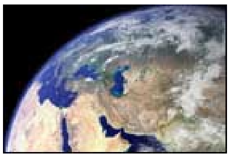


Scientific Facts on

Climate Change

2007 Update

Source document:
IPCC (2007)

Summary & Details:
GreenFacts

Level 2 - Details on Climate Change

This Digest is a faithful summary of the leading scientific consensus report produced in 2007 by the Intergovernmental Panel on Climate Change (IPCC): *"Fourth Assessment Report (AR4)"*. More specifically, it is a summary of the reports by the three Working Groups: "The Physical Science Basis" (WGI), "Impacts, Adaptation and Vulnerability" (WGII), and "Mitigation of Climate Change" (WGIII).

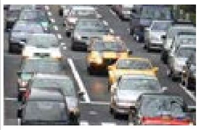
The full Digest is available at: https://www.greenfacts.org/en/climate-change-ar4/

This PDF Document is the Level 2 of a GreenFacts Digest. GreenFacts Digests are published in several languages as questions and answers, in a copyrighted user-friendly Three-Level Structure of increasing detail:

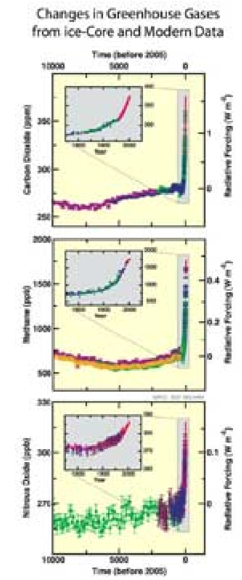
- Each question is answered in Level 1 with a short summary.
- These answers are developed in more detail in Level 2.
- Level 3 consists of the Source document, the internationally recognised scientific consensus report which is faithfully summarised in Level 2 and further in Level 1.

All GreenFacts Digests are available at: http://www.greenfacts.org/

1. What makes the climate change?


Greenhouse gases are produced mainly by the burning of fossil fuels

The Earth's climate is influenced by many factors, such as the amount of greenhouse gases and aerosols in the atmosphere, the amount of energy coming from the sun or the properties the Earth's surface. Changes in those factors, through human-related or natural processes, have a warming or a cooling effect on the planet because they alter how much of this solar energy is retained or reflected back to space.



Greenhouse gas concentrations over the last 10 000 years.
[see Annex 1, p. 19]

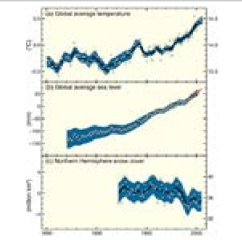
The concentrations in the atmosphere of greenhouse gases such as carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) have all increased markedly since 1750, and now exceed by far their pre-industrial levels.

Carbon dioxide is the most important anthropogenic greenhouse gas. Its concentration in the atmosphere (379 ppm in 2005) is now far higher than the natural range over the last 650 000 years (180 to 300 ppm) and is growing faster than ever since the beginning of its continuous direct measurement in 1960, mainly due to fossil fuel use and to a lesser extent to land use change. For instance, emissions of carbon dioxide from fossil fuel use increased from 6.4 Gt per year in the 90s to 7.2 Gt of carbon per year over the period 2000-2005. Concentrations of methane and nitrous oxide in the atmosphere have also greatly increased since pre-industrial times, and those increases are mostly due to human activities such as agriculture and fossil fuel use.

The effect on climate of each of the different drivers is expressed in terms of "radiative forcing", with positive forcing causing a warming of the surface and negative forcing a cooling of it. The overall effect of human activities since 1750 is very likely (> 90% certainty) to be one of warming, with an estimated increase of energy, or radiative forcing, of 1.6 Watt per square meter over the whole planet. The relative contribution of various factors can be seen in figure 2. The main warming drivers are the various greenhouse gases and it is likely that the warming that they cause has been increasing during the industrial era at a higher rate than at any time over the last 10 000 years. The main cooling drivers are aerosols and the changes in cloud cover that they cause.

2. How is climate changing and how has it changed in the past?

2.1 What changes have been observed so far in climate?


Changes in temperature, sea level and snow cover since 1850
[see Annex 4, p. 22]

Since the Third Assessment Report (TAR), improvements in terms of data, geographical coverage, understanding of uncertainties, and variety of measurements have allowed for a better understanding of how climate is changing in space and time. The warming of global climate is unequivocal and is evidenced by numerous observations of increasing air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level (see Figure SPM-3 [see Annex 4, p. 22]).

Eleven of the last twelve years (1995 -2006) rank among the 12 warmest years ever recorded since global surface temperatures are measured (1850). Over the last 100 years, (1906–2005) there has been an increase in surface temperature of 0.74°C, which is larger than the 0.6°C increase given in the TAR for the 1901-2000 period. And the warming trend over the last 50 years (0.13°C per decade) is nearly twice that for the last 100 years. Temperatures in the higher atmosphere and in the oceans (to depths of at least 3000m) have also been rising, along with the water vapor content of the atmosphere. Mountain glaciers, snow cover and ice caps have declined on average in both hemispheres, contributing in part to the rise of global sea level. The Greenland and Antarctic ice sheets have also contributed to the observed rise of sea level, which amounted to 17cm in total over the course of the 20th century.

At continental, regional, and ocean basin scales, numerous long-term changes in climate have been observed. These include changes in Arctic temperatures and ice, widespread changes in precipitation amounts, ocean salinity, wind patterns and aspects of extreme weather including droughts, heavy precipitation, heat waves and the intensity of tropical cyclones (Table SPM-1 [see Annex 15, p. 32]). Some aspects of climate have not been observed to change. The difference of temperature between day and night, for example, has remained the same, since daytime and nighttime temperatures have risen by the same amount. Contrary to sea ice in the Arctic, there has been no significant decrease in sea ice in Antarctica, which fits with the lack of observed warming in Antarctica.

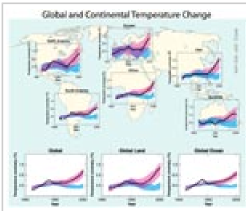
2.2 How has climate changed in the past?

Studies of past climate have allowed inferences to be made about past changes in global climate on time scales ranging from a few decades to millions of years. The uncertainties related to these conclusions on past climate generally increase with time into the past.

This information on past climate show that the overall temperatures of the last half century is unusual in at least the previous 1300 years. The last time that the climate was significantly warmer than now for an extended period (about 125,000 years ago, during the last interglacial period), reductions in polar ice volume led to 4 to 6 metres of sea level rise.

2.3 What is causing the present-day changes in climate?

It is very likely that a significant part of temperature variability in the Northern hemisphere during the past seven centuries prior to 1950 is due to volcanic eruptions and changes in the intensity of solar radiation. However, most of the observed increase in global temperature since then is very likely due to the observed increase in atmospheric greenhouse gas concentrations due to human activities. Human activities now clearly affect other aspects of climate, including ocean warming, continental-average temperatures, temperature extremes and wind patterns.



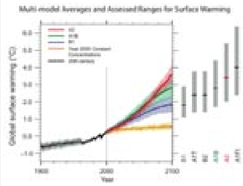
Global and Continental temperature changes since 1900 [see Annex 7, p. 25]

It is likely that these increases in greenhouse gas concentrations alone would have caused more warming than observed, had volcanic and human-induced aerosols not offset some of the warming that would otherwise have taken place.

Current climate models that simulate the observed temperature evolution on each of six continents provide stronger evidence of human influence on climate than was available in the 2001 Third Assessment Report (TAR). Difficulties remain in simulating temperature changes at smaller scales, where natural climate variability is larger and makes it harder to estimate the current and future impact of greenhouse gas increases due to human activities.

3. How is the climate going to change in the future?

3.1 What are the projected changes in temperature for the 21^{st} century?



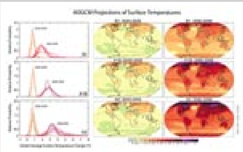
Modeled temperature projection to 2100 [see Annex 8, p. 26]

According to a series of emission scenarios, global temperature is projected to increase by about 0.2°C per decade for the next two decades. Previous projections had suggested a warming of 0.15 to 0.3°C per decade for 1990 to 2005.

Even if the concentrations of all greenhouse gases and aerosols had been kept constant at year 2000 levels, a further warming of about 0.1°C per decade would be expected, mainly due to the long time it takes for oceans to release the heat they accumulated. Continued greenhouse gas emissions at or above current rates would cause further warming and induce many changes in the global climate system during the 21^{st} century that would very likely be larger than those observed during the 20^{th} century. In addition, warming tends to reduce land and ocean uptake of atmospheric CO_2, increasing the amount of human-induced emissions that remains in the atmosphere

Best estimates for globally average surface air warming between the 1980s and the 2090s in the selected scenarios range from 1.8°C (likely range is 1.1°C to 2.9°C) to 4.0°C (likely range is 2.4°C to 6.4°C). Uncertainties are related to model differences and to differences in energy use scenarios.

3.2 What are the other projected changes for the 21^{st} century?



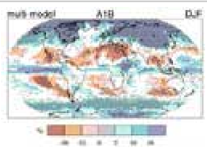
Projected temperatures up to 2100 [see Annex 10, p. 28]

Global average sea level is projected to rise by 18 to 59 cm by the end of the 21^{st} century (2090-2099), depending on the scenario (Table 3 [see Annex 17, p. 34]). However, models used to date do not include uncertainties about certain climate mechanisms because of lack of knowledge. For instance, projections of sea level rise do not take into account the fact that the flow of ice from the ice sheets in Greenland and Antarctica could be faster in the future than they were in recent years. These changes could increase the projections by 10 to 20 cm, maybe even more, but understanding is still too limited to include them in the models with any level of certainty.

Geographical patterns in climate changes are expected to remain similar to those observed over the past several decades. Warming is expected to be greatest over land and at most high northern latitudes, and smallest over the Southern Ocean and parts of the North Atlantic Ocean.

Other projected changes include:

- increased acidification of the oceans caused by increasing carbon dioxide concentrations in the atmosphere;
- shrinking snow cover and sea ice, and decreased permafrost;
- increasingly frequent hot extremes, heat waves, and heavy precipitation events



Relative changes in precipitation (in percent) for the period 2090–2099, relative to 1980–1999 [see Annex 12, p. 30]

- more intense tropical cyclones (typhoons and hurricanes);
- a moving of extra-tropical storm tracks towards the poles, with consequent changes in wind, precipitation, and temperature patterns;
- greater amounts of precipitation in high-latitudes and less rain in most subtropical land regions; and
- a slowing of the Atlantic Ocean circulation.

3.3 What changes are projected on the longer term?

From 1980 to the end of the 21st century, temperatures are projected to increase by 1.8°C to 4.0°C.

Warming and sea level rise caused by human activities will continue for centuries, even if greenhouse gas concentrations were to be stabilized, because of the long timescales associated with climate processes and feedbacks.

Warming is expected to affect the carbon cycle, resulting in even higher carbon dioxide concentration in the atmosphere, but the magnitude of this is uncertain.

If greenhouse gas concentrations in the atmosphere were to stabilize in 2100 at levels projected in the B1 and A1B emission scenarios, a further increase in global average temperature of about 0.5°C would still be expected around 2200. Under this A1B scenario, the thermal expansion of the oceans alone would lead to an increase of 30 to 80 cm of global sea level by 2300, and this rise would continue over many centuries after that.

The melting of the Greenland ice sheet is projected to continue and to contribute to sea level rise after 2100. If it were to keep melting for millennia until Greenland ice disappeared completely, global sea level would rise by about 7m.

The vulnerability of the ice sheets to warming could be increased by dynamical processes related to ice flow (not included in current models but suggested by recent observations) thereby increasing future sea level rise. Current global model studies project that the Antarctic ice sheet will remain too cold for widespread surface melting and is expected to gain in mass due to increased snowfall.

Both past and future human emissions of carbon dioxide will continue to contribute to warming and sea level rise for more than a millennium, due to the long time it takes for this gas to disappear from the atmosphere.

The Emission Scenarios of the IPCC Special Report on Emission Scenarios (SRES) [see Annex 23, p. 38]

4. What impacts of climate change have already been observed?

Glaciers are melting in many places worldwide.

