

Climate Change

Climate change is the world's greatest environmental challenge and it is clear that the emission of greenhouse gases, associated with industrialisation and economic growth from a world population that has increased six-fold in 200 years, is causing global warming at a rate that is unsustainable.

The Intergovernmental Panel on Climate Change (IPCC), Third Assessment Report (TAR) conclude that climate change due to human actions is already happening, and that future emissions of greenhouse gases were likely to raise global temperatures by between 1.4 and 5.8°C during this century and that without actions to reduce emissions, climate will continue to change, with increasingly adverse effects on the environment and human society. While warming at the low end of this range would likely be relatively less stressful, it would still be significant for some 'unique and valuable systems'. Warming at the high end of the range could have widespread catastrophic consequences, as a temperature change of 5–7°C on a globally-averaged basis is about the difference between an ice age and an interglacial.

In 1990 carbon dioxide levels were 354 parts per million – now they are at around 377 parts per million and still rising. Since 1990 global temperatures have increased by about 0.2°C and the ten warmest years in the global record have occurred. Absolute temperature records for the UK were broken in 2003 as we passed the 100°F mark. By 2001 the IPCC was able to say that 'there is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities'. Atmospheric carbon dioxide has increased by more than 30% in the past few centuries and it is undeniable that the cause is human activity, predominantly the burning of fossil fuels. To a lesser extent, deforestation and other land-use changes and industrial and agricultural activities like cement production and animal husbandry have also contributed to greenhouse gas buildups since 1800.

All countries contribute to the problem to varying degrees, but no one country can solve the problem by acting alone. Therefore an international approach is essential. We may not be able to do much to reduce climate change over the next few decades, but what we do now, will affect how much and how quickly the climate changes. The UK has already committed to a 60% reduction in carbon dioxide (CO₂) emissions by 2050. Since 1990, global emissions of CO₂ alone have increased by 20% and by 2010 without the Kyoto Protocol in place, emissions could have risen to 30% above 1990 levels. A radical change in how we generate and use energy will be needed, and there will not be just one solution, but a whole portfolio of measures. The world's largest current and future emitters all need to be involved in tackling climate change. Businesses must also play a central role in delivering a low carbon economy and to do so, industry and investors need the long term incentives to investment in new technology.

The International Energy Agency (IEA) World Energy Outlook 2004 predicts that CO₂ emissions will increase by 63% over 2002 levels by 2030, which is generally consistent with the IPCC emission scenarios, published in 2000. Therefore the world will, in the absence of urgent and strenuous mitigation actions in the next 20 years, almost certainly be committed to a temperature rise of between about 0.5°C and 2°C relative to today by 2050.

In addition, models suggest that delaying action would require greater action later for the same temperature target and that even a delay of 5 years could be significant. If action to reduce emissions is delayed by 20 years, rates of emission reduction may need to be 3 to 7 times greater to meet the same temperature target.

FACT: there has been an anomalous rise in global average surface temperatures since the time of the Industrial Revolution. The Earth's temperature is highly variable, with year-to-year changes often

masking the overall rise of approximately 0.7°C that has occurred since 1860, but the 20th century upward trend is obvious. Especially noticeable is the rapid rise at the end of the 20th century.

FACT: there has been a decrease in Arctic sea ice extent by 10 to 15% and in thickness by 40%; and a decrease in Arctic snow cover area by some 10% since satellite observations started in 1960.

In 1996, the European Council adopted a climate target that reads ‘the Council believes that global average temperatures should not exceed 2 degrees above pre-industrial level’. This target has since been reaffirmed by the EU on a number of occasions, such as March 2005. Furthermore, stabilisation of atmospheric concentrations of greenhouse gases, which keeps mean global surface temperatures at below 2°C, appears necessary if the worst damage to species and ecosystems is to be avoided.

The 1992 United Nations Framework Convention on Climate Change (UNFCCC) calls for the stabilization of greenhouse gases to ‘prevent dangerous anthropogenic interference with the climate system’. The Framework Convention further suggests that: ‘Such a level should be achieved within a time frame sufficient

- ⑥ To allow ecosystems to adapt naturally to climate change;
- ⑥ To ensure that food production is not threatened and;
- ⑥ To enable economic development to proceed in a sustainable manner’.

