Greenhouse Gases

Greenhouse gases

Changing the climate

Greenhouse Gases

Atmosphere

	%
Nitrogen	78.084 000
Oxygen	20.946 000
Argon	0.934 000
CO2	0.035 000
Neon	0.001 818
Helium	0.000 524
Methane	0.000 175
Krypton	0.000 114
Hydrogen	0.000 055

Greenhouse Gases

Six key greenhouse gases

Carbon dioxide (CO_2)
Methane (CH_4)
Nitrous oxide (N_2O)
Sulphur hexafluoride (SH6)
Hydrofluorocarbons (HFCs)
Perfluorocarbons (PFCs)

Harmfulness of greenhouse gases - Global Warming Potential- [1]

The power of the main greenhouse gases to "force" temperature rises varies substantially. The conventional way of expressing these forcings is the "Global Warming Potential" (GWP). The GWP for carbon dioxide is set equal to 1.

Carbon dioxide = 1
Methane = 23
Nitrous oxide = 296
Hydroflurocarbons = 12 to 12000 depending on the gas
Perfluorocarbons = 5000 to 12000
Sulphur hexafluoride = 22200

However, CO_2 remains the most important gas because of the quantities in which it is emitted.

[1] The Economics of Climate Change. House of Lords. 06 July 2005
http://www.publications.parliament.uk/pa/ld200506/ldselect/ldeconaf/12/12i.pdf

Greenhouse Gases

Primary Energies in Germany 2008
Fossil fuels provide 82% of energy demand.

Nuclear power plants are planed to phase out with deadline 2020.
Hard coal will take over another 6%

Nearly 90% will then be generated with greenhouse gases emitting technologies.

Crude Oil	35%	
Natural Gas	22%	
Hard Coal	13%	Coal
Lignite	11%	= 24%
Nuclear Energy	12%	
Renewable Energies	7%	

Food production accounts for 14% of the emission of CO2.

Where to start a change?

At the other 86% accounting for:

1 - Electricity production
2 - Transportation
3 - Heating of Buildings
4 - Industry

Greenhouse Gases

1 - Carbon dioxide

Greenhouse gas: Carbon dioxide is a greenhouse gas as it transmits visible light but absorbs strongly in the infrared and near-infrared.

Carbonic acid: $CO_2 + H_2O \rightleftharpoons H_2CO_3$

As carbonic acid it may acidify the ocean if stored at deep sea.

CO2 is toxic in higher concentrations: 0,5 % of CO2 is considered very unhealthy, 1% (10,000 ppm) will make some people feel drowsy. Concentrations of 7% to 10% cause dizziness, headache, visual and hearing dysfunction, and unconsciousness within a few minutes to an hour.

Iron industry: Iron is reduced from its oxides with coke in a blast furnace, producing pig iron and carbon dioxide:

$Fe_2O_3 + 3\ CO \rightarrow 2\ Fe + 3\ CO_2$ There is a great demand of vegetable charcoal in Brazil for steel production

Carbon dioxide is produced mainly from seven processes:

1. From combustion of fossil fuels and wood;
2. Cement production
3. Land use deforestation and as a by-product of hydrogen production plants, where methane is converted to CO2;
4. As a by-product of fermentation of sugar in the brewing of beer, whisky and other alcoholic beverages;
5. From thermal decomposition of limestone, CaCO3, in the manufacture of lime, CaO;
6. As a by-product of sodium phosphate manufacture;
7. Directly from natural carbon dioxide springs, where it is produced by the action of acidified water on limestone or dolomite.

Greenhouse Gases

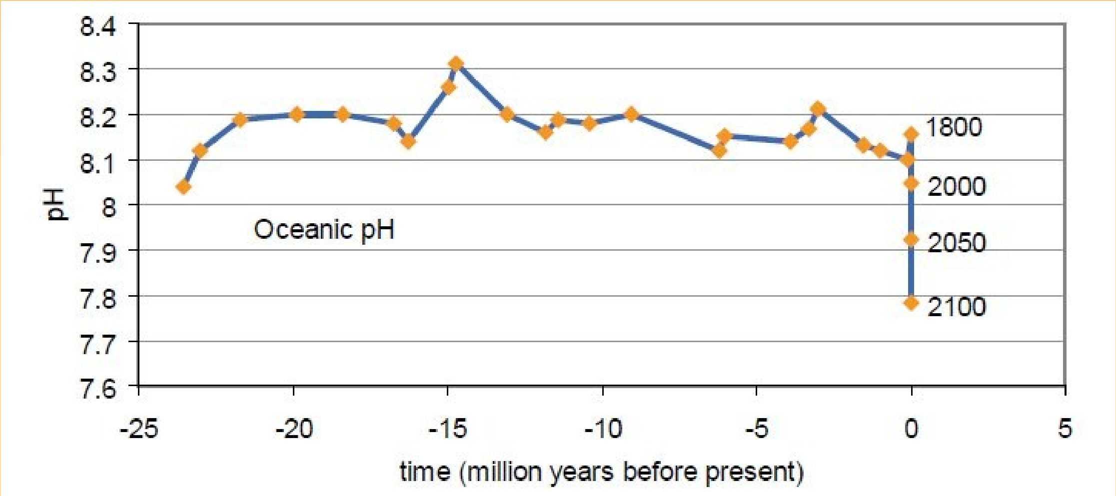
Greenhouse Gases

In 2008, combined global emissions of carbon dioxide (CO2) from fossil fuel burning, cement production and land use change (mainly deforestation) were 27% higher than in the year 1990 (Le Quéré et al. 2009).

Of this combined total, the CO2 emissions
from fossil fuel burning and cement production were 40% higher in 2008 compared to 1990.

The global rate of increase of fossil fuel CO2 emissions has accelerated three-fold over the
last 18 years, increasing from 1.0% per year in the 1990s to 3.4% per year between 2000-2008.