In all regions of the world observations show that many natural systems are being affected by regional climate change, particularly by temperature increases.

Snow and ice are melting and frozen ground is thawing. The number of glacial lakes is increasing and so is ground instability in permafrost regions. The flow of rivers that are fed by melting snow and glaciers has increased, and the temperature of lakes and rivers has risen. Spring events such as migrations are starting earlier and the geographical spread of species is extending towards the poles. In addition, the CO_2 emitted by human activities has caused an increase of ocean acidity, with poorly understood but potentially important negative impacts.

Evidence accumulated over the past five years indicates that changes in many physical and biological systems are linked to the warming caused by human activities.

see also our Arctic Climate Change Digest [see https://www.greenfacts.org/en/arctic-climate-change/index.htm]

- Most of the warming observed since 1950 is very likely due to the increase of greenhouse gases generated by human activities.
- In most cases, when long term measurements revealed significant environmental change, the change went in the direction that would be expected as a result of a warming climate.
- Regions with significant changes are also the ones experiencing significant warming.
- Model projections have linked the changes in some physical and biological systems to the warming induced by human activities.

Despite limitations and gaps in knowledge, there is sufficient evidence to conclude with high confidence that over the last three decades the warming induced by human activities has had a measurable impact on many physical and biological systems.

Some impacts of regional climate change are only emerging at this stage. They remain difficult to discern because they also depend on factors other than climate or because some adaptation has taken place. Temperature increases could for instance already have affected agricultural and forest management, the number of heat related deaths, the spread of vectors of disease such as insects carrying malaria.

Recent changes are beginning to have effects, for instance mountain settlements are at risk of floods due to melting glaciers, the growing season in the Sahelian region of Africa is shortening, and damage from coastal flooding is increasing.

5. What impacts are expected in the future?

5.1 What impacts are expected on natural systems?

Over the course of the 21^{st} Century, many impacts are projected in a range of natural systems if no actions are taken to mitigate climate change.

5.1.1 **Water** availability and average river flow are projected to increase at high latitudes and in some wet tropical areas, and decrease in some dry regions at mid-latitudes and in the dry tropics. It is likely that larger and more numerous areas will be affected by droughts, while more frequent heavy precipitation events will increase flood risk. The amount of water stored in glaciers and snow cover is expected to decline, reducing water availability in regions where one-sixth of the world population currently lives.

5.1.2 The capacity of many **ecosystems** to adapt to change is likely to be exceeded this century if climate change and ongoing land use changes are unmitigated. With significant global warming (exceeding 1.5-2.5°C), 20 to 30% of plant and animal species assessed so far are likely to be at higher risk of extinction and major changes in ecosystems are expected, which would affect not only biodiversity, but also the supply of water and food.

see also our Ecosystem Change Digest [see https://www.greenfacts.org/en/ecosystems/index.htm]

5.2 What impacts are expected on human populations?

5.2.1 Globally, the potential for **food production** could increase if local average temperatures rise by 1 to 3°C, but would decrease if temperatures rise further. In response to a modest warming, agricultural methods in low and mid- to high latitude could be adapted to maintain cereal yields. Without adaptation, crop productivity is projected to decrease at lower latitudes for even small local warming, which would increase risk of hunger. For fisheries and aquaculture, a continued warming is projected to have adverse effects. Commercial **timber** productivity is globally expected to rise modestly in the short- to medium-term, with large regional variability.

5.2.2 **Coasts** will be exposed to increasing risks, such as coastal erosion, due to climate change and sea-level rise. Coastal ecosystems such as coral reefs, wetlands, and mangroves will be negatively affected. Many millions more people are projected to be flooded each year, particularly in densely-populated low-lying areas. Adaptation in coastal regions will be more challenging for developing countries.

5.2.3 For **industries, settlements and societies**, the net effects of climate change is expected to be more negative the larger the change in climate. Poor communities can be especially vulnerable, particularly those concentrated in high-risk areas such as low-lying coastal areas. The economic and social costs of extreme weather events will increase substantially in areas where they become more intense or more frequent.

5.2.4 The consequences of climate change are likely to affect the **health** of millions of people, particularly those who have a lower capacity to adapt. Impacts include:

- increases in malnutrition;
- increased disease, injury, and deaths due to heat waves, floods, storms, fires, and droughts;
- increased burden of diarrhoeal disease;
- increased frequency of problems due to higher concentrations of ground level ozone related to climate change; and,
- altered spatial distribution of some infectious disease vectors.

Climate change is expected to have some mixed effects, such as the decrease or increase of the range and transmission potential of malaria in Africa. In some areas, there might be some positive effects, such as fewer deaths from cold exposure in temperate areas, but overall the negative effects will be larger.

5.3 What impacts are expected in specific regions?

More specific information is now available across the regions of the world concerning the nature of future impacts in the coming decades if climate change is unmitigated.

5.3.1 **Africa** is particularly vulnerable to climate change because of the existing pressures on its ecosystems and its low capacity to adapt. By 2020, between 75 and 250 million people are projected to be affected by increasing water shortages. Agricultural production and fisheries resources are expected to decrease, reducing local food supplies and exacerbating malnutrition.

see also our Diet Digest [see https://www.greenfacts.org/en/diet-nutrition/index.htm]

5.3.2 In **Asia**, climate change is projected to increase pressures on natural resources and the environment and thus hamper sustainable development. Glacier melt in the Himalayas is projected to increase flooding and rock avalanches, and affect water resources within the next two to three decades. It is expected that less fresh water will be available due to both climate change and population growth. Heavily populated coastal areas will be at greatest risk due to increased flooding. Crop yields could increase in East and Southeast Asia while they could decrease in Central and South Asia by the mid-21st century. The projected increase in floods and droughts is expected to increase the associated health problems and deaths due to diarrhoea.

5.3.3 In **Australia and New Zealand** a significant loss of biodiversity is projected to occur in some ecologically-rich sites, such as the Great Barrier Reef. Water security problems are projected to intensify and production from agriculture and forestry is expected to decline due to increased drought and fire. Ongoing coastal development and population growth are projected to exacerbate the risks resulting from sea-level rise and increases in the severity and frequency of storms and coastal flooding by 2050. The region has a substantial capacity to adapt because of its well-developed economy and scientific and technical capability, but natural systems can only adapt so far.

5.3.4 In **Europe**, wide ranging impacts of changes in current climate have been documented: retreating glaciers, longer growing seasons, shifts in the geographic spread of species, and health impacts due to an unprecedented heat wave. It is anticipated that nearly all European regions will be negatively affected, amplifying regional differences in natural resources and assets, with consequences for many economic sectors. Health risks due to heat waves are projected to increase in Southern, Central and Eastern Europe. Negative impacts will also include increased risk of inland and coastal floods and extensive species losses in mountain areas. In Northern Europe, climate change is initially projected to bring some benefits such as reduced demand for heating. But, as climate change continues, its negative impacts are likely to outweigh its benefits.

5.3.5 In **Latin America**, warming and associated drier soils are projected to lead to a gradual replacement of tropical forest by savanna, and to salinization and desertification of agricultural lands. There is a risk of significant species extinction in many tropical areas. Changes in precipitation patterns and the disappearance of glaciers are projected to significantly affect water availability for human consumption, agriculture and energy generation. Some countries have made efforts to adapt, through ecosystem conservation, use of early warning systems, etc. However, the effectiveness of these efforts is outweighed by technological, financial, political and social constraints.

5.3.6 In **North America**, warming in western mountains is projected to cause more winter flooding and reduce summer flows. Moderate climate change in the coming decades is projected to increase overall yields by 5-20% on agricultural lands that rely of rainfall, although major challenges are projected for crops that are near the warm end of their suitable range. Pests, diseases, and fires are expected to have increasing impacts on forests. Cities that currently suffer from heat waves are expected to see them increase in number, intensity and duration. The growth of populations in coastal areas increases vulnerability to tropical storms which could become more intense.

5.3.7 In the **Polar Regions**, the main effect foreseen is a reduction in thickness and extent of glaciers, ice sheets, sea ice, and permafrost, and associated impacts on infrastructures, ecosystems, and traditional ways of life. Beneficial impacts would include reduced heating costs and more navigable northern sea routes. Arctic human communities are already adapting to climate change, but their capacity to adapt is limited.


see also our Arctic Climate Change Digest [see https://www.greenfacts.org/en/arctic-climate-change/index.htm]

5.3.8 **Small Islands** are especially vulnerable to the effects of climate change, sea level rise and extreme events. They are at risk of coastal erosion, floods, storm surges, which could harm tourism and affect the livelihood of local communities. Climate change could also cause reduce water resources and increase the risk of invasion by non-native species.

5.4 What is the magnitude of expected impacts?

Thanks to recent data, the magnitude of impacts can now be better estimated for possible increases in global average temperature. Impacts are expected to increase with temperature, as indicated in Figure SPM-2. [see Annex 3, p. 21] For instance:

- Some crops will have better productivity if temperatures increase by 1 to 2°C, but if temperatures rise by 3-4°C, those same crops will be negatively affected.
- Coral reefs are already affected by small global temperature increase. They would further suffer if temperatures increased by 1 to 2°C, and many would die if it increased by 2.5°C.


Key impacts with increasing temperatures
[see Annex 3, p. 21]

If warm temperatures persist after the 21st century, it could result in very large impacts. For instance, the large sea-level rise (up to 12 m) that would result from the melting of the Greenland and Antarctic ice sheets would have major impacts on coastal areas, with effects both on biological systems and human populations.

It is very unlikely that the North Atlantic Ocean circulation that gives rise to the Gulf Stream will undergo a large abrupt transition during the 21st century. A slowing of this circulation is very likely over this century, but temperatures over the Atlantic and Europe are projected to increase nevertheless, due to global warming.

Global mean losses could be 1-5% of the world Gross Domestic Product (GDP) for 4°C of warming, with larger percentage losses in developing countries (Note: 1% represented US$ 650 billion in 2006).

Many estimates of net costs of damages from climate change across the globe are now available. The average estimate for 2005 was US$12 per tonne of carbon dioxide with a large variability between estimates. Such global cost estimates tend to mask significant differences across sectors, regions, countries, and populations. In some locations and amongst some groups net costs will be significantly larger.

Overall, the published evidence indicates that the net cost of climate change is likely to be significant and to increase as global temperatures increase.

5.5 What are the projected impacts of extreme climate events?

An increase in the severity and frequency of extreme weather events is projected to have major impacts over the course of the 21st century (See Table SPM-1 [see Annex 16, p. 33]). For instance:

- An increase in the frequency and intensity of heat waves would decrease agriculture production in affected areas, cause water availability problems and increase the number of heat-related deaths.
- In colder regions, an increase in temperature would lead to fewer cold nights and more frequent warm days, which in turn would lead, to increased agricultural productivity, fewer deaths from cold exposure, and reduced energy demand for heating.
- An increase in heavy precipitation events would lead to increased floods, to soil erosion, and to negative impacts on surface and groundwater quality.

6. How do people adapt to climate change?

6.1 What are the current adaptation strategies?

Some adaptation of human activities to both observed and anticipated climate change is already taking place. For instance, climate change is taken into account in coastal defense projects in the Maldives and the Netherlands. Other examples include prevention of glacial lake outburst flooding in Nepal, water management strategies in Australia, and government responses to heat waves in some European countries.


Changes in consumption habits can help address climate change.

Past emissions are expected to cause some unavoidable warming (about a further 0.6°C by the end of the century) even if the amount of greenhouse gas concentrations in the atmosphere remained at the same level as they were in the year 2000. There are thus some impacts for which adaptation is the only option.

Although many early impacts of climate change can be effectively addressed through adaptation, the options for successful adaptation diminish and the associated costs increase with increasing climate change.

A wide array of adaptation options exist, including technological solutions such as coastal defenses, behaviour changes such as the modification of consumption habits, as well as policy and managerial solutions. While the limits to adaptation are not yet known, it is not expected that adaptation alone will be sufficient to cope with all projected impacts as they increase in magnitude.

6.2 What makes populations vulnerable to climate change?

The vulnerability of natural environments and human societies to climate change can be exacerbated by factors such as poverty, pollution, conflicts, or epidemics such as AIDS.