However, whilst all ecosystems will not respond equally to the changing climate, evidence that at least some are already being affected adversely would indicate that dangerous levels are being approached, as at least one species would appear to have become extinct due to recent, human-induced climate change: the golden toad of Costa Rica. However, simply because species are affected by climate change, it does not necessarily mean that the effects will be adverse; some may be beneficial. Neither does it necessarily follow that ecosystems will be threatened or lost, as different species and ecosystems will respond at different rates and extents to any particular temperature rise.

The European Climate Forum (ECF) symposium identified three concepts of danger:

- ⑥ **Determinative dangers** are, on their own, enough to define dangerous levels of climate change. The ECF’s list of determinative dangers resulting from climate change include: circumstances that could lead to global and unprecedented consequences, extinction of ‘iconic’ species or loss of entire ecosystems, loss of human cultures, water resource threats, and substantial increases in mortality levels, among others.
- ⑥ **Early warning dangers** are dangers already present in certain areas that are likely to spread and worsen over time with increased warming. These dangers could include Arctic Sea ice retreat, boreal forest fires, and increases in frequency of drought, and they could become determinative over time or taken together with other dangers.
- ⑥ **Regional dangers** are widespread dangers over a large region, most likely related to food security, water resources, infrastructure, or ecosystems. They are not considered determinative, as they are largely confined to a single region.

Adaptive capacity is highly important to lessening the potential future dangerous effects of climate change. Adaptation and alternative development pathways need to be taken into account in developing strategies to avoid dangerous anthropogenic climate change. This is particularly important if the potential impacts of climate change in Africa are to be avoided.

Globalisation and market forces will drive the developing countries to follow the same pattern practiced by the developed countries. However, demonstrated energy efficiency improvements under

the present market system in industrialised countries, are not enough to offset increases in demand caused by economic growth in developing countries. Efficiency improvements and alternative energy supply such as nuclear and renewables are of priority for developing countries to contribute their share to the effort of stabilisation. Major investment is needed in both mitigation and adaptation.

Due to anthropogenic greenhouse gas emissions, key components of the climate system are being increasingly stressed. The primary changes in climate and sea level will be relatively slow and steady. However, superimposed on these trends, there may well be abrupt and possibly irreversible changes that would have far more serious consequences, e.g.

- the melting of large ice sheets in Greenland and Antarctica, and
- the slow down or collapse of the ocean's thermohaline circulation.

In assessing what is 'dangerous' we have to look at every aspect of the impacts on health, agriculture, water resources, coastal areas, species and natural assets. In coastal areas, natural disasters will take place and we can certainly warn communities against them, but only if we have adequate and effective warning systems. But we must understand that natural disasters are going to take place no matter what.

The IPCC Third Assessment Report identified that the number of disasters of hydro-meteorological origin have increased significantly, along with an increase in precipitation in the mountains accompanied by melting of glaciers, increased incidence of floods, mud slides, and severe land slides. Humanity certainly can adapt to changes like deforestation, because we have the means by which we can carry out afforestation, i.e. we can plant trees in areas wherever deforestation is taking place. But can we bring back the loss of biodiversity which is taking place?

Based on temperature forecasts, the IPCC has produced a list of likely effects of climate change, most of which are negative. These include:

- more frequent heat waves (and less frequent cold spells);
- more intense storms (hurricanes, tropical cyclones, etc.) and a surge in weather-related damage;
- increased intensity of floods and droughts;
- warmer surface temperatures, especially at higher latitudes;
- more rapid spread of disease;
- loss of farming productivity in many regions and/or movement of farming to other regions, most at higher latitudes;
- rising sea levels, which could inundate coastal areas and small island nations; and
- species extinction and loss of biodiversity.

On the positive side, there is

- longer growing seasons at high latitudes and
- the opening of commercial shipping in the normally ice-plagued Arctic.