Greenhouse Gases



“Normal” pH of ocean is 8.20

Ocean Acidifi cation – the other half of the CO2 problem. Plymouth Marine Laboratory
http://iodeweb3.vliz.be/oanet/OAdocs/FS7_oceanacidification.pdf

Ocean acidification

Atmospheric 400 ppm CO_2 concentration will cause massive impact on the marine biotypes. Pre-industrial 280 ppm have risen to actual 380 ppm. The surface waters of the oceans have already taken up over 500 gigatonnes (Gt) of CO_2, about half of all that generated by burning fossil fuels and cement manufacturing since 1800.

Ocean pH

Surface ocean pH has declined by about 0.1 since pre-industrial times. This may not sound much, but pH is measured on a logarithmic scale and measures the amount of hydrogen ions (H^+) in the water; a 0.1 reduction, in fact, means that the amount of H^+ has increased by 30%.

Carol Turley from Plymouth Marine Laboratory predicts that if all fossil-fuel reserves are burned
pH would rise by as much as 0.4 units from its current level (around pH 8.1) by the year 2100 and 0.67 by 2300.

Greenhouse Gases

Aragonite

Aragonite, a mineral from of calcium carbonate used by corals to make their hard skeletal reefs, will be so low in tropical waters where CO_2 has doubled that coral calcification will be reduced by 20 to 60%. Corals will be weakened and more erodible.

Warm water corals also suffer from another global warming impact: coral bleaching caused by rising sea surface temperatures. By around 2050 coral reefs will become rare because of raised sea temperature and declining aragonite saturation.

Other species depend on calcification of their exostructures such as echinoderms.

Greenhouse Gases

CO2 emission only measure to avoid acidification

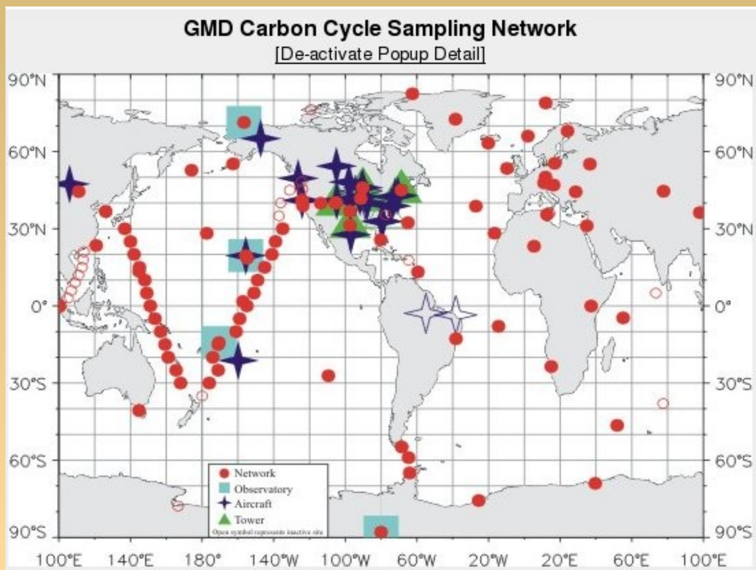
Currently, expert opinion is that the only method of reducing the impacts of ocean acidification on a global scale is through urgent and substantial reductions in anthropogenic CO2 emissions.

