7	43.9	0.0	174.2
	LPG	796.0	0.0	119.9	0.0	0.0	0.0	915.9
	Other Petroleum	0.0	240.2	25.4	0.0	0.0	0.0	265.6
Commercial Total		8081.4	8136.3	1867.3	8720.9	690.4	262.2	27758.5
Renewable	Biogas	411.9	0.0	0.0	0.0	0.0	0.0	411.9
	Microhydro	23.0	0.0	0.0	0.0	0.0	0.0	23.0
	Solar	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Renewable Total		434.8	0.0	0.0	0.0	0.0	0.0	434.8
Grand Total		267542.3	11771.3	2840.3	8720.9	690.4	262.2	291827.4

Radiation forcing

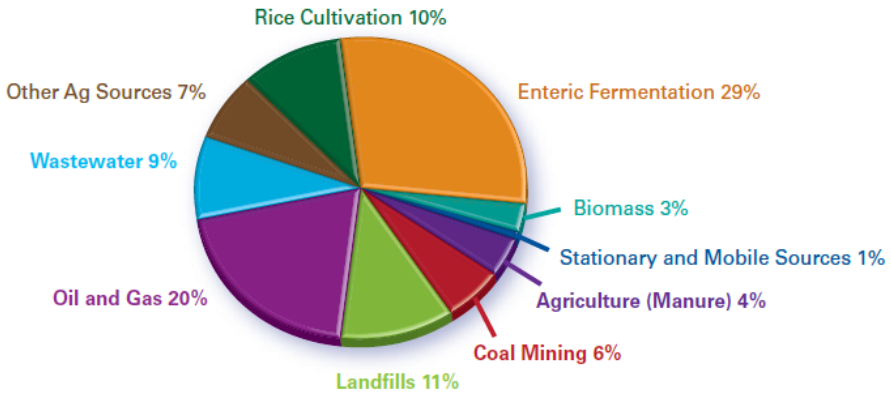


Sources of GHG emissions

An activity that impacts the organization's operations and results in the emission of greenhouse gases.

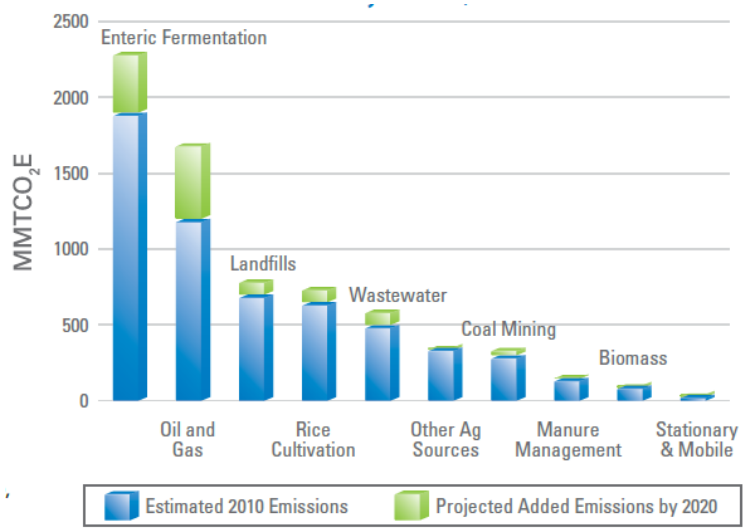
- Natural gas heating
- Water use
- Electricity use
- Business travel
- Company vehicle fuel use
- Air conditioning
- Waste sent to municipal landfill