Future vulnerability will depend not only on the changes in climate but also on the development path chosen. Indeed different development scenarios foresee large differences in regional population, income and technological development, which strongly affect vulnerability to climate change.

A sustainable approach to development, for instance, can help reduce vulnerability to climate change by increasing the capacity of populations to adapt. However, climate change itself can become an obstacle to development, slowing down progress and potentially preventing the achievement of the Millennium Development Goals (MDG).

6.3 What are the relative roles of mitigation and adaptation?

Many impacts can be avoided, reduced or delayed by mitigation, which mainly aims to reduce greenhouse gase emissions. However even the most severe mitigation measures cannot completely avoid impacts of climate change in the next few decades. Measures to adapt to impacts also have their limits.

There is therefore a need for or mix of strategies that includes mitigation, adaptation, technological development (to enhance both adaptation and mitigation) and research (on climate science, impacts, adaptation and mitigation).

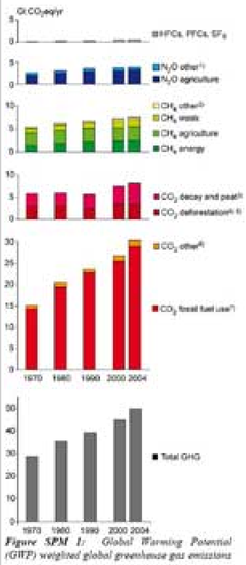
7. What are the current trends in greenhouse gas emissions?

Since pre-industrial times, increasing emissions of greenhouse gases due to human activities have led to a marked increase in the concentration of greenhouse gases in the atmosphere. Between 1970 and 2004, global emissions have increased by 70%. Over this period, emissions from the energy and transport sectors have more than doubled.

Global greenhouse gas emissions include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and fluorinated greenhouse gases (HFCs, PFCs and SF6). The gases are each weighted by their global warming potential and the total is expressed in Gigatonnes of carbon dioxide equivalents ($GtCO_2$-eq). In 2004, total greenhouse gas emissions due to human activities reached 49 Gigatonnes of carbon dioxide equivalents ($GtCO_2$-eq) and CO_2 alone represented 77% of the total.

Although since the 1970s less and less energy is needed to generate a given amount of GDP, this decrease has been offset by the global economic and population growth. Emission reduction policies have been put in place in some countries that have been effective in reducing emissions in those countries to a certain degree, but not sufficiently to counteract the global growth in emissions.

With current mitigation policies and sustainable development practices alone, global greenhouse gas emissions will continue to grow. Indeed, in the absence of additional mitigation measures, emission scenarios project an increase of 25 to 90% in greenhouse gas emissions in 2030 compared to 2000. (See The Emission Scenarios of the IPCC [see Annex 23, p. 38])



Greenhouse gas emissions [see Annex 2, p. 20]

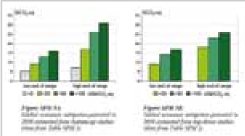
Per-capita GHG emissions [see Annex 5, p. 23]

GHG emissions per unit of GDP [see Annex 6, p. 24]

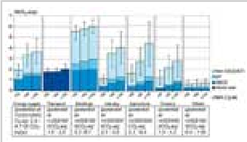
Fossil fuels are expected to maintain their dominant position in the global energy mix beyond 2030. Hence between 2000 and 2030, CO_2 emissions from energy use are projected to grow 45 to 110% over that period, particularly in developing regions (non-Annex I regions [see Annex 14, p. 31]). CO_2 emissions per capita are expected to remain substantially higher in developped countries compared to the rest of the world (Annex I regions [see Annex 14, p. 31]). However, developed countries are expected to use less energy per unit of GDP than developing countries.

8. What actions can be taken to reduce greenhouse gas emissions?

8.1 What is the cost of mitigation?



Economic mitigation potential
[see Annex 9, p. 27]



GHG emission scenarios
[see Annex 11, p. 29]

Mitigation measures aim to reduce greenhouse gas emissions and can help avoid, reduce or delay many impacts of climate change.

Mitigation measures entail a certain cost. However, they also provide economic benefits by reducing the impacts of climate change and the associated costs. In addition, they can bring economic benefits by reducing local air pollution and energy resource depletion.

The mitigation potential can be assessed either by looking at technological and regulatory options for specific sectors ("bottom-up"), or by looking at the economy as a whole ("top-down"). Both bottom-up and top-down studies indicate that there is substantial economic potential for the mitigation of global greenhouse gas emissions over the coming decades, that could offset the projected growth of global emissions or reduce emissions below current levels.

Even if the benefits of avoided climate change are not taken into account, there are a number of opportunities whose benefits, such as reduced energy costs and reduced local pollution, equal or exceed their costs to society. Just by implementing those mitigation measures, emissions of greenhouse gases could be reduced by about 6 $GtCO_2$-eq per year in 2030 (for reference, emissions in 2000 were 43 $GtCO_2$-eq).

Incentives for mitigation would increase if the benefits of avoided climate change were taken into account and a "carbon price" was established for each unit of greenhouse gas emission. Indeed policies can provide a real or implicit "price of carbon", for instance through taxes, regulations or emission trading schemes: the higher the "carbon price" the greater the incentive for producers and consumers to invest in products, technologies and processes which emit less greenhouse gases. For instance, at a "carbon price" of 100$ per ton CO_2-equivalent, emissions could be reduced by 16 to 31 $GtCO_2$-eq/yr.

This assumes that the market is functioning efficiently, that implementation barriers are removed and that all sectors contribute to the overall mitigation efforts.

Stabilizing global greenhouse gas concentrations around 445-535 ppm of CO_2-eq (in 2005, this was about 455 ppm) would cause less than a 3% decrease of the global GDP in 2030, while stabilizing them at 590-710 ppm of CO_2-eq could even bring a small GDP increase. However these costs vary significantly between regions.

Studies indicate that costs may be lower if:

- Revenues from carbon taxes and emission permits are used to promote low-carbon technologies or to replace other existing taxes
- Mitigation policies include all greenhouse gases and carbon sinks
- Mitigation policies address market inefficiencies such as distortionary taxes and subsidies.

Table SPM-4. Estimated global macro-economic costs in 2030 [see Annex 19, p. 36]

8.2 How can changes in lifestyle and behaviour patterns contribute?

Public transport can help reduce greenhouse gas emissions.
Source: GreenFacts

Changes in lifestyles and consumption patterns that emphasize resource conservation can contribute to developing a low-carbon economy that is both equitable and sustainable. Education and training programmes can lead to the acceptance of energy efficiency and bring significant reductions in greenhouse gas emissions:

- In buildings, changes in occupant behaviour, cultural patterns and consumer choice can reduce energy consumption.
- In cities, urban planning and education can reduce car usage and promote efficient driving habits.
- In industrial organizations, staff training, reward systems, regular feedback, and documentation of existing practices can reduce energy use.

8.3 What are the co-benefits of mitigation?

Not only do mitigation measures help reduce or delay impacts of climate change, they also have other beneficial effects, for instance on energy use and local air pollution.

Reduced air pollution resulting from the reduction of greenhouse gas emissions could have substantial health benefits and thereby offset part of the cost of mitigation.

Mitigation actions can also improve energy security and agricultural production while reducing pressure on natural ecosystems.

However, mitigation in one country or group of countries could lead to higher emissions elsewhere ("carbon leakage") or effects on the global economy ("spill-over effects").

8.4 How can different sectors reduce emissions?

For different sectors of human activities a number of key technologies and practices are currently commercially available that could contribute to climate change mitigation (see Table SPM-3 for more details [see Annex 18, p. 35]).

- **Energy Supply**: Energy infrastructure investments decisions will have long term impacts on greenhouse gas emissions, because of the long life-times of energy infrastructure. They can create opportunities to achieve emission reductions by 2030, notably through:
  - investing in the reduction of energy consumption rather than in new energy supply infrastructure
  - switching from coal to gas;
  - nuclear power, although safety, weapons proliferation and waste management remain as constraints;
  - renewable energy (hydro, solar, wind, geothermal and bioenergy);

- combined heat and power generation,
- application of Carbon Capture and Sequestration (CCS) technologies.

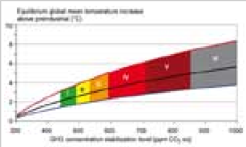
An increase in the price of fossil fuel could make low-carbon alternative more competitive, but could also lead to the use of high-carbon alternatives such as oil sands and heavy oils.

- **Transport**: There are multiple mitigation options in the transport sector, such as more fuel efficient vehicles, hybrid vehicles, cleaner diesel engines, biofuels, shift from road transport to rail and public transport, alternatives such as cycling and walking, and urban planning that reduces the need for road transport. However, mitigation efforts may be counteracted by the growth in the sector as well as barriers such as consumer preferences and lack of policy frameworks.
- **Buildings**: Energy efficiency options for new and existing buildings could considerably reduce CO_2 emissions with net economic benefit, though many barriers against tapping this potential remain. Available options include efficient lighting, appliances, heating and air conditioning, improved insulation, solar heating and cooling, as well as recycling or using alternatives for fluorinated gases in refrigeration.
- **Industry**: The mitigation potential is highest in energy intensive industries. Methods include the use of more efficient electrical equipment, heat and power recovery, recycling, and control of non-CO_2 gas emissions. Many industrial facilities in developing countries are new and include the latest technology. However, upgrading the many older, inefficient facilities remaining in both industrialized and developing countries could deliver significant emission reductions
- **Agriculture**: Agricultural practices collectively can make a significant contribution at low cost by increasing the amount of carbon stored away in soil (carbon sinks), by reducing methane and nitrous oxide emissions, by producing crops for energy use, by improving rice cultivation techniques and livestock and manure management to reduce methane emissions and by improving fertilizer application to reduce nitrous oxide emissions. However, biomass production for energy may compete with other land uses and have both positive and negative impacts on the environment and on food security.
- **Forestry**: Forest-related mitigation activities such as afforestation, reforestation, improved forest management, reduced deforestation, and use of forestry products to replace fossil fuels can considerably reduce greenhouse gas emissions and help capture CO_2 from the atmosphere. Such efforts can also improve sustainable development and adaptation to climate change. Most of the potential lies in the tropical regions, and could notably be achieved by reducing deforestation.
- **Waste**: The post-consumer waste sector is a small contributor to global greenhouse gas emissions (<5%), yet it can contribute to mitigation efforts at low cost through landfill methane recovery, waste incineration with energy recovery, composting, recycling, and waste minimization.

Large-scale geo-engineering options, such as ocean fertilization to remove CO_2 directly from the atmosphere, or blocking sunlight by bringing material into the upper atmosphere, remain largely speculative and unproven, with the risk of unknown side-effects.

8.5 What are the longer term implications of mitigation actions?

In order to stabilize the concentration of greenhouse gases in the atmosphere by 2100 or beyond, emissions would have to stop increasing and then decline. The lower the stabilization level aimed for, the more quickly this decline would need to occur. Mitigation efforts over the next two to three decades will have a large impact on the stabilization level in the longer term.



GHG stabilization and global temperatures
[see Annex 13, p. 31]

Mitigation scenarios have been assessed for six different stabilization levels (Category I to VI, as illustrated in table SPM-5 [see Annex 20, p. 36] and figure SPM-8 [see Annex 13, p. 31]).

- On the one hand, to achieve low stabilization at less than 490 ppm CO_2-eq (Category I) would imply that emissions stop increasing and start declining before 2015. This could lead to a global mean temperature increase of about 2 to 2.4°C above pre-industrial levels.
- On the other hand, a delayed decline in emission, for instance starting between 2060 and 2090, could lead to a stabilization level of up to 1030 ppm CO_2-eq (Category VI) which could lead to a global mean temperature increase of about 4.9 to 6.3°C above pre-industrial levels.

These stabilization levels of greenhouse gases in the atmosphere can be achieved by deploying currently available technologies and technologies that are expected to be commercially available in the coming decades. Increased energy efficiency measures, as well as world-wide investments and deployment of low-emission technologies and research into new energy sources will be necessary to achieve stabilization. It will require effective incentives for the development, acquisition, deployment and diffusion of technologies and for addressing related barriers.