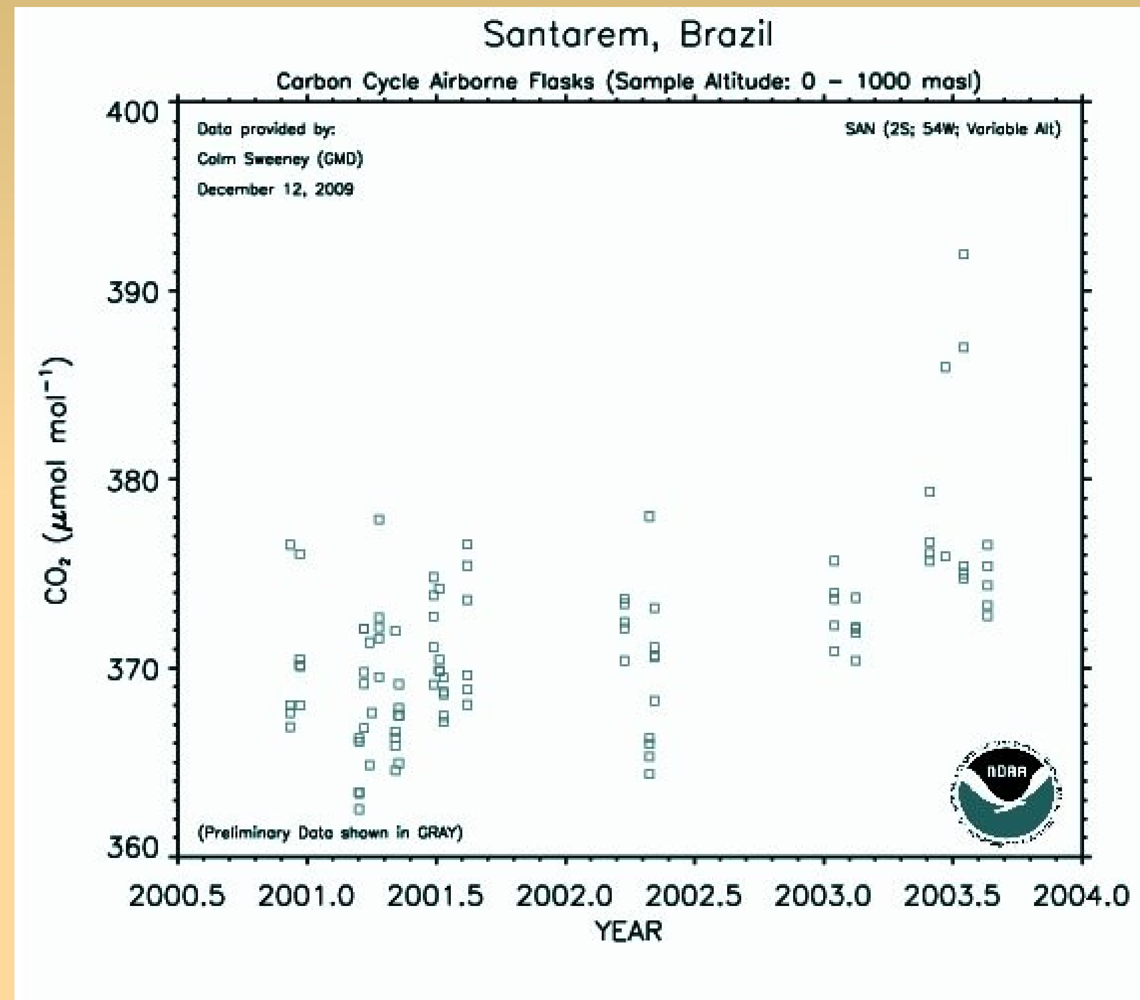
Aragonite undersaturation

A guard rail, beyond which we should not cross, of a decrease in pH of 0.2 below the pre-industrial average value in any larger ocean region (nor in the global mean), has been recommended by the German Advisory Council on Global Change in order to avoid aragonite undersaturation in surface waters, disruption of calcification of marine organisms and the resultant risk of fundamentally altering marine food webs.

In terms of CO2 atmospheric concentration this would be just above the 450 ppm stabilisation scenario.

Greenhouse Gases





Time series from air collected approximately weekly in glass containers from aircraft and returned to GMD for analysis. Data from all flights were combined and then grouped by the range of sample collection altitudes specified. Squares are thought to be regionally representative, influenced by local sources and sinks

Earth System Research Laboratory
Global Monitoring Division
Interactive Atmospheric Data Visualization
http://www.esrl.noaa.gov/gmd/ccgg/iadv/

Greenhouse Gases

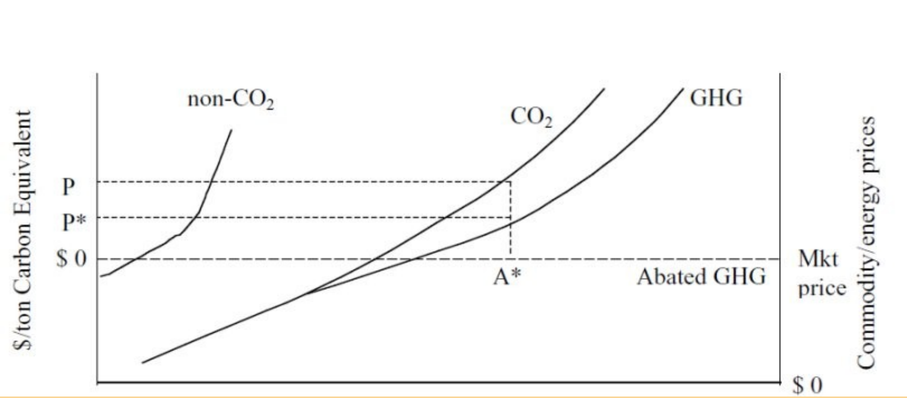
Non-CO2 gases reduction

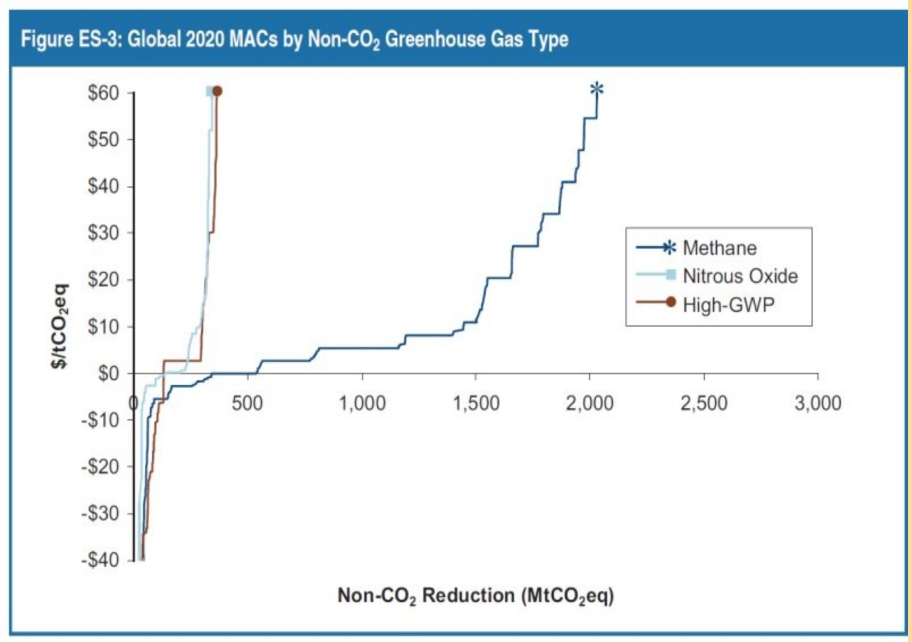
Carbon dioxide (CO2) emissions currently account for about 82 percent of the total U.S. greenhouse gas emissions weighted by 100-year global warming potentials. However, a number of recent analyses suggest that the non-CO2 greenhouse gases included in the Kyoto Protocol — methane, nitrous oxide, and the high-GWP (global warming potential) gases (HFCs, PFCs, and SF6) — can make a significant contribution to cost-effective emissions reductions.

These gases trap more heat within the atmosphere than CO2 per unit weight.

Approximately 30 percent of the anthropogenic greenhouse effect since preindustrial times can be attributed to these non-CO2 greenhouse gases (Intergovernmental Panel for Climate Change [IPCC] 2001;

The mitigation of noncarbon dioxide (non-CO2) greenhouse gas emissions can be a relatively inexpensive supplement to CO2-only mitigation strategies.