Estimated global anthropogenic methane emissions by source, 2010

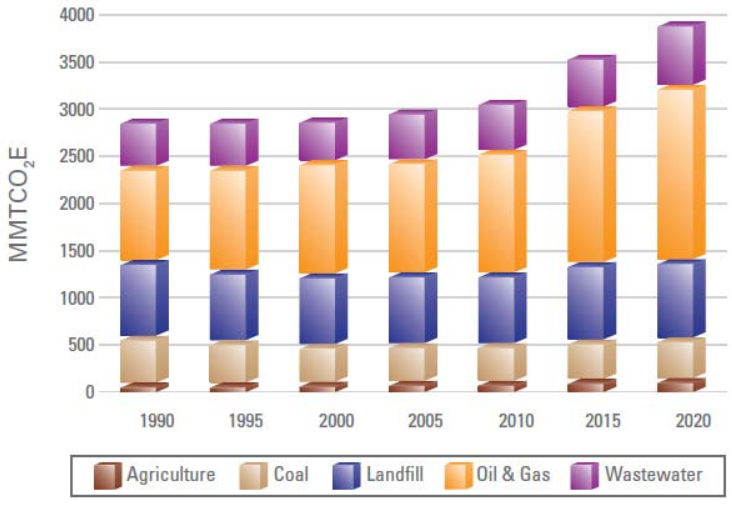


Source: www.globalmethane.org

Estimated and projected global anthropogenic methane emissions by source, 2010 and 2020



Global methane emissions by sector



Anthropogenic methane

- Landfills
- Natural gas and petroleum systems
- Coal mining
- Livestock enteric fermentation
- Wastewater treatment
- Rice cultivation

Natural sources of methane emissions

- Wetlands
- Termites
- Oceans, rivers and estuaries
- Hydrates
- Geologic sources (deep within the Earth's crust)
- Wildfires
- Wild animals

Methane and Nitrous Oxide Emissions from natural sources, April 2010. [http://www.epa.gov/methane/sources.html]

Methane (CH_4)

- Enteric Fermentation
  - Refers to the digestive process in animals in which microbes ferment food consumed by the animals
  - Methane is a natural by-product of Enteric Fermentation
    - The methane is exhaled
  - The amount of methane produced and excreted by the animal depends on the animal's digestive system as well as the type of feed they consume

Methane

- Ruminant animals v. non-ruminant animals
  - Ruminant animals (cattle, buffalo, sheep, goats, and camels) are the major emitters of methane because of their unique digestive process that occurs in a large "fore-stomach"
    - This process allows ruminant animals to digest coarse plant material that non-ruminant animals can't
  - Non-ruminant animals (swine, horses, mules) also emit methane, but at smaller levels

Methane

- Feed quality and quantity effect the amount of methane emitted
  - Lower quality feed increases methane emissions
  - Higher quantity of feed increases methane emissions

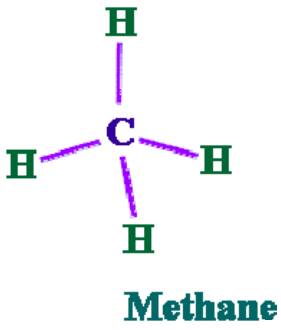
Methane

- In 2002 it was estimated that 5.5 tonnes of methane was emitted from enteric fermentation in the US
  - This accounted for 19% of total methane emissions in the US

Methane

- Anaerobic decomposition of manure
  - Occurs when manure is treated and not left out
  - Methane is emitted during the decomposition of manure
  - Emissions are dependent on the storage of the manure
    - Factors like temperature and moisture can facilitate in the growth of methane producing bacteria
  - Emissions are dependent on the manure composition which is effected by feed type and the animals digestive system
    - Feed that is easier to digest leads to manure with lower manure emissions

Methane



- Globally, methane emissions from manure have been estimated to total 10 million tonnes
  - Methane emissions from manure have been estimated to account for 4% of methane emissions in 2005

Animal agriculture is the single largest source of methane emissions in the USA!