By 2050, for low stabilization levels, estimates indicate that mitigation efforts could lead to a global GDP reduction of up to 5.5%. However, costs may differ significantly between regions.

Table SPM-6: Estimated global macro-economic costs in 2050 relative to the baseline for least-cost trajectories towards different long-term stabilization targets [see Annex 21, p. 37]

Choices about the scale and timing of greenhouse gas mitigation imply risk management decisions. It involves balancing the economic costs of rapid emission reductions against the climate risks of delayed action. Delayed emission reduction measures would lead to investments in more emission-intensive infrastructure which significantly limits the opportunities to achieve lower stabilization and increases the risk of more severe climate change impacts.

9. How can governments create incentives for mitigation?

9.1 What are the implications of different policy instruments?

A wide variety of policy tools can be applied by governments to create incentives for mitigation action taking into account national circumstances and interactions between policies. Experience from various countries and sectors shows there are advantages and drawbacks for any given policy instrument. It is important to consider environmental effectiveness of policies and instruments, their cost effectiveness, institutional feasibility and how costs and benefits are distributed.

Examples of policies and instruments:

- Integrating climate policies into broader development policies makes implementation easier.
- Regulations and standards generally provide some certainty about emission levels, but they may not encourage innovation and the development of new technologies.

- Taxes and charges can set a "carbon price" (a cost for each unit of greenhouse gas emissions) and be an effective mitigation incentive, but cannot guarantee a particular level of emissions.
- Tradable emission permits establish a "carbon price". The volume of allowed emissions determines their environmental effectiveness, while the way permits are allocated determines who bears the costs. Fluctuation in the "carbon price" makes it difficult to estimate the total cost of complying with emission permits.
- Subsidies and tax credits can provide financial incentives for the development and diffusion of new technologies. Though sometimes costly, they are often critical to overcome barriers.
- Voluntary agreements between industry and governments are politically attractive, raise awareness, and have played a role in the evolution of many national policies. Only a few of them have led to measurable emission reductions.
- Awareness campaigns may positively affect environmental quality by promoting informed choices and possibly contributing to behavioural change. However, their impact on emissions has not been measured yet.
- Research, Development and Demonstration (RD&D) can stimulate technological advances, reduce costs, and enable progress toward stabilization.

Economic instruments, government funding or regulation that lead to a "carbon price" (a cost for each unit of greenhouse gas emissions) could create incentives for producers and consumers to significantly invest in products, technologies and processes reduce greenhouse gas emissions.

Government support through financial contributions, tax credits, standard setting and market creation is important for effective technology development, innovation and deployment. Effective transfer of technology to developing countries requires appropriate financial, institutional, policy, legal and regulatory frameworks.

Table SPM-7: Selected sectoral policies, measures and instruments that have shown to be environmentally effective in the respective sector in at least a number of national cases. [see Annex 22, p. 38]

The impact of the Kyoto protocol's first commitment period 2008-2012 on global carbon emissions is expected to be limited. However, notable achievements of the United Nations Framework Convention on Climate Change (UNFCCC) and its Kyoto protocol are the establishment of a global response to the climate problem, stimulation of an array of national policies, the creation of an international carbon market and the establishment of new institutional mechanisms that may provide the foundation for future mitigation efforts.

9.2 How is climate change mitigation linked to sustainable development?

Switching to more sustainable development paths can make a major contribution to climate change mitigation, but implementation may require overcoming multiple barriers. Climate change and other sustainable development policies often benefit each other, though not always. There is a growing understanding of the possibilities to choose and implement mitigation options in several sectors to create synergies and avoid conflicts with other aspects of sustainable development.

For instance, climate change policies related to energy efficiency and renewable energy are often economically beneficial, improve energy security, and reduce local air pollution. Reducing both loss of natural habitat and deforestation can have significant benefits for biodiversity, soil and water conservation, and can be implemented in a socially and economically sustainable manner.

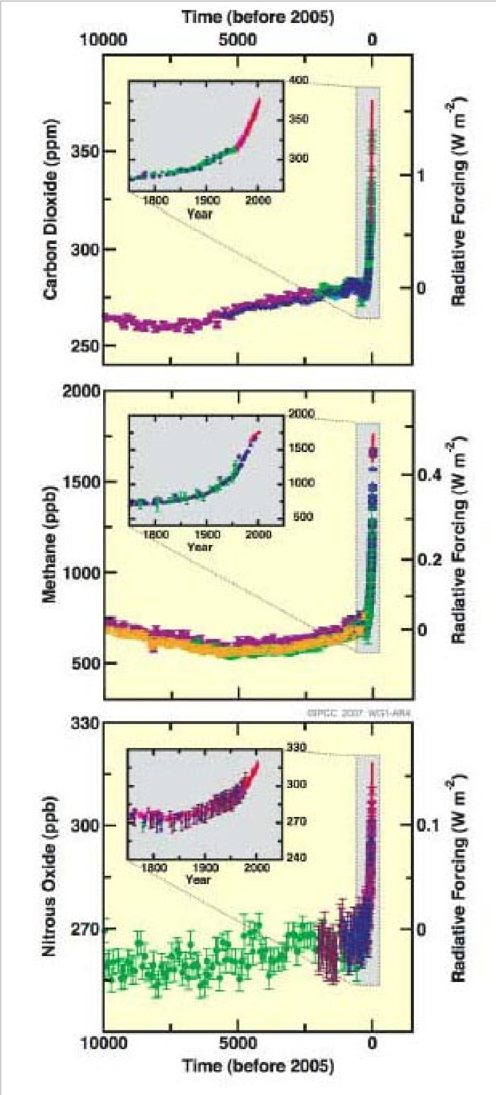
No matter how stringent the mitigation measures, some impacts of climate change are unavoidable and adaptation will be necessary. Sustainable development can increase the capacity for both adaptation and mitigation, and reduce vulnerability to the impacts of climate change.

Gaps in knowledge remain regarding some aspects of mitigation of climate change, especially in developing countries. Additional research addressing those gaps would further reduce uncertainties and thus facilitate decision-making related to mitigation of climate change.

Annex

Annex 1:
Figure SPM-1. (WGI) Changes in Greenhouse Gases from Ice-core and Modern Data

Atmospheric concentrations of carbon dioxide, methane and nitrous oxide over the last 10,000 years (large panels) and since 1750 (inset panels). Measurements are shown from ice cores (symbols with different colours for different studies) and atmospheric samples (red lines). The corresponding radiative forcings are shown on the right hand axes of the large panels.



Source: IPCC Climate Change 2007: The Physical Science Basis, Summary for Policymakers (2007) [see http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_wg1_report_the_physical_science_basis.htm], p3

Annex 2:
Figure SPM-1. (WGIII) Emissions of different greenhouse gases 1970-2004

(GreenFacts note: Emissions are expressed in Giga tonnes of CO_2 equivalent per year which scales emissions using global warming potentials (GWPs).

1 Giga tonne = 1 000 000 000 tonnes)

100 year GWPs from IPCC 1996 (SAR) were used to convert emissions to CO_2-eq. (cf. UNFCCC reporting guidelines). CO_2, CH4, N2O, HFCs, PFCs and SF6 from all sources are included.

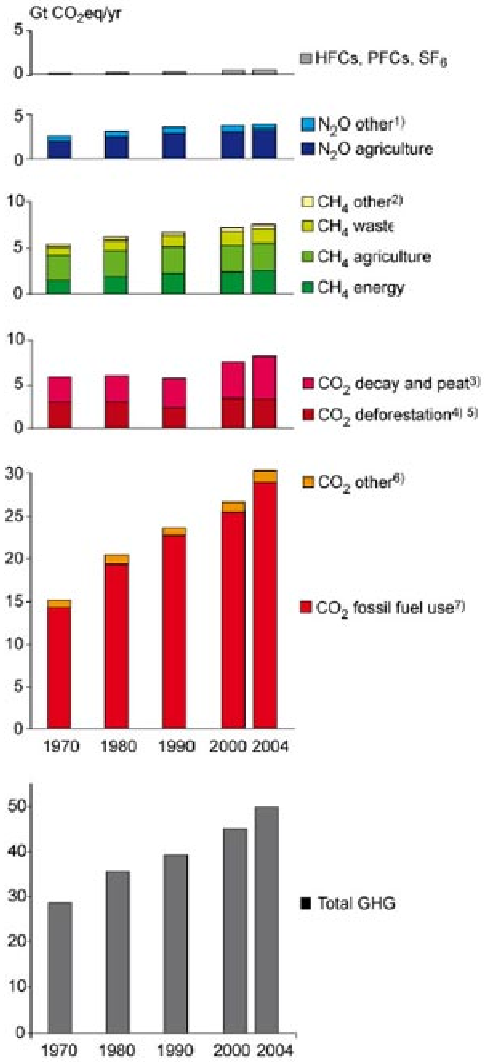
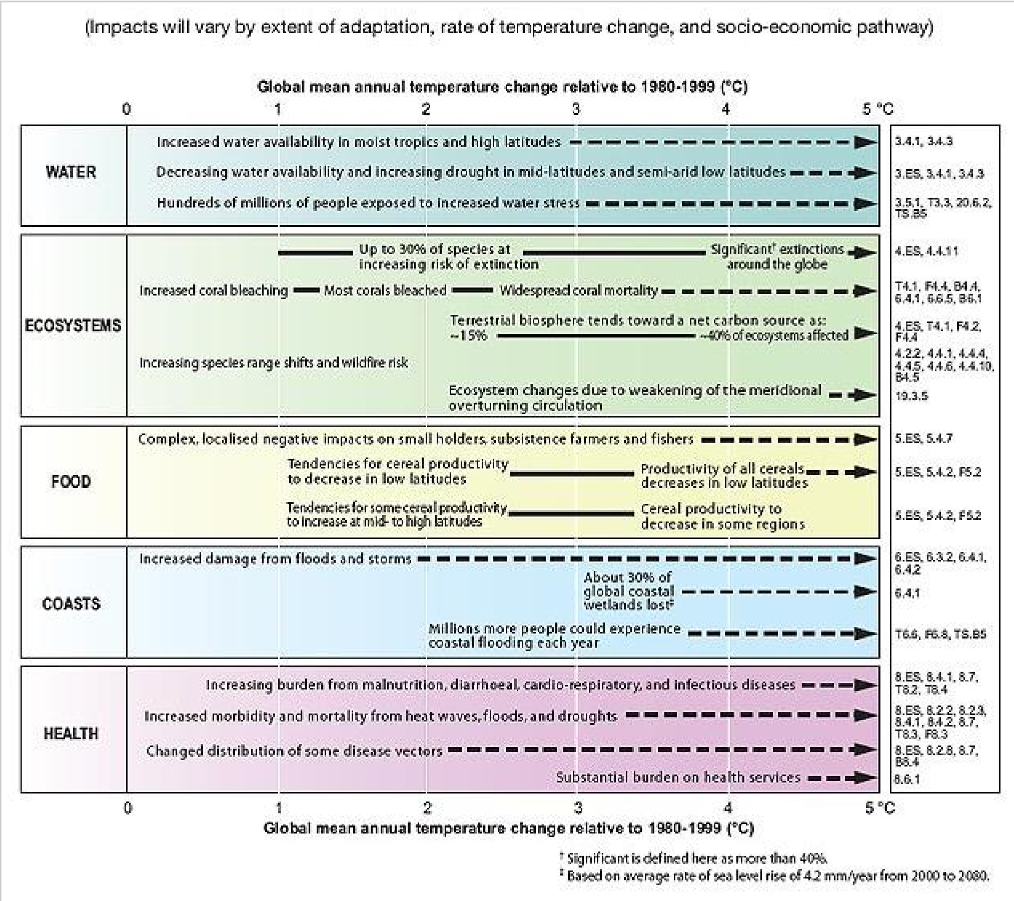


Figure SPM 1: Global Warming Potential (GWP) weighted global greenhouse gas emissions

Source: IPCC Climate Change 2007: IPCC Climate Change 2007: "Mitigation, Summary for Policymakers" (2007) [see http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_wg3_report_mitigation_of_climate_change.htm], p4

Annex 3:

Figure SPM-2. (WGII) Key impacts as a function of increasing global average temperature change