EPA: Global mitigation of non-CO2 greenhouse gases
http://www.epa.gov/climatechange/economics/downloads/GM_ES.pdf
http://www.ornl.gov/sci/eere/cef/CEF-E6.pdf

Greenhouse Gases

2 - Methane (CH_4) : Methane is a relatively potent greenhouse gas with a high global warming potential of 72 (averaged over 20 years) or 25 (averaged over 100 years). Methane in the atmosphere is eventually oxidized, producing carbon dioxide and water. As a result, methane in the atmosphere has a half life of seven years.
The radiative forcing effect due to this increase in methane abundance is about one-third of that of the CO_2 increase.[2] In addition, there is a large, but unknown, amount of methane in methane clathrates in the ocean floors. The Earth's crust contains huge amounts of methane. Large amounts of methane are produced anaerobically by methanogenesis. Other sources include mud volcanoes, which are connected with deep geological faults, and livestock (primarily cattle) from enteric fermentation.

Compared to other hydrocarbon fuels, burning methane produces less carbon dioxide for each unit of heat released. At about 891 kJ/mol, methane's heat of combustion is lower than any other hydrocarbon; but a ratio with the molecular mass (16.0 g/mol) divided by the heat of combustion (891 kJ/mol) shows that methane, being the simplest hydrocarbon, produces more heat per mass unit than other complex hydrocarbons. In many cities, methane is piped into homes for domestic heating and cooking purposes. In this context it is usually known as natural gas, and is considered to have an energy content of 39 megajoules per cubic meter, or 1,000 BTU per standard cubic foot.

Methane in the form of compressed natural gas is used as a vehicle fuel, and is claimed to be more environmentally friendly than other fossil fuels such as gasoline/petrol and diesel.

[1] http://en.wikipedia.org/wiki/Methane

Greenhouse Gases

18.08.2009: Release of methane from methane hydrate from the arctic seabed [1]
Methane hydrate is an ice-like substance composed of water and methane. It is stable under high pressure and low temperature.

Westbrook and colleagues 2009 found that methane hydrate is being broken down and methane rises as bubble plumes. Warming of the northward-flowing West Spitsbergen current by 1°C over the last thirty years causes the break down of the methane hydrate.

Methane released from the seabed is seen as an agent of climate change. The authors stress that if this process continues, enormous amounts of methane may come free.

[1] Westbrook, Graham K.; Thatcher, Kate E.; Rohling, Eelco J.; Piotrowski, Alexander M.; Pälike, Heiko; Osborne, Anne H.; Nisbet, Euan G.; Minshull, Tim A.; Lanoisellé, Mathias; James, Rachael H.; Hühnerbach, Veit; Green, Darryl; Fisher, Rebecca E.; Crocker, Anya J.; Chabert, Anne; Bolton, Clara; Beszczynska-Möller, Agnieszka; Berndt, Christian; Aquilina, Alfred: Escape of methane gas from the seabed along the West Spitsbergen continental margin. Geophysical Research Letters, 2009; Doi: 10.1029/2009GL039191 http://www.agu.org/pubs/crossref/2009/2009GL039191.shtml

Greenhouse Gases

Nitrous oxide (N2 0)

Nitrous oxide is a greenhouse gas, accounting for around 6% of the heating effect of greenhouse gases in the atmosphere. According to 2006 data from the United States Environmental Protection Agency, industrial sources make up only about 20% of all anthropogenic sources, and include the production of nylon, and the burning of fossil fuel in internal combustion engines.

The EPA sets NO2 at a level of 100 parts per billion (ppb). EPA also is retaining the existing annual average standard of 53 ppb. NO2 is formed from vehicle, power plant and other industrial emissions, and contributes to the formation of fine particle pollution and smog.

Human activity is thought to account for 30%; tropical soils and oceanic release account for 70%. However, a 2008 study by Nobel Laureatte Paul Crutzen suggests that the amount of nitrous oxide release attributable to agricultural nitrate fertilizers has been seriously underestimated, most of which would presumably come under soil and oceanic release in the Environmental Protection Agency data.

Atmospheric levels have risen by more than 15% since 1750. Nitrous oxide also causes ozone depletion. A new study suggest that N2O emission currently is the single most important ozone-depleting substance (ODS) emission and is expected to remain the largest throughout the 21st century

"Sources and Emissions -- Where Does Nitrous Oxide Come From?". U. S. Environmental Protection Agency. 2006. http://www.epa.gov/nitrousoxide/sources.html. Retrieved 2008-02-02.

Nitrous Oxide Emissions by Source (TgCO2 Equivalents)

Source Category	1990	1995	2000	2005	2006	2007
Agricultural Soil Management	200.3	202.3	204.5	210.6	208.4	207.9
Mobile Combustion	43.7	53.7	52.8	36.7	33.5	30.1
Nitric Acid Production	20.0	22.3	21.9	18.6	18.2	21.7
Manure Management	12.1	12.9	14.0	14.2	14.6	14.7
Stationary Combustion	12.8	13.3	14.5	14.8	14.5	14.7
Adipic Acid Production	15.3	17.3	6.2	5.9	5.9	5.9
Wastewater Treatment	3.7	4.0	4.5	4.8	4.8	4.9
N_2O from Product Uses	4.4	4.6	4.9	4.4	4.4	4.4
Forest Land Remaining Forest Land	0.5	0.8	2.4	1.8	3.5	3.3
Composting	0.4	0.8	1.4	1.7	1.8	1.8
Settlements Remaining Settlements	1.0	1.2	1.2	1.5	1.5	1.6
Field Burning of Agricultural Residues	0.4	0.4	0.5	0.5	0.5	0.5
Incineration of Waste	0.5	0.5	0.4	0.4	0.4	0.4
Wetlands Remaining Wetlands	+	+	+	+	+	+
International Bunker Fuels	1.1	0.9	0.9	1.0	1.0	1.0
Total for U.S.	**315.0**	**334.1**	**329.2**	**315.9**	**312.1**	**311.9**

Units of teragrams of carbon dioxide equivalents (Tg CO2 Eq.).
Conversion: Tg = 109 kg = 106 metric tons = 1 million metric tons

Greenhouse Gases

Monitoring

EPA is establishing new monitoring requirements in urban areas that will measure NO_2 levels around major roads and across the community. Monitors must be located near roadways in cities with at least 500,000 residents.