Mitigation Options

- Enteric Fermentation and CH_4 emissions
  - Increase production efficiency
    - Decrease the number of animals
    - Decrease the time they are emitting methane
  - Increase nutrition
    - Decreases the amount of methane produced

Mitigation Options

- Manure Management and CH_4 and N_2O emissions
  - Be mindful of temperature, moisture levels, time of storage, and other factors that lead to higher emissions
  - Give livestock easily digestable feed to control manure contents

SF6 emissions

Sulfur hexafluoride (SF6)

- Sulfur hexafluoride (SF6) is a man-made fluorinated compound with a long atmospheric lifetime of 3,200 years and has the ability to trap heat in the Earth's atmosphere 23,900 times more than that of carbon dioxide (CO2).
- U.S. electric utilities that participate in this program (SF6 Partners) have recognized the opportunity to reduce their carbon footprint through cost-effective reductions in SF6 gas emissions.
- Sulfur hexafluoride is the industry's preferred gas for high voltage electrical insulation, current interruption, and arc quenching in the transmission and distribution of electricity; the gas is used extensively in circuit breakers, gas-insulated substations, and switchgear because of its inertness and dielectric properties.

Reducing SF6

Methods Partners Use to Reduce Emissions of SF6 Gas:

- Equipment leak detection and repair.
- Equipment upgrades and the replacement of old with new equipment.
- Training of employees to carefully handle, manage, and monitor SF6.
- Systematic operations tracking including managing cylinder usage and SF6 gas recycling carts usage.

Cumulative SF6 emissions reductions of 1,184,210 pounds relative to the 1999 baseline are equivalent to mitigating CO2 emissions due to:

- 2.8 million cars not driven for one year;
- 29.4 million barrels of oil not used; or
- 3.3 million households reducing electricity use by 50 percent for one year.

Source: http://www.usctcgateway.net/tool/

SF6 emissions

- For example, in the year 1996 the American company Nike in the US filled by its own quite 288 tons SF6 in soles of sport shoes. This quantity equals roughly the annual atmospheric SF6 emissions of all 15 EU countries together. Nike is now phasing out SF6.
- Let's have a statistical look at the German domestic SF6 consumption based on information from the SF6 producers and traders. In 1998 they supplied to customers in Germany about 570 tons.

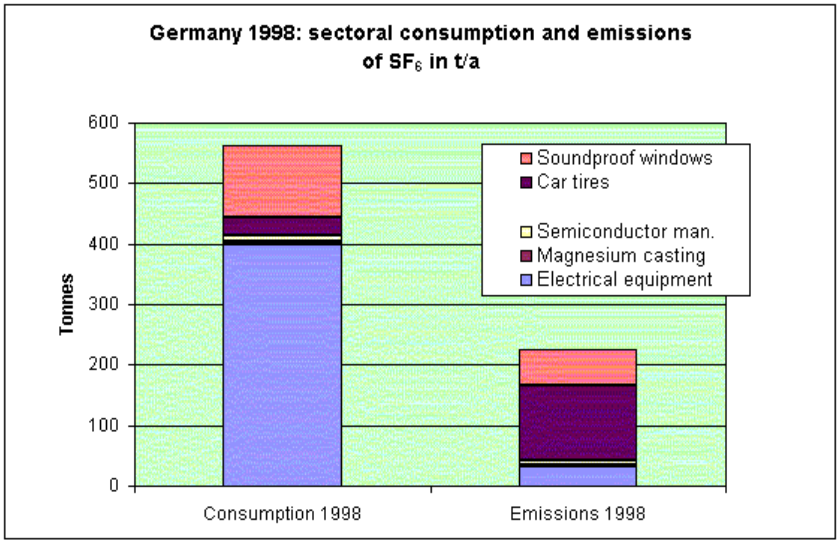


Diagram 1, left side, shows: The biggest part was used by the manufacturers of electrical equipments: 400 tons. In addition 3 tons by magnesium casters and 11 tons by the semiconductor industry.