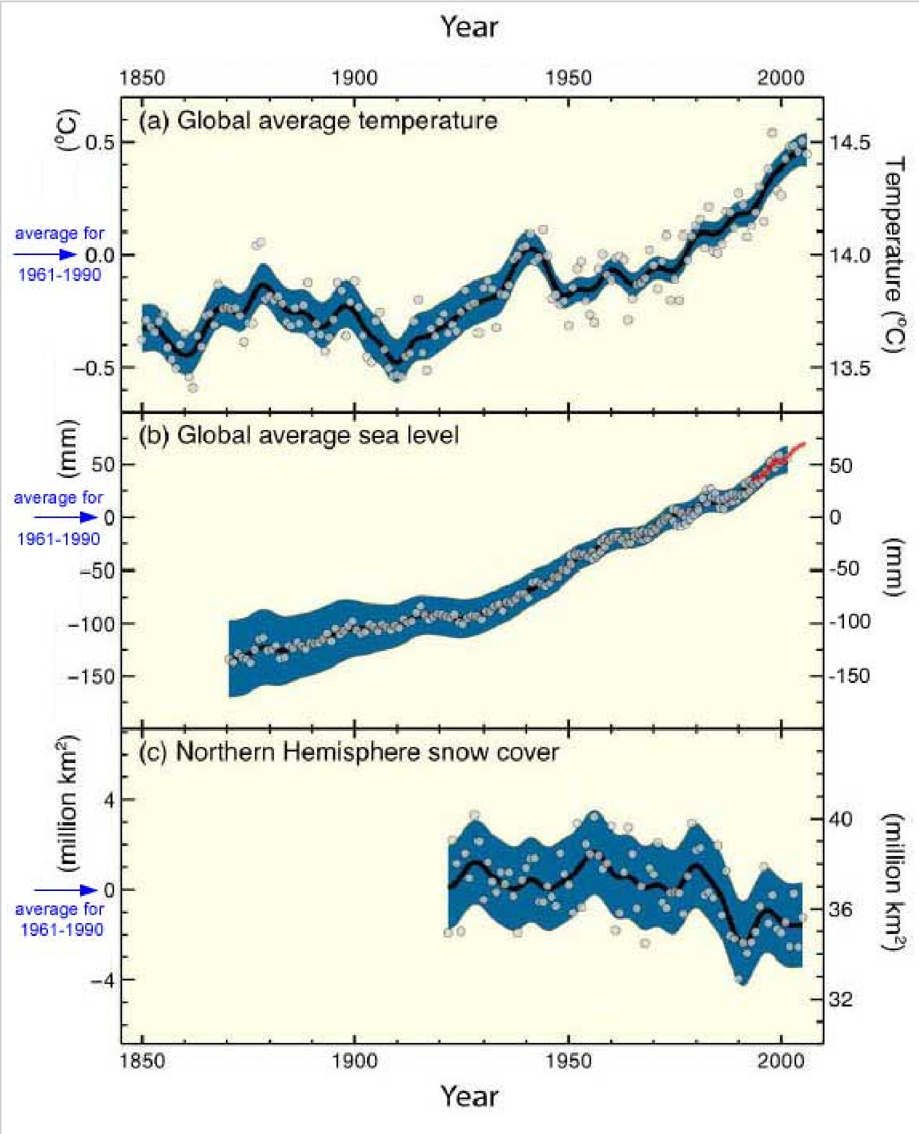
Illustrative examples of global impacts projected for climate changes (and sea-level and atmospheric carbon dioxide where relevant) associated with different amounts of increase in global average surface temperature in the 21st century. [T20.7] The black lines link impacts, dotted arrows indicate impacts continuing with increasing temperature. Entries are placed so that the left hand side of text indicates approximate onset of a given impact. Quantitative entries for water scarcity and flooding represent the additional impacts of climate change relative to the conditions projected across the range of SRES scenarios A1FI, A2, B1 and B2 (see Endbox 3). Adaptation to climate change is not included in these estimations. All entries are from published studies recorded in the chapters of the Assessment. Sources are given in the right hand column of the Table. Confidence levels for all statements are high.

Source: IPCC Climate Change 2007: Impacts, Adaptation and Vulnerability, Summary for Policymakers (2007) [see http://www.gtp89.dial.pipex.com/spm.pdf], p16

Annex 4:

Figure SPM-3. (WGI) Changes in Temperatures, Sea Level and Snow Cover between 1850 and 2010

Observed changes in (a) global average surface temperature; (b) global average sea level rise from tide gauge (blue) and satellite (red) data and (c) Northern Hemisphere snow cover for March-April. All changes are relative to corresponding averages for the period 1961-1990. Smoothed curves represent decadal averaged values while circles show yearly values. The shaded areas are the uncertainty intervals estimated from a comprehensive analysis of known uncertainties (a and b) and from the time series (c).



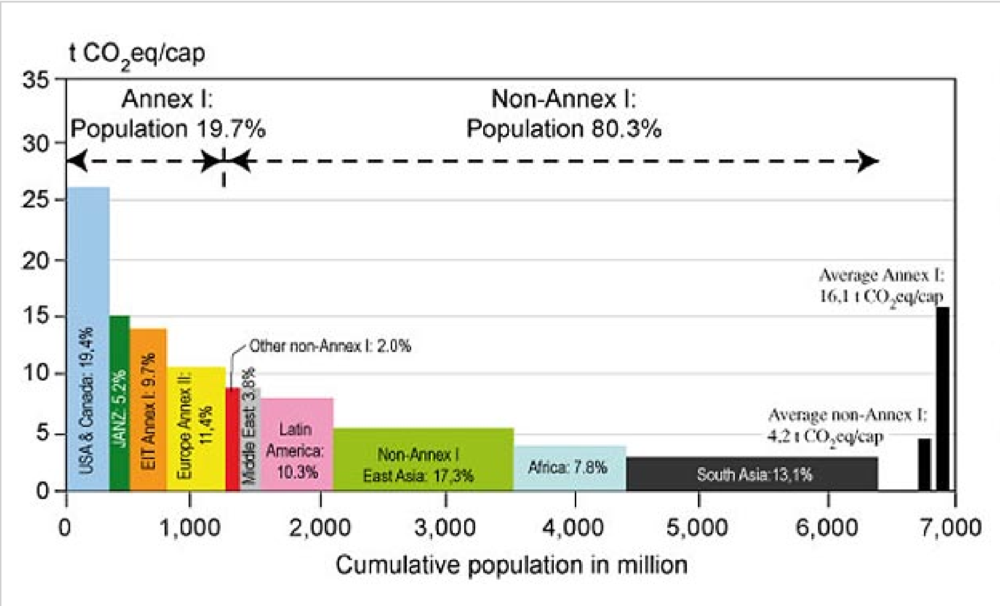
Source: based on IPCC Climate Change 2007: The Physical Science Basis, Summary for Policymakers (2007) [see http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_wg1_report_the_physical_science_basis.htm], p6

Annex 5:

Figure SPM-3a. (WGIII) Distribution of regional per capita greenhouse gas emissions

Year 2004 distribution of regional per capita GHG emissions (all Kyoto gases, including those from land-use) over the population of different country groupings.

The percentages in the bars indicate a regions share in global GHG emissions [Figure 1.4a].



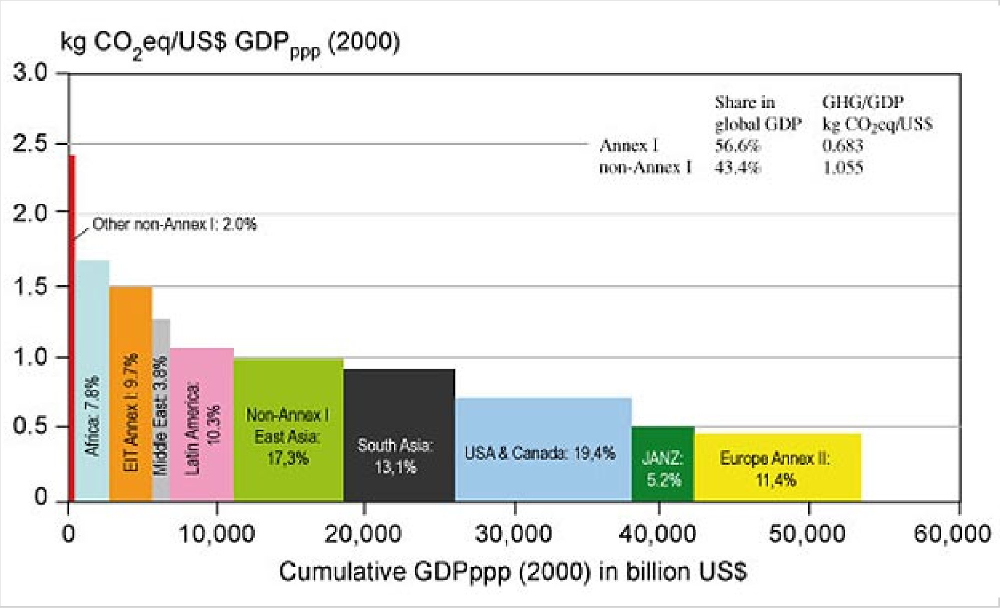
Source: IPCC Climate Change 2007: "Mitigation, Summary for Policymakers" (2007) [see http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_wg3_report_mitigation_of_climate_change.htm], p5

Annex 6:

Figure SPM-3b. (WGIII) Distribution of regional greenhouse gas emissions per unit of income

Year 2004 distribution of regional GHG emissions (all Kyoto gases, including those from land-use) per US$ of GDPppp over the GDPppp of different country groupings. The percentages in the bars indicate a regions share in global GHG emissions [Figure 1.4b].

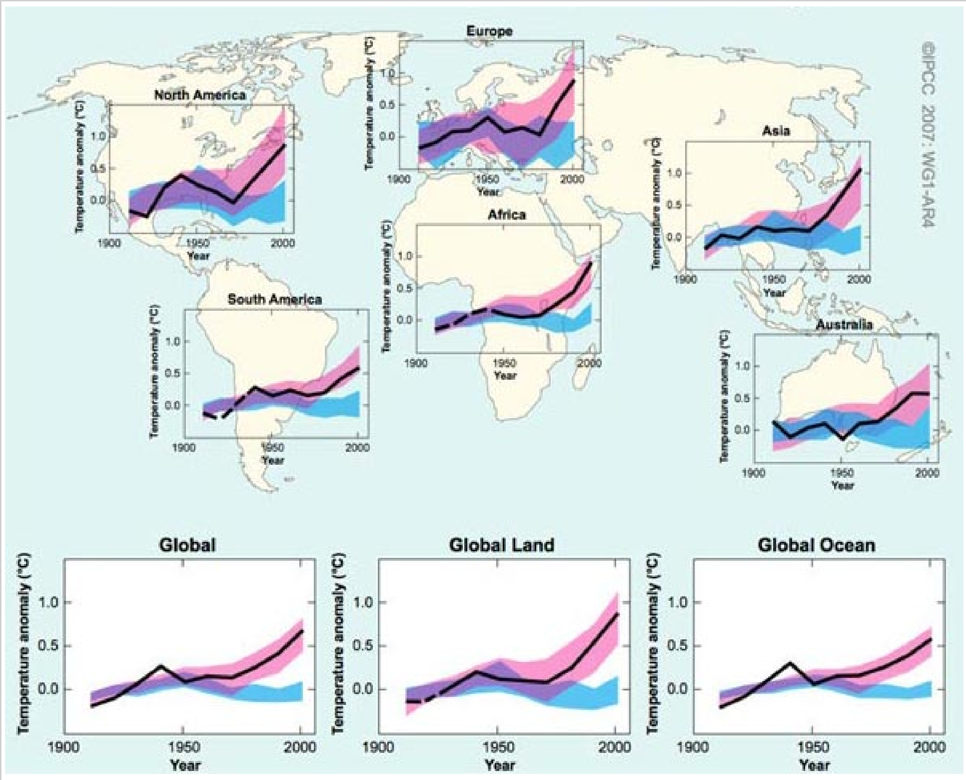
(GreenFacts note: GDPppp stands for Gross Domestic Product based on Purchasing Power Parity which adjusts the gross domestic product to account for the purchasing power of a country with respect to the purchasing power of US dollars. In other words, a basket of goods is cheaper in India than in USA, and the Gross Domestic Product based on Purchasing Power Parity accounts for this change.)