Agricultural soil management

Nitrous oxide is produced naturally in soils through the microbial processes of denitrification and nitrification. These natural emissions of N_2O can be increased by a variety of agricultural practices and activities, including the use of synthetic and organic fertilizers, production of nitrogen-fixing crops, cultivation of high organic content soils, and the application of livestock manure to croplands and pasture.

All of these practices directly add additional nitrogen to soils, which can then be converted to N_2O. Indirect additions of nitrogen to soils can also result in N_2O emissions. Indirect additions include those processes by which applied fertilizer or manure nitrogen volatilizes into ammonia and oxides of nitrogen and then is ultimately re-deposited onto the soil in the form of particulate ammonium, nitric acid, and oxides of nitrogen. Surface run-off and leaching of applied nitrogen into ground water and surface waters can also result in indirect additions of nitrogen to the soil.

Greenhouse Gases

Sulphur hexafluorid (SF6)

SF6 is used in the electrical industry as a gaseous dielectric medium for high-voltage.
The IPCC says that sulphur hexafluorid (SF6) is the most potent greenhouse gas that it has evaluated, with a global warming potential of 22,800 times that of CO2 when compared over a 100 year period. Due to its high density relative to air, it stays at the lower part of the atmosphere and does not heat the atmosphere.

SF6 is very stable with a lifetime of 3200 years. Its mixing ratio in the atmosphere is lower than that of CO2 about 6.5 parts per trillion (ppt) in 2008 versus 380 ppm of carbon dioxide, but has steadily increased (from a figure of 4.0 parts per trillion in the late 1990s).

In Europe, SF6 fall under the F-Gas directive which ban or control its usage for several applications. Since January 1st 2006, SF6 is banned as a tracer gas and in all applications except high voltage switchgear.

Greenhouse Gases

Ozone-depleting substances ODSs

Hydrofluorocarbons [1]

ODSs are: HFCs, hydrochlorofluorocarbons (HCFCs) PFCs, and Sulfur hexafluoride (SF6), chlorofluorocarbons (CFCs), halons, carbon tetrachloride, methyl chloroform, and hydrochlorofluorocarbons (HCFCs)

The Montreal Protocol and the United States' Clean Air Act Amendments of 1990, forced the first step moving to more ozone friendly chemicals, such as hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs), In Dezember 2009 EPA published rules to further cut ozone-depleting pollutants, protecting the Earth's ozone layer and reducing harmful greenhouse gases. The rules restrict the production and import of HCFCs, sale or distribution of pre-charged air-conditioning and refrigeration products and components containing HCFC-22 or HCFC-142b.

Ozone-depleting pollutants are used as

- Propelants
- Refrigerants
- Foam Blowing
- Solvent Cleaning
- Fire and Explosion Protection
- Aerosols
- Sterilants
- Tobacco Expansion
- Adhesives, Coatings, and Inks

[1] EPA ozone
http://www.epa.gov/ozone/title6/phaseout/rulesoverview.html
http://www.epa.gov/Ozone/snap/emissions/downloads/ODSsubsappendix.pdf

Greenhouse Gases

Acceptable Substitutes Ozone Depleting Substances [1]

R – 404 A
R – 407 C
R – 410 A
R – 507

HFC – 134a

Ammonia Vapor Compression
Evaporative Cooling
Desiccant Cooling
Ammonia / Water Absorption
Water / Lithium Bromide Absorption

EPA: The 2010 HCFC Regulations
http://www.epa.gov/ozone/title6/phaseout/rulesoverview.html
http://www.epa.gov/Ozone/snap/emissions/downloads/ODSsubsappendix.pdf

Greenhouse Gases

Globally, the Sectors with the Greatest Potential for Mitigation of Non-CO2 Greenhouse Gases are the Energy and Agriculture Sectors.
Methane Mitigation has the Largest Potential across All the Non-CO2 Greenhouse Gases.

Major Emitting Regions of the World Offer Large Potential Mitigation Opportunities.

China, the United States, EU, India, and Brazil are the countries or regions that emit the most non-CO2 greenhouse gases. As the largest emitters, they also offer important mitigation opportunities. These regions show significant mitigation potential in the lower range of breakeven prices, with the MACs getting steeper in the higher range of breakeven prices as each additional ton of emissions becomes more expensive to reduce.

EPA: Global Anthropogenic Emissions of Non-CO2 Greenhouse Gases 1990-2020 (EPA Report 430-R-06-003)
http://www.epa.gov/climatechange/economics/downloads/GlobalAnthroEmissionsReport.pdf

Greenhouse Gases

Greenhouse Gases are the primary driver of climate change, says EPA

The U.S. Environmental Protection Agency (EPA) announced that greenhouse gases (GHGs) threaten the public health and welfare of the American people. EPA also finds that GHG emissions from on-road vehicles contribute to that threat.

GHGs are the primary driver of climate change, which can lead to hotter, longer heat waves that threaten the health of the sick, poor or elderly; increases in ground-level ozone pollution linked to asthma and other respiratory illnesses; as well as other threats to the health and welfare of Americans.

EPA's final findings respond to the 2007 U.S. Supreme Court decision that GHGs fit within the Clean Air Act definition of air pollutants. The findings do not in and of themselves impose any emission reduction requirements but rather allow EPA to finalize the GHG standards proposed earlier this year for new light-duty vehicles as part of the joint rulemaking with the Department of Transportation.