N2O Emissions

Radiative forcing of CO2, CH4, N2O

- Radiative forcing is a measure of how the energy balance of the Earth-atmosphere system is influenced when factors that affect climate are altered.
- Radiative forcing is usually quantified as the "rate of energy change per unit area of the globe as measured at the top of the atmosphere," and is expressed in units of watts per square meter (W/m2).
- When radiative forcing from a factor or group of factors is evaluated as positive, the energy of the Earth-atmosphere system will ultimately increase, leading to a warming of the system. In contrast, for a negative radiative forcing, the energy will ultimately decrease, leading to a cooling of the system.
- As of 2005, atmospheric CH4 and N2O are the second- and third-largest contributors to radiative forcing among greenhouse gases, after CO2 (IPCC, 2007):
- CO2 +1.66 W/m2
- CH4 +0.48 W/m2
- N2O +0.16 W/m2

http://www.epa.gov/methane/sources.html

N2O Emissions

- N2O is also produced by bacteria. Major anthropogenic sources of these gases include fossil fuel combustion and agriculture. Some sources can be related to both natural and anthropogenic processes.

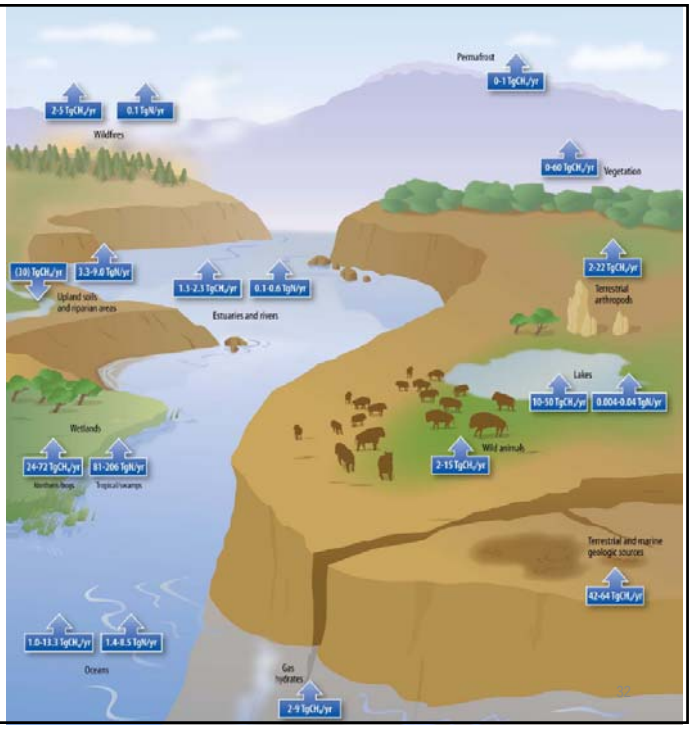
N2O emissions

- Natural sources of N2O are estimated to contribute about 64 percent of the total inputs to the atmosphere. The largest sources of natural N2O emissions are soils (contributing 6.6 Tg N/yr) and oceans, rivers, and estuaries (contributing 5.4 Tg N/yr).
- However, there is some controversy as to what fraction of the emissions associated with rivers and estuaries should be considered natural source emissions, as they are driven primarily by anthropogenic contributions of nitrogen to the water bodies (e.g., from agricultural runoff).

Natural sources of GHG emissions

Natural sources	CH4	N2O
Wetlands	X	X
Upland soils and riparian zones	X	X
Oceans, estuaries, and rivers	X	X
Permafrost	X	X
Lakes	X	
Gas hydrates [Methane clathrate (CH_4•5.75H_2O]	X	
Terrestrial and marine geologic sources	X	
Wildfires	X	X
Vegetation	X	
Terrestrial arthropods and wild animals	X	

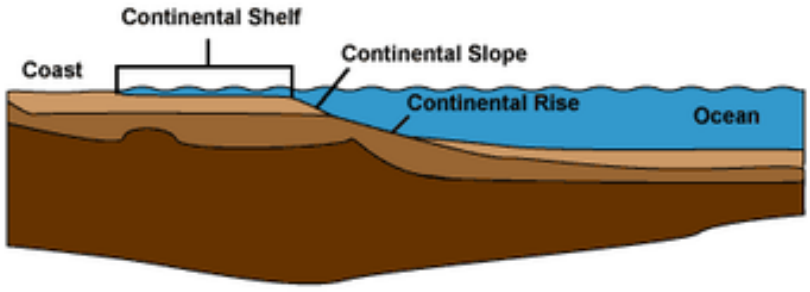
Estimated annual emissions of CH4 and N2O from natural sources. N2O emissions are presented as Tg of nitrogen (N). Note that permafrost and any permafrost sources of methane occur mostly at high latitudes, not high elevations.