Source: IPCC Climate Change 2007: "Mitigation, Summary for Policymakers" (2007) [see http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_wg3_report_mitigation_of_climate_change.htm], p5

Annex 7:
Figure SPM-4. (WGI) Global and Continental Temperature Change

Comparison of observed continental- and global-scale changes in surface temperature with results simulated by climate models using natural and anthropogenic forcings. Decadal averages of observations are shown for the period 1906–2005 (black line) plotted against the centre of the decade and relative to the corresponding average for 1901–1950. Lines are dashed where spatial coverage is less than 50%. Blue shaded bands show the 5–95% range for 19 simulations from 5 climate models using only the natural forcings due to solar activity and volcanoes. Red shaded bands show the 5–95% range for 58 simulations from 14 climate models using both natural and anthropogenic forcings.

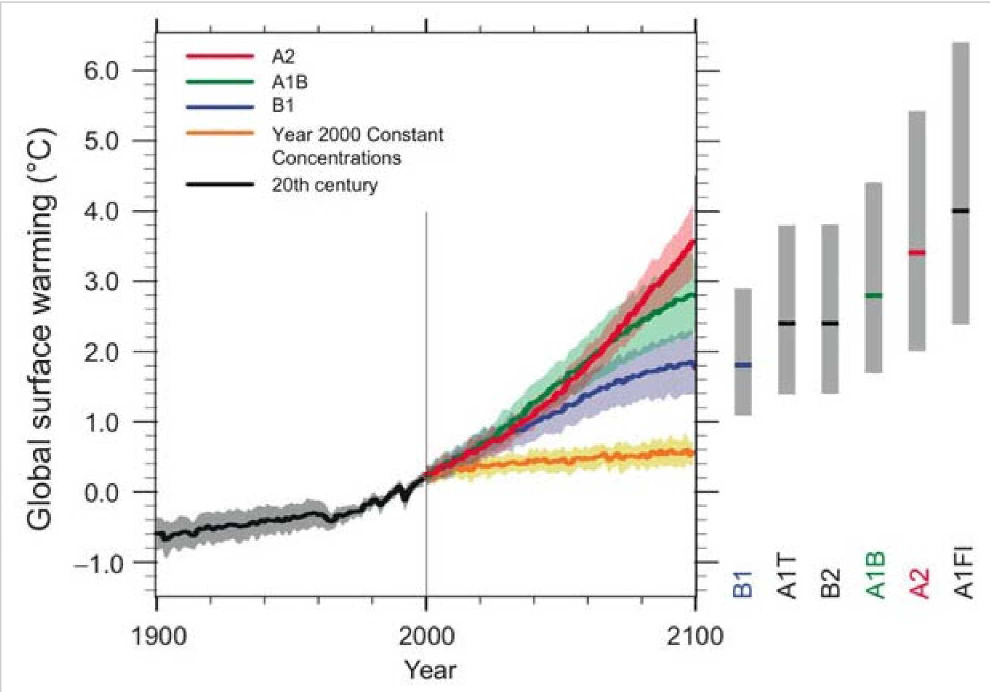


Source: IPCC Climate Change 2007: The Physical Science Basis, Summary for Policymakers (2007) [see http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_wg1_report_the_physical_science_basis.htm], p11

Annex 8:

Figure SPM-5. (WGI) Multi-model Averages and Assessed Ranges for Surface Warming

Solid lines are multi-model global averages of surface warming (relative to 1980-99) for the scenarios A2, A1B and B1, shown as continuations of the 20th century simulations. Shading denotes the plus/minus one standard deviation range of individual model annual averages. The orange line is for the experiment where concentrations were held constant at year 2000 values. The gray bars at right indicate the best estimate (solid line within each bar) and the likely range assessed for the six SRES marker scenarios. The assessment of the best estimate and likely ranges in the gray bars includes the AOGCMs in the left part of the figure, as well as results from a hierarchy of independent models and observational constraints. {Figures 10.4 and 10.29}



Source: IPCC Climate Change 2007: The Physical Science Basis, Summary for Policymakers (2007) [see http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_wg1_report_the_physical_science_basis.htm], p14

Annex 9:
Figure SPM-5a/5b. (WGIII) Estimated global economic mitigation potential

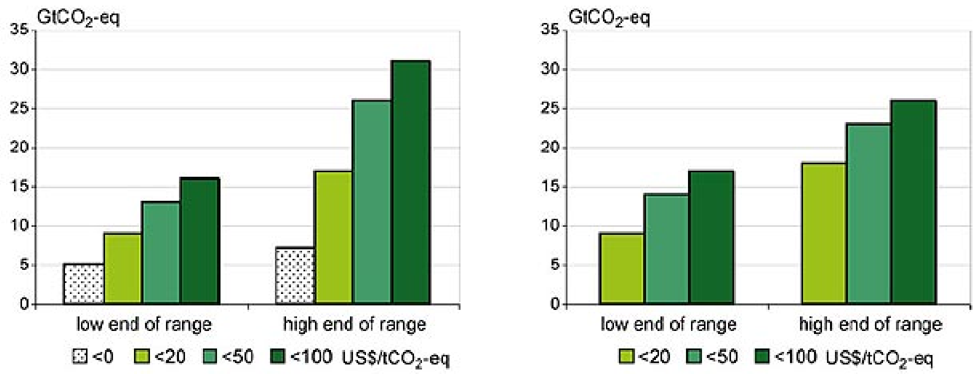


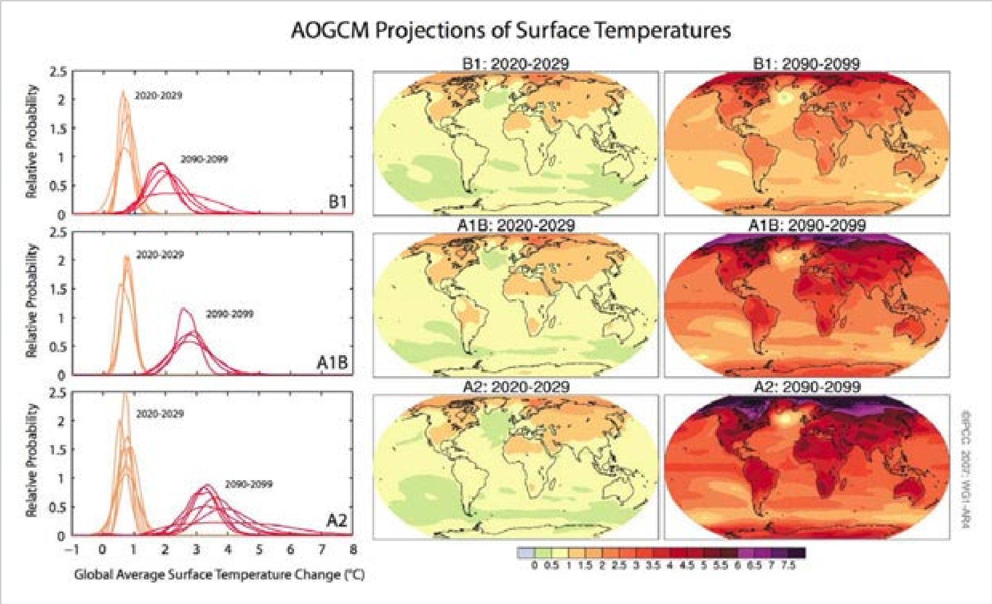
Figure SPM 5A:
Global economic mitigation potential in 2030 estimated from bottom-up studies (data from Table SPM 1)

Figure SPM 5B:
Global economic mitigation potential in 2030 estimated from top-down studies (data from Table SPM 2)

Source: IPCC Climate Change 2007: "Mitigation, Summary for Policymakers" [see http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_wg3_report_mitigation_of_climate_change.htm], p10

Annex 10:
Figure SPM-6. (WGI) AOGCM Projections of Surface Temperatures

Projected surface temperature changes for the early and late 21st century relative to the period 1980–1999. The central and right panels show the Atmosphere-Ocean General Circulation multi-Model average projections for the B1 (top), A1B (middle) and A2 (bottom) SRES scenarios averaged over decades 2020–2029 (center) and 2090–2099 (right). The left panel shows corresponding uncertainties as the relative probabilities of estimated global average warming from several different AOGCM and EMICs studies for the same periods. Some studies present results only for a subset of the SRES scenarios, or for various model versions. Therefore the difference in the number of curves, shown in the left- hand panels, is due only to differences in the availability of results. {Figures 10.8 and 10.28}



Source: IPCC Climate Change 2007: The Physical Science Basis, Summary for Policymakers (2007) [see http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_wg1_report_the_physical_science_basis.htm], p15

Annex 11:

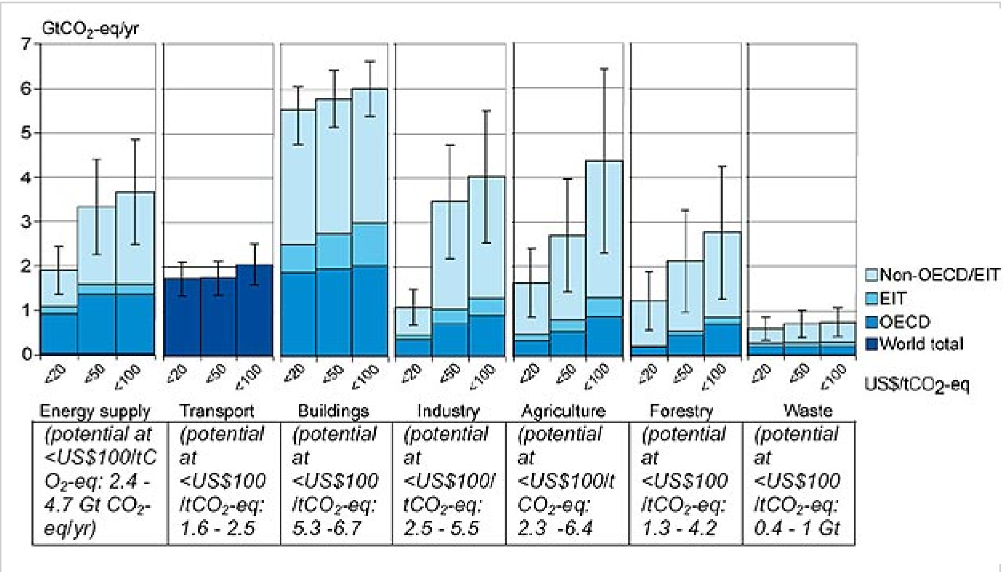
Figure SPM-6. (WGIII) Estimated economic mitigation potential in 2030 as a function of carbon price

Estimated sectoral economic potential for global mitigation for different regions as a function of carbon price in 2030 from bottom-up studies, compared to the respective baselines assumed in the sector assessments. A full explanation of the derivation of this figure is found in 11.3.

(GreenFacts note: The mitigation potential is expressed in Giga tonnes of CO_2 equivalent per year.

1 Giga tonne = 1 000 000 000 tonnes.

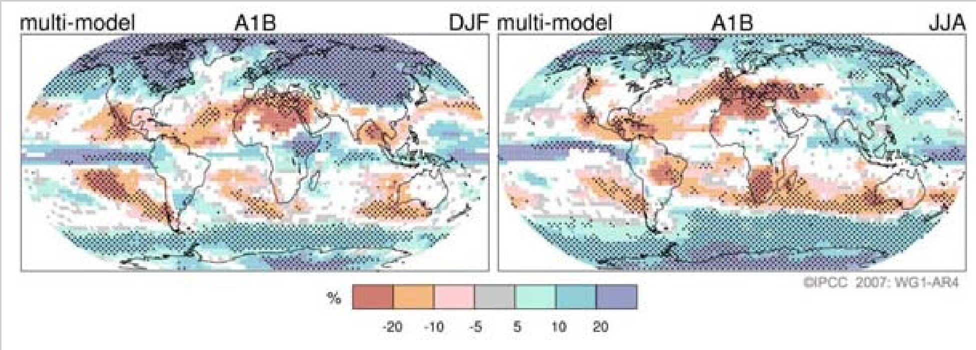
The economic mitigation potential for a “carbon price” of up to 20 USD, up to 50 USD and up to 100 USD was considered for each sector)



Source: IPCC Climate Change 2007: "Mitigation, Summary for Policymakers" [see http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_wg3_report_mitigation_of_climate_change.htm], p11

Annex 12:
Figure SPM-7. (WGI) Projected Patterns of Precipitation Changes

Relative changes in precipitation (in percent) for the period 2090–2099, relative to 1980–1999. Values are multi-model averages based on the SRES A1B scenario for December to February (left) and June to August (right). White areas are where less than 66% of the models agree in the sign of the change and stippled areas are where more than 90% of the models agree in the sign of the change.