On-road vehicles contribute more than 23 percent of total U.S. GHG emissions. EPA's proposed GHG standards for light-duty vehicles, a subset of on-road vehicles, would reduce GHG emissions by nearly 950 million metric tons and conserve 1.8 billion barrels of oil over the lifetime of model year 2012-2016 vehicles.

Endangerment and Cause or Contribute Findings for Greenhouse Gases under the Clean Air Act
http://www.epa.gov/climatechange/endangerment.html

Greenhouse Gases

Traffic

On-road vehicles contribute more than 23 percent of total U.S. GHG emissions. EPA's proposed GHG standards for light-duty vehicles, a subset of on-road vehicles, would reduce GHG emissions by nearly 950 million metric tons and conserve 1.8 billion barrels of oil over the lifetime of model year 2012-2016 vehicles.

GHG concentrations in the atmosphere are at record high levels and data shows that the Earth has been warming over the past 100 years, with the steepest increase in warming in recent decades. The evidence of human-induced climate change goes beyond observed increases in average surface temperatures; it includes melting ice in the Arctic, melting glaciers around the world, increasing ocean temperatures, rising sea levels, acidification of the oceans due to excess carbon dioxide, changing precipitation patterns, and changing patterns of ecosystems and wildlife.

Endangerment and Cause or Contribute Findings for Greenhouse Gases under the Clean Air Act
http://www.epa.gov/climatechange/endangerment.html

Greenhouse Gases

SO2 and the acid rain

Emissions of SO_2 and NOx are precursors to formation of fine particulate matter (PM2.5), while NOx also contributes to the formation of ground-level ozone.

These air pollutants are detrimental to human health. By reducing power sector emissions of SO_2 and NOx, ambient air quality is improved thus improving human health.

Benefits from the ARP include the prevention of human health-related impacts, such as premature death, asthma exacerbation, and hospital admissions for respiratory and cardiovascular ailments.

EPA: Acid Rain and Related Programs: 2008 Highlights
http://www.epa.gov/airmarkets/progress/ARP_4.html

Greenhouse Gases

U.S. Emits 8.95 million tons SO_2/year

In a new report, EPA highlights progress made in reducing SO-2 emissions under the Acid Rain Program. Key achievements of the program include:

- All 3,572 electric generating units subject to the program's SO2 requirements held enough allowances to cover their SO2 emissions, resulting in 100 percent compliance in 2008;

- Emission reductions under the Acid Rain Program have led to improvements in air quality with significant benefits to human health; and

- Sensitive water bodies in the east are showing signs of recovery from acidification.

The Acid Rain Program was established under the 1990 Clean Air Act Amendments and requires major emission reductions of SO2 and nitrogen oxides (NOx) from the electric power industry. The program sets a permanent cap on the total amount of SO2 that may be emitted by electric generating units in the United States, and includes provisions for trading and banking allowances.
The Clean Air Act Amendments set a goal of reducing annual SO2 emissions by 10 million tons from all sources (8.4 million tons from power plants) below 1980 levels.
2010 SO2 cap set at 8.95 million tons, a level of about one-half of the emissions from the power sector in 1980.

EPA: Acid Rain and Related Programs: 2008 Highlights

http://www.epa.gov/airmarkets/progress/ARP_4.html

Greenhouse Gases

Allowance Allocation: The EPA allocates allowances to affected utility units based on their historic fuel consumption and a specific emissions rate. Each allowance permits a unit to emit 1 ton of SO_2 during or after a specified year.

Annual Reconciliation: For each ton of SO_2 emitted in a given year, one allowance is retired, that is, it can no longer be used. If they need to, they may buy allowances during the grace period. Sources may sell allowances that exceed their emissions or bank them for use in future years.

Allowance Trading: SO_2 allowance trading minimizes compliance costs, and since unused allowances can be sold to other program participants, the system encourages units to reduce emissions beyond required levels.

Flexible Compliance: Each source can choose the most efficient way to reduce its SO_2 emissions. Installing new control technology, switching to lower-sulfur fuel, or optimizing existing controls are all options.

EPA: Acid Rain and Related Programs: 2008 Highlights

http://www.epa.gov/airmarkets/progress/ARP_4.html

Greenhouse Gases

Stringent Monitoring: Each source must continuously measure and record its emissions of SO_2, NO_x, and CO_2, as well as heat input, volumetric flow, and opacity. In most cases, a continuous emission monitoring system (CEMS) must be used.

Automatic Penalties and Enforcement: Any source that fails to hold enough allowances to match its SO_2 emissions for the previous year must pay to EPA by July 1 an automatic penalty of $2,000 (inflation-adjusted to $3,337 for 2008) per ton of emissions in excess of allowances held.