Natural emissions of N2O from oceans, estuaries, and rivers

Natural sources	Annual emissions, Tg N/y	Percent of total emissions
Open ocean	3.2	59%
Continental shelves	1.5	28%
Upwelling zones	0.4	7%
Estuaries	0.2	4%
Rivers	0.1	2%
Total	5.4	100%

The **continental shelf** is the extended perimeter of each continent and associated coastal plain.

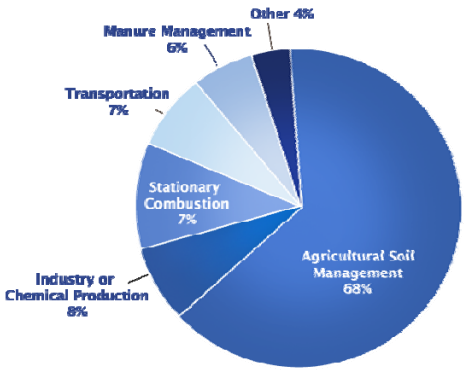


Anthropogenic N2O emissions

Globally, about 40% of total N_2O emissions come from human activities. [1] Nitrous oxide is emitted from agriculture, transportation, and industry activities, described below.

- Agriculture. Nitrous oxide is emitted when people add nitrogen to the soil through the use of synthetic fertilizers. Agricultural soil management is the largest source of N_2O emissions in the United States, accounting for about 68% of total U.S. N_2O emissions in 2010. Nitrous oxide is also emitted during the breakdown of nitrogen in livestock manure and urine, which contributed to 6% of N_2O emissions in 2010.
- Transportation. Nitrous oxide is emitted when transportation fuels are burned. Motor vehicles, including passenger cars and trucks, are the primary source of N_2O emissions from transportation. The amount of N_2O emitted from transportation depends on the type of fuel and vehicle technology, maintenance, and operating practices.
- Industry. Nitrous oxide is generated as a byproduct during the production of nitric acid, which is used to make synthetic commercial fertilizer, and in the production of adipic acid, which is used to make fibers, like nylon, and other synthetic products.

U.S. Nitrous Oxide Emissions, By Source



Note: All emission estimates from the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2010*.

- Natural emissions of N_2O are mainly from bacteria breaking down nitrogen in soils and the oceans.
- Nitrous oxide is removed from the atmosphere when it is absorbed by certain types of bacteria or destroyed by ultraviolet radiation or chemical reactions.

Examples of reduction opportunities for N2O emissions

Emission source	Examples of how emissions can be reduced
Agriculture	The application of fertilizers accounts for the majority of N_2O emissions. Emissions can be reduced by reducing nitrogen-based fertilizer applications and applying fertilizers more efficiently, [3] as well as following better manure management practices.
Transportation	Nitrous oxide is a byproduct of fuel combustion, so reducing mobile fuel consumption in motor vehicles can reduce transportation emissions. Additionally, the introduction of pollution control technologies, such as catalytic converters to reduce exhaust pollutants from passenger cars, can also reduce emissions of N_2O.
Industry	Nitrous oxide is generally emitted from industry through fossil fuel combustion so technological upgrades and fuel switching are effective ways to reduce industry emissions of N_2O. Production of adipic acid results in N_2O emissions that can be reduced through technological upgrades.

Reading materials

- Chapter 3 from book Global Warming
- Methane and Nitrous Oxide Emissions from natural sources, April 2010. [http://www.epa.gov/methane/sources.html]