Source: IPCC Climate Change 2007: The Physical Science Basis, Summary for Policymakers (2007) [see http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_wg1_report_the_physical_science_basis.htm], p16

Annex 13:

Figure SPM-8. (WGIII) Relationship between stabilization scenario categories and equilibrium global mean temperature change

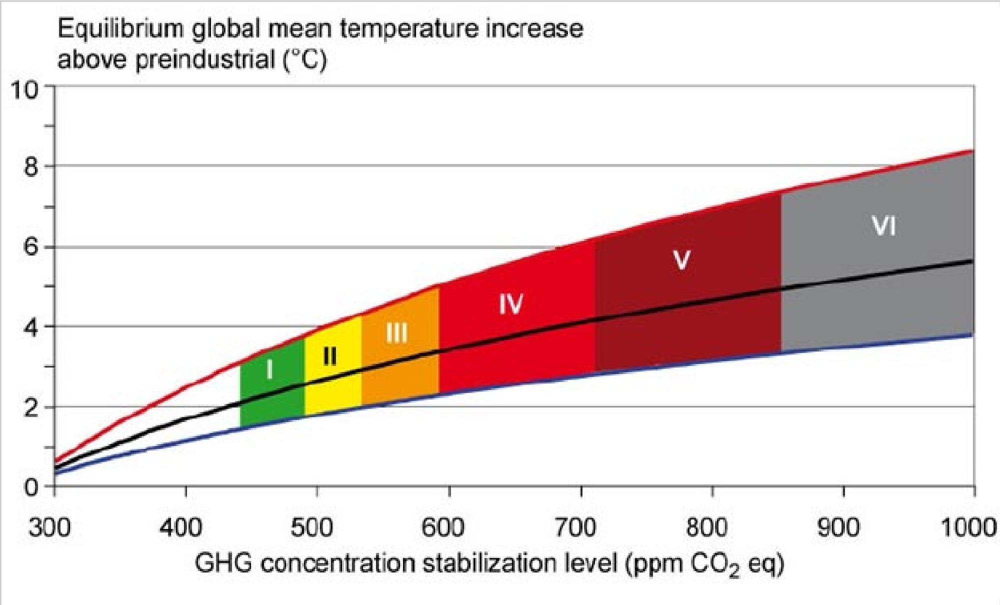
Stabilization scenario categories as reported in Figure SPM.7 (coloured bands) and their relationship to equilibrium global mean temperature change above pre- industrial, using

(i) “best estimate” climate sensitivity of 3°C (black line in middle of shaded area),

(ii) upper bound of likely range of climate sensitivity of 4.5°C (red line at top of shaded area)

(iii) lower bound of likely range of climate sensitivity of 2°C (blue line at bottom of shaded area).

Coloured shading shows the concentration bands for stabilization of greenhouse gases in the atmosphere corresponding to the stabilization scenario categories I to VI as indicated in Figure SPM.7. The data are drawn from AR4 WGI, Chapter 10.8.



Source: IPCC Climate Change 2007: "Mitigation, Summary for Policymakers" [see http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_wg3_report_mitigation_of_climate_change.htm], p17

Annex 14:

Parties & Observers of the UNFCCC

Annex I

Parties include the industrialized countries that were members of the OECD (Organisation for Economic Co-operation and Development) in 1992, plus countries with economies in transition (the EIT Parties), including the Russian Federation, the Baltic States, and several Central and Eastern European States.

Annex II

Parties consist of the OECD members of Annex I, but not the EIT Parties. They are required to provide financial resources to enable developing countries to undertake emissions reduction activities under the Convention and to help them adapt to adverse effects of climate change. In addition, they have to "take all practicable steps" to promote the development and transfer of environmentally friendly technologies to EIT Parties and developing countries. Funding provided by Annex II Parties is channelled mostly through the Convention's financial mechanism.

Non-Annex I

Parties are mostly developing countries. Certain groups of developing countries are recognized by the Convention as being especially vulnerable to the adverse impacts of climate change, including countries with low-lying coastal areas and those prone to desertification and drought. Others (such as countries that rely heavily on income from fossil fuel production and commerce) feel more vulnerable to the potential economic impacts of climate change response measures. The Convention emphasizes activities that promise to answer the special needs and concerns of these vulnerable countries, such as investment, insurance and technology transfer.

The 48 Parties, classified as least developed countries (LDCs) by the United Nations, are given special consideration under the Convention on account of their limited capacity to respond to climate change and adapt to its adverse effects. Parties are urged to take full account of the special situation of LDCs when considering funding and technology-transfer activities.

Source & © http://unfccc.int/parties_and_observers/items/2704.php [see http://unfccc.int/parties_and_observers/items/2704.php]

Annex 15:

Table SPM-1. (WGI) Observed rate of sea level rise and estimated contributions from different sources.

Source of sea level rise	Rate of sea level rise (mm per year)	
	1961 – 2003	1993 – 2003
Thermal expansion	0.42 ± 0.12	1.6 ± 0.5
Glaciers and ice caps	0.50 ± 0.18	0.77 ± 0.22
Greenland ice sheet	0.05 ± 0.12	0.21 ± 0.07
Antarctic ice sheet	0.14 ± 0.41	0.21 ± 0.35
Sum of individual climate contributions to sea level rise	**1.1 ± 0.5**	**2.8 ± 0.7**
Observed total sea level rise	1.8 ± 0.5[a]	3.1 ± 0.7[a]
Difference (Observed minus sum of estimated climate contributions)	0.7 ± 0.7	0.3 ± 1.0

Table note:
[a] Data prior to 1993 are from tide gauges and after 1993 are from satellite altimetry.

Source: IPCC Climate Change 2007: The Physical Science Basis, Summary for Policymakers (2007) [see http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_wg1_report_the_physical_science_basis.htm], p7

Annex 16:

Table SPM-1. (WGII) Examples of possible impacts of climate change due to changes in extreme weather and climate events

based on projections to the mid- to late 21st century. These do not take into account any changes or developments in adaptive capacity. Examples of all entries are to be found in chapters in the full Assessment (see source at top of columns). The first two columns of the table (shaded yellow) are taken directly from the Working Group I Fourth Assessment (Table SPM-2). The likelihood estimates in Column 2 relate to the phenomena listed in Column 1.

Phenomenon[a] and direction of trend	Likelihood of future trends based on projections for 21st century using SRES scenarios	Examples of major projected impacts by sector			
		Agriculture, forestry and ecosystems [4.4, 5.4]	**Water ressources [3.4]**	**Human health [8.2, 8.4]**	**Industry, settlement and society [7.4]**
Over most land areas, warmer and fewer cold days and nights, warmer and more frequent hot days and nights	Virtually certain[b]	Increased yields in colder environments; decreased yields in warmer environments; increased insect outbreaks	Effects on water resources relying on snow melt; effects on some water supplies	Reduced human mortality from decreased cold exposure	Reduced energy demand for heating; increased demand for cooling; declining air quality in cities; reduced disruption to transport due to snow, ice; effects on winter tourism
Warm spells/heat waves. Frequency increases over most land areas	Very likely	Reduced yields in warmer regions due to heat stress; increased danger of wildfire	Increased water demand; water quality problems, e.g., algal blooms	Increased risk of heat-related mortality, especially for the elderly, chronically sick, very young and socially- isolated	Reduction in quality of life for people in warm areas without appropriate housing; impacts on the elderly, very young and poor
Heavy precipitation events. Frequency increases over most areas	Very likely	Damage to crops; soil erosion, inability to cultivate land due to waterlogging of soils	Adverse effects on quality of surface and groundwater; contamination of water supply; water scarcity may be relieved	Increased risk of deaths, injuries and infectious, respiratory and skin diseases	Disruption of settlements, commerce, transport and societies due to flooding; pressures on urban and rural infrastructures; loss of property
Area affected by drought increases	Likely	Land degradation; lower yields/crop damage and failure; increased livestock deaths; increased risk of wildfire	More widespread water stress	Increased risk of food and water shortage; increased risk of malnutrition; increased risk of water- and food- borne diseases	Water shortages for settlements, industry and societies; reduced hydropower generation potentials; potential for population migration
Intense tropical cyclone activity increases	Likely	Damage to crops; windthrow (uprooting) of trees; damage to coral reefs	Power outages causing disruption of public water supply	Increased risk of deaths, injuries, water- and food- borne diseases; post-traumatic stress disorders	Disruption by flood and high winds; withdrawal of risk coverage in vulnerable areas by private insurers, potential for population migrations, loss of property
Increased incidence of extreme high sea level (excludes tsunamis)[c]	Likely [d]	Salinisation of irrigation water, estuaries and freshwater systems	Decreased freshwater availability due to saltwater intrusion	Increased risk of deaths and injuries by drowning in floods; migration- related health effects	Costs of coastal protection versus costs of land-use relocation; potential for movement of populations and infrastructure; also see tropical cyclones above

a See Working Group I Fourth Assessment Table 3.7 for further details regarding definitions.
b Warming of the most extreme days and nights each year.
c Extreme high sea level depends on average sea level and on regional weather systems. It is defined as the highest 1% of hourly values of observed sea level at a station for a given reference period.
d In all scenarios, the projected global average sea level at 2100 is higher than in the reference period [Working Group I Fourth Assessment 10.6]. The effect of changes in regional weather systems on sea level extremes has not been assessed.

Source: IPCC Climate Change 2007: Impacts, Adaptation and Vulnerability, Summary for Policymakers (2007) [see http://www.gtp89.dial.pipex.com/spm.pdf], p18

Annex 17:

Table SPM-3. (WGI) Projected globally averaged surface warming and sea level rise at the end of the 21st century.

Case	Temperature Change (°C at 2090-2099 relative to 1980-1999) [a]		Sea Level Rise (m at 2090-2099 relative to 1980-1999)
	Best estimate	*Likely* range	Model-based range excluding future rapid dynamical changes in ice flow
Constant Year 2000 concentrations [b]	0.6	0.3 – 0.9	NA
B1 scenario	1.8	1.1 – 2.9	0.18 – 0.38
A1T scenario	2.4	1.4 – 3.8	0.20 – 0.45
B2 scenario	2.4	1.4 – 3.8	0.20 – 0.43
A1B scenario	2.8	1.7 – 4.4	0.21 – 0.48
A2 scenario	3.4	2.0 – 5.4	0.23 – 0.51
A1FI scenario	4.0	2.4 – 6.4	0.26 – 0.59

Table notes:
a These estimates are assessed from a hierarchy of models that encompass a simple climate model, several Earth Models of Intermediate Complexity (EMICs), and a large number of Atmosphere-Ocean Global Circulaion Models (AOGCMs).
b Year 2000 constant composition is derived from AOGCMs only.
NA = not available

Source: IPCC Climate Change 2007: "Mitigation, Summary for Policymakers" [see http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_wg3_report_mitigation_of_climate_change.htm], p10

Annex 18:

Table SPM-3. (WGIII)

Key mitigation technologies and practices by sector. Sectors and technologies are listed in no particular order. Non-technological practices, such as lifestyle changes, which are cross-cutting, are not included in this table (but are addressed in paragraph 7 in this SPM).