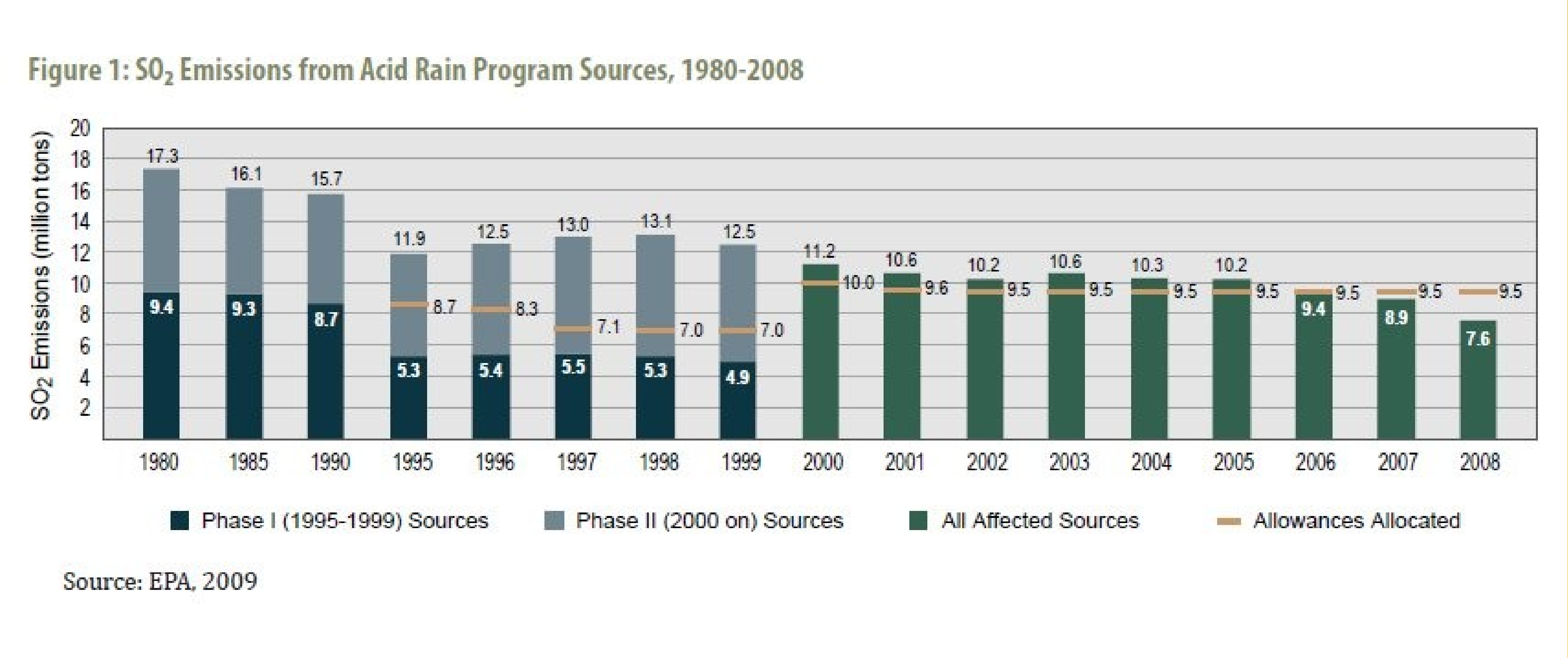
Affected Units: The SO_2 requirements under the ARP apply to EGUs, fossil fuel-fired combustors that serve a generator that provides electricity for sale. The vast majority of ARP SO_2 emissions result from coal-fired EGUs (close to 99 percent), although the program also applies to oil and gas units.

EPA: Acid Rain and Related Programs: 2008 Highlights
http://www.epa.gov/airmarkets/progress/ARP_4.html

Greenhouse Gases

Key Components of the ARP SO2 Trading Program

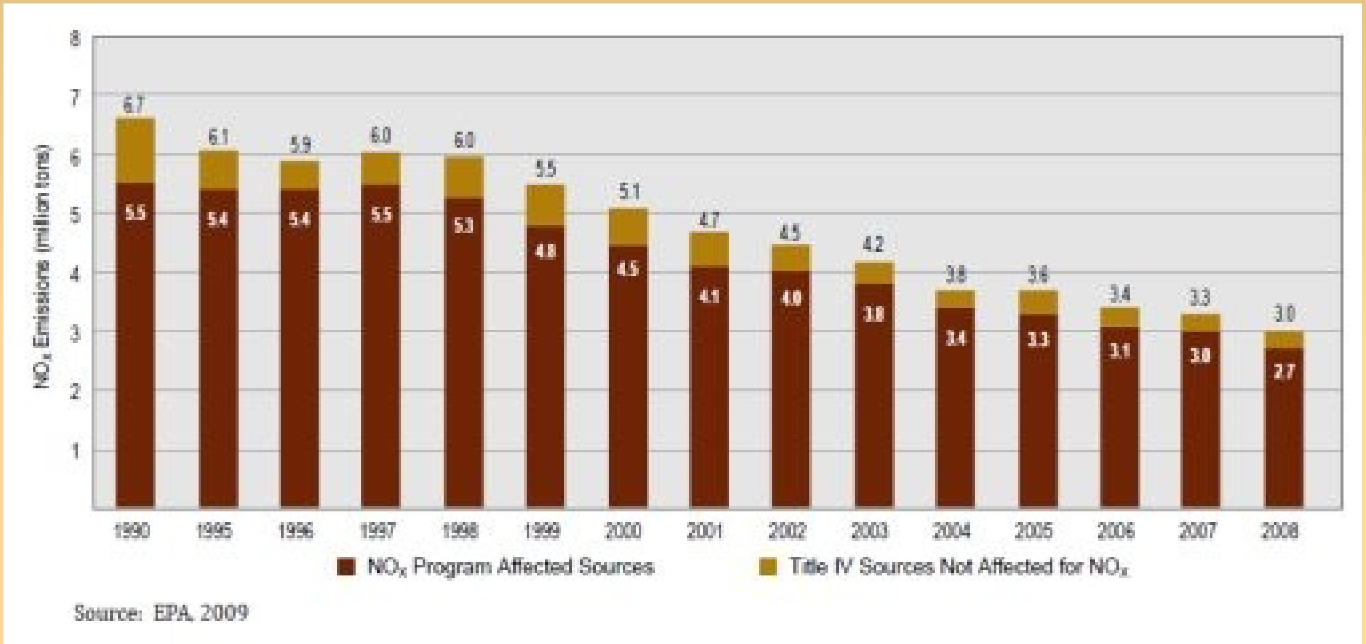
SO2 Emission Reductions: The annual SO2 emissions was reduced by 56 percent compared with 1980 levels and 52 percent compared with 1990 levels. Sources emitted 7.6 million tons of SO2 in 2008, well below the current annual emission cap of 9.5 million tons, and already below the statutory annual cap of 8.95 million tons set for compliance in 2010.



EPA: Acid Rain and Related Programs: 2008 Highlights
http://www.epa.gov/airmarkets/progress/ARP_4.html

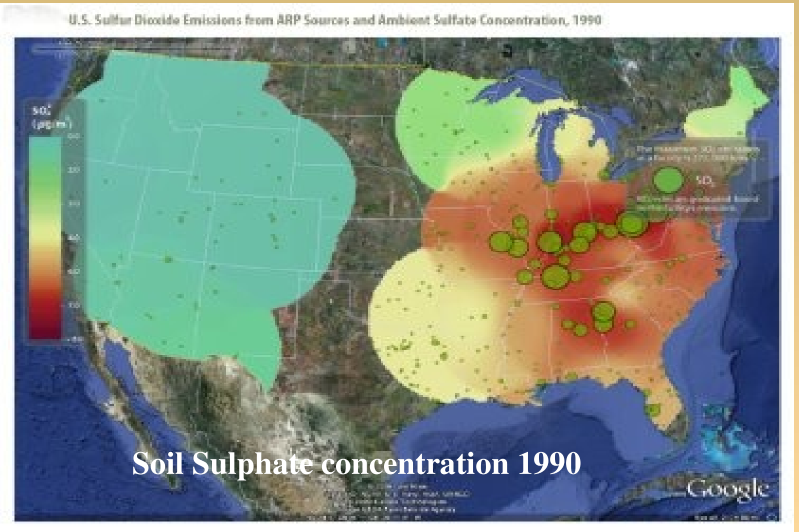
Greenhouse Gases

6.7 million tons of Nox/year how does the atmosphere carry such weights?



The answer is: It does not! Million of tons are droped down as sulphuric, nitric and hydrochloric acids.

Greenhouse Gases



Sulphate concentration in soil has decreased from 7.5 in 1990 to 3.8 in 2008.

It demonstrates hat reductions are feasible, but are not enough.

EPA: Acid Rain and Related Programs: 2008 Highlights
http://www.epa.gov/airmarkets/progress/ARP_4.html

Greenhouse Gases

Human Health Benefits
Benefits from the Acid Rain Program (ARP) include the prevention of human health-related impacts, such as premature death, asthma exacerbation, and hospital admissions for respiratory and cardiovascular ailments. Emissions of SO2 and NOx are precursors to formation of fine particulate matter (PM2.5), while NOx also contributes to the formation of ground-level ozone. These air pollutants are detrimental to human health. By reducing power sector emissions of SO2 and NOx, ambient air quality is improved thus improving human health.

EPA recently updated the estimated U.S. PM2.5 and ozone health-related benefits due to ARP implementation for the prospective year 2010 that were originally published in a 2005 journal article.1 The results of the revised assessment show that estimated PM2.5 health benefits due to ARP implementation in 2010 are valued at $170–$410 billion (2008 dollars). The benefits are primarily from reduced premature mortality of 20,000 to 50,000 incidences per year in 2010. Using updated methods to assess ground-level ozone benefits from ARP implementation in 2010 results in total health benefits ranging from $4.1–$17 billion (2008 dollars). The benefits are primarily from reduced premature mortality of 430 to 2,000 incidences per year in 2010. These updated benefits do not include human welfare benefits due to better ecological conditions, such as improved visibility and reduced acidification of lakes and streams.

Conclusion: These data dont say how good we are, but it does show how bad it was and where the roots of the depletion are.

EPA: Acid Rain and Related Programs: 2008 Highlights
http://www.epa.gov/airmarkets/progress/ARP_4.html

Greenhouse Gases

Complex mechanisms affecting the environment

Not air temperature, but rising ocean temperature endanger Greenland's

NASA glaciologist Jay Zwally, wrote that warmer summer temperatures increased surface meltwater production and water flow to the base, lubrificating the bases of Greenland glaciers which slide into the ocean [1]. However, Ian Howat of Ohio State University said we would probably see regular seasonal and even daily cycles of movement, and this is not the case [2]

Meltwater, seeping through cracks from surface lakes down through glaciers certainly contributes to the movement of glaciers, perhaps 100 metres per year, but along the coast, glaciers are flowing into the sea at rates as high as 10 kilometres per year, and the meltwater cannot explain that. Further, there is no apparent correlation between between peak meltwater in summer and the sudden acceleration in outlet glaciers. Some glaciers even accelerate in the dead of winter, when there is no significant meltwater, he noted.

Howat suggested that sudden increases in ocean temperature might be the explanation, affecting the friction that holds glacial outlets firm against the walls of the fjords through which they flow. Howard concludes that the most profound changes in the ice sheets currently result from glacier dynamics at ocean margins.

[1] Zwally HJ, Abdalati W, Herring T, Larson K, Saba J, Steffen K.: Surface melt-induced acceleration of Greenland ice-sheet flow. Science. 2002 Jul 12;297(5579):218-22. Epub 2002 Jun 6
http://www.ncbi.nlm.nih.gov/pubmed/12052902

[2] AGU 2009: Getting to the bottom of glacial melting
http://blogs.nature.com/climatefeedback/2009/12/agu_2009_getting_to_the_bottom.html

[3] Pritchard HD, Arthern RJ, Vaughan DG, Edwards LA.: Extensive dynamic thinning on the margins of the Greenland and Antarctic ice sheets. Nature. 2009 Oct 15;461(7266):971-5.
http://www.ncbi.nlm.nih.gov/pubmed/19776741

Greenhouse Gases

Complex mechanisms affecting the environment

Humidity more than heat causes vanishing of glaciers of Kilimanjaro
According to Michael Winkler of the University of Innsbruck (Austria) the summit glaciers of Kilimanjaro are regressing.

When in shadow, the cliffs of the glaciers do not melt, only sublimate, when in sunlight, the cliffs can melt as well as sublimate. The retreat is slowly in shadow and 20 to 30 times faster at sunlight.

Winkler stresses that the glaciers are mainly responsive to humidity. The glaciers are retreating because the climate is getting dryer, not warmer. To avoid this large rains and snowfalls which stopped around 1850. Changes in the sea surface temperature and currents in the nearby Indian Ocean may cause a water scarcity in the region, says Winkler.

The End