Sector	Key mitigation technologies and practices currently commercially available.	Key mitigation technologies and practices projected to be commercialized before 2030.
Energy Supply [4.3, 4.4]	Improved supply and distribution efficiency; fuel switching from coal to gas; nuclear power; renewable heat and power (hydropower, solar, wind, geothermal and bioenergy); combined heat and power; early applications of CCS (e.g. storage of removed $CO_2$from natural gas)	Carbon Capture and Storage (CCS) for gas, biomass and coal-fired electricity generating facilities; advanced nuclear power; advanced renewable energy, including tidal and waves energy, concentrating solar, and solar PV.
Transport [5.4]	More fuel efficient vehicles; hybrid vehicles; cleaner diesel vehicles; biofuels; modal shifts from road transport to rail and public transport systems; non-motorised transport (cycling, walking); land-use and transport planning	Second generation biofuels; higher efficiency aircraft; advanced electric and hybrid vehicles with more powerful and reliable batteries
Buildings [6.5]	Efficient lighting and daylighting; more efficient electrical appliances and heating and cooling devices; improved cook stoves, improved insulation ; passive and active solar design for heating and cooling; alternative refrigeration fluids, recovery and recycle of fluorinated gases	Integrated design of commercial buildings including technologies, such as intelligent meters that provide feedback and control; solar PV integrated in buildings
Industry [7.5]	More efficient end-use electrical equipment; heat and power recovery; material recycling and substitution; control of non-CO_2gas emissions; and a wide array of process-specific technologies	Advanced energy efficiency; CCS for cement, ammonia, and iron manufacture; inert electrodes for aluminium manufacture
Agriculture [8.4]	Improved crop and grazing land management to increase soil carbon storage; restoration of cultivated peaty soils and degraded lands; improved rice cultivation techniques and livestock and manure management to reduce CH_4 emissions; improved nitrogen fertilizer application techniques to reduce N_2O emissions; dedicated energy crops to replace fossil fuel use; improved energy efficiency	Improvements of crops yields
Forestry/forests [9.4]	Afforestation; reforestation; forest management; reduced deforestation; harvested wood product management; use of forestry products for bioenergy to replace fossil fuel use	Tree species improvement to increase biomass productivity and carbon sequestration. Improved remote sensing technologies for analysis of vegetation/ soil carbon sequestration potential and mapping land use change
Waste [10.4]	Landfill methane recovery; waste incineration with energy recovery; composting of organic waste; controlled waste water treatment; recycling and waste minimization	Biocovers and biofilters to optimize CH_4 oxidation

Source: IPCC Climate Change 2007: Working Group III Report "Mitigation of Climate Change, Summary for Policymakers" [see http://www.ipcc.ch/SPM040507.pdf], p14

Annex 19:

Table SPM-4. (WGIII) Estimated global macro-economic costs in 2030[a] for least-cost trajectories towards different long-term stabilization levels.[b,c]

Stabilization levels	Median GDP reduction[d]	Range of GDP reduction[d,e]	Reduction of average annual GDP growth rates[d,f]
(ppm CO_2-eq)	(%)	(%)	(percentage points)
590-710	0.2	-0.6 – 1.2	< 0.06
535-590	0.6	0.2 – 2.5	< 0.1
445-535[g]	not available	< 3	< 0.12

a) For a given stabilization level, GDP reduction would increase over time in most models after 2030. Longterm costs also become more uncertain. [Figure 3.25]
b) Results based on studies using various baselines.
c) Studies vary in terms of the point in time stabilization is achieved; generally this is in 2100 or later.
d) This is global GDP based market exchange rates.
e) The median and the 10th and 90th percentile range of the analyzed data are given.
f) The calculation of the reduction of the annual growth rate is based on the average reduction during the period till 2030 that would result in the indicated GDP decrease in 2030.
g) The number of studies that report GDP results is relatively small and they generally use low baselines.

Source: IPCC Climate Change 2007: "Mitigation, Summary for Policymakers" [see http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_wg3_report_mitigation_of_climate_change.htm], p12

Annex 20:

Table SPM-5. (WGIII) Characteristics of post-TAR stabilization scenarios

[Table TS 2, 3.10][a]

Category	Radiative Forcing	CO_2 Concentration[c]	CO_2-eq Concentration[c]	Global mean temperature increase above pre-industrial at equilibrium, using "best estimate" climate sensitivity[b,c]	Peaking year for CO_2 emissions[d]	Change in global CO_2 emissions in 2050 (% of 2000 emissions)[d]	No. of assessed scenarios
	(W/m2)	(ppm)	(ppm)	(°C)	(year)	(%)	
I	2.5 – 3.0	350 – 400	445 – 490	2.0 – 2.4	2000 - 2015	-85 to -50	6
II	3.0 – 3.5	400 – 440	490 – 535	2.4 – 2.8	2000 - 2020	-60 to -30	18
III	3.5 – 4.0	440 – 485	535 – 590	2.8 – 3.2	2010 – 2030	-30 to +5	21
IV	4.0 – 5.0	485 – 570	590 – 710	3.2 – 4.0	2020 – 2060	+10 to +60	118
V	5.0 – 6.0	570 – 660	710 – 855	4.0 – 4.9	2050 – 2080	+25 to +85	9
VI	6.0 – 7.5	660 – 790	855 – 1130	4.9 – 6.1	2060 – 2090	+90 to +140	5
						Total	177

a) The understanding of the climate system response to radiative forcing as well as feedbacks is assessed in detail in the AR4 WGI Report. Feedbacks between the carbon cycle and climate change affect the required mitigation for a particular stabilization level of atmospheric carbon dioxide concentration. These 5 emission reductions to meet a particular stabilization level reported in the mitigation studies assessed here might be underestimated.
b) The best estimate of climate sensitivity is 3ºC [WG 1 SPM].
c) Note that global mean temperature at equilibrium is different from expected global mean temperature at the time of stabilization of GHG concentrations due to the inertia of the climate system. For the majority of scenarios assessed, stabilisation of GHG concentrations occurs between 2100 and 2150. Ranges correspond to the 15th to 85th percentile of the post-TAR scenario distribution. CO_2 emissions are shown so multi-gas scenarios can be compared with
d) 10 CO_2-only scenarios.

Source: IPCC Climate Change 2007: "Mitigation, Summary for Policymakers" [see http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_wg3_report_mitigation_of_climate_change.htm], p15

Annex 21:

Table SPM-6. (WGIII) Estimated global macro-economic costs in 2050 relative to the baseline for least-cost trajectories towards different long-term stabilization targets[a]

[3.3, 13.3]

Stabilization levels	Median GDP reduction[b]	Range of GDP reduction [b,c]	Reduction of average annual GDP growth rates[b,d]
(ppm CO_2-eq)	**(%)**	**(%)**	**(percentage points)**
590 - 710	0.5	-1 – 2	< 0.05
535 - 590	1.3	slightly negative – 4	< 0.1
445 - 535 [e]	not available	< 5.5	< 0.12

a) This corresponds to the full literature across all baselines and mitigation scenarios that provide GDP numbers.
b) This is global GDP based market exchange rates.
c) The median and the 10th and 90th percentile range of the analyzed data are given.
d) The calculation of the reduction of the annual growth rate is based on the average reduction during the 15 period until 2050 that would result in the indicated GDP decrease in 2050.
e) The number of studies is relatively small and they generally use low baselines. High emissions baselines generally lead to higher costs.

Source: IPCC Climate Change 2007: "Mitigation, Summary for Policymakers" [see http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_wg3_report_mitigation_of_climate_change.htm], p27

Annex 22:

Table SPM-7. (WGIII) Selected sectoral policies, measures and instruments that have shown to be environmentally effective in the respective sector in at least a number of national cases.

Sector	Policies[a], measures and instruments shown to be environmentally effective	Key constraints or opportunities
Energy supply [4.5]	Reduction of fossil fuel subsidies	Resistance by vested interests may make them difficult to implement
	Taxes or carbon charges on fossil fuels	
	Feed-in tariffs for renewable energy technologies	May be appropriate to create markets for low emissions technologies
	Renewable energy obligations	
	Producer subsidies	
Transport [5.5]	Mandatory fuel economy, biofuel blending and CO_2 standards for road transport	Partial coverage of vehicle fleet may limit effectiveness
	Taxes on vehicle purchase, registration, use and motor fuels, road and parking pricing	Effectiveness may drop with higher incomes
	Influence mobility needs through land use regulations, and infrastructure planning	Particularly appropriate for countries that are building up their transportation systems
	Investment in attractive public transport facilities and non-motorised forms of transport	
Buildings [6.8]	Appliance standards and labelling	Periodic revision of standards needed
	Building codes and certification	Attractive for new buildings. Enforcement can be difficult
	Demand-side management programmes	Need for regulations so that utilities may profit
	Public sector leadership programmes, including procurement	Government purchasing can expand demand for energy-efficient products
	Incentives for energy service companies (ESCOs)	Success factor: Access to third party financing
Industry [7.9]	Provision of benchmark information	May be appropriate to stimulate technology uptake. Stability of national policy important in view of international competitiveness
	Performance standards	
	Subsidies, tax credits	
	Tradable permits	Predictable allocation mechanisms and stable price signals important for investments
	Voluntary agreements	Success factors include: clear targets, a baseline scenario, third party involvement in design and review and formal provisions of monitoring, close cooperation between government and industry.
Agriculture [8.6, 8.7, 8.8]	Financial incentives and regulations for improved land management, maintaining soil carbon content, efficient use of fertilizers and irrigation	May encourage synergy with sustainable development and with reducing vulnerability to climate change, thereby overcoming barriers to implementation
Forestry/Forests [9.6]	Financial incentives (national and international) to increase forest area, to reduce deforestation, and to maintain and manage forests	Constraints include lack of investment capital and land tenure issues. Can help poverty alleviation.
	Land use regulation and enforcement	
Waste management [10.5]	Financial incentives for improved waste and wastewater management	May stimulate technology diffusion
	Renewable energy incentives or obligations	Local availability of low-cost fuel
	Waste management regulations	Most effectively applied at national level with enforcement strategies
a) Public RD&D investment in low emission technologies have proven to be effective in all sectors.		

Source: IPCC Climate Change 2007: "Mitigation, Summary for Policymakers" [see http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_wg3_report_mitigation_of_climate_change.htm], p20

Annex 23:

The Emission Scenarios of the IPCC Special Report on Emission Scenarios (SRES)

A1. The A1 storyline and scenario family describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies.

Major underlying themes are convergence among regions, capacity building and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. The A1 scenario family develops into three groups that describe alternative directions of technological change in the energy system. The three A1 groups are distinguished by their technological emphasis: fossil intensive (A1FI), non-fossil energy sources (A1T), or a balance across all sources (A1B) (where balanced is defined as not relying too heavily on one particular energy source, on the assumption that similar improvement rates apply to all energy supply and end use technologies).

A2. The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing population. Economic development is primarily regionally oriented and per capita economic growth and technological change more fragmented and slower than other storylines.

B1. The B1 storyline and scenario family describes a convergent world with the same global population, that peaks in mid-century and declines thereafter, as in the A1 storyline, but with rapid change in economic structures toward a service and information economy, with reductions in material intensity and the introduction of clean and resource efficient technologies. The emphasis is on global solutions to economic, social and environmental sustainability, including improved equity, but without additional climate initiatives.

B2. The B2 storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social and environmental sustainability. It is a world with continuously increasing global population, at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines. While the scenario is also oriented towards environmental protection and social equity, it focuses on local and regional levels.

An illustrative scenario was chosen for each of the six scenario groups A1B, A1FI, A1T, A2, B1 and B2. All should be considered equally sound.

The SRES scenarios do not include additional climate initiatives, which means that no scenarios are included that explicitly assume implementation of the United Nations Framework Convention on Climate Change or the emissions targets of the Kyoto Protocol.

Emission scenarios are not assessed in this Working Group One report of the IPCC. This box summarizing the SRES scenarios is taken fromthe TAR and has been subject to prior line by line approval by the Panel.

Source & © IPCC Climate Change 2007:
The Physical Science Basis, Summary for Policymakers (2007) [see http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_wg1_report_the_physical_science_basis.htm], p18

Partners for this publication

The Levels 1 & 2 are summaries written by GreenFacts with financial support from the **Swiss Agency for Development and Cooperation** (SDC) and the **Alliance of Communication for Sustainable Development** (COM+).

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Agency for Development and Cooperation SDC

Alliance of Communicators for Sustainable Development COM+