Tighter political climate protection targets are therefore needed to cope with the greater vulnerability of species and ecosystems. The history of the Earth's climate has been characterized by many changes. But the extent and the rate of current climate change now exceeds most natural variation.

The Antarctic Ice Sheet and Sea Level Rise

Antarctica is the fifth largest continent and is the Earth's highest, windiest, coldest, and driest land mass. Its surface is 99.7% covered by a vast ice sheet with an average thickness of 2 km and a total

volume of 25M km³. The weight of the ice depresses the Earth's crust beneath it by 0.8 km and were it to melt, global sea level would rise by 57 m. Even a small percentage ice loss would have a significant impact on low-lying coastal regions worldwide.

More generally, the IPCC TAR considered the Antarctic ice sheet overall to be a net minor player in the contemporary 1.8 mm/y mean sea level rise, and in its projections for accelerated rise over the next century. It stated:

‘The Antarctic ice sheet is likely to gain mass because of greater precipitation ...’

Conclusions

- (a) The East Antarctic Ice Sheet is growing, apparently as a result of increased precipitation, as predicted by the IPCC TAR.
 - (b) The Antarctic ice in the Peninsula is responding strongly to the regional climatic warming.
 - (c) The extension of ice stream tributaries deep into the ice sheet interior might allow for more rapid drainage than had previously been appreciated.
 - (d) The disintegration of ice shelves can result in a significant acceleration of the feed glaciers, although it is not known yet whether this can be sustained.
 - (e) The Amundsen Sea Embayment region of the West Antarctic Ice Sheet (WAIS) is exhibiting strong discharge, which, if sustained over the long-term, could result in a greater contribution to sea level rise than accounted for in the IPCC projections.
- Therefore, the issue of the contribution of Antarctica to global sea level rise needs to be reassessed.

The Greenland Ice Sheet and Sea level rise

If the Greenland ice sheet were to melt completely, it would raise global sea levels by around 7 m and studies suggest that complete or partial deglaciation of Greenland may be triggered for even quite modest stabilisation targets. Additionally, the ice sheet can only persist if the loss of ice by ablation and iceberg discharge is balanced by accumulation.

Overall, sea level is reported to have risen during the 20th century by between 1 and 2 mm per year and the IPCC Third Assessment Report (TAR) suggest the projected rise from 1990 to 2100 was 9 to 88 cm with a mid estimate of 48cm). Consequently, there is a concern that future increases in sea level will lead to sizeable coastal impacts and without upgraded sea defences, this would inundate many villages, towns and cities around the world; e.g.

- Bangladesh - a low-lying country which is particularly vulnerable to sea level rise and the impacts that this would bring.
- Egypt - a country that would lose 12–15% of its alluvial land.

In 1990, it was estimated that 1.2 billion (or 23%) of the world's population lived in the near-coastal zone, at densities about three times higher than the global mean. The highest population density occurs below 20-m elevation. Net migration to the coast is also widely reported and under the Special Report on Emissions Scenarios, the near coastal population could increase to 2.4 to 5.2 billion people by the 2080s, living in dominantly urban settings.

The overall main causes of increased global average sea level during the 21st century and beyond, are likely to be thermal expansion of the ocean, melting of small glaciers, and the melting of the Greenland and Antarctic ice sheets, with fresh water from Greenland presenting a major concern, as it could help trigger a slowdown or collapse of the ocean thermohaline circulation, in turn leading to

significant cooling over much of the northern hemisphere. Furthermore, Sea level is likely to continue rising for more than 1000 years after greenhouse gas concentrations have been stabilised.

Arctic Climate Impact Assessment

The Arctic is extremely vulnerable to observed and projected climate change impacts and is now experiencing some of the most rapid and severe climate change on Earth and the Arctic average temperature has risen at almost twice the rate as that of the rest of the world in the past few decades.

Over the next 100 years, climate change is expected to accelerate, due to ongoing increases in concentrations of greenhouse gases in the Earth's atmosphere, thus contributing to major physical, ecological, social, and economic changes, many of which have already begun. While greenhouse gas emissions do not primarily originate in the Arctic, they are projected to bring wide ranging changes and impacts to the Arctic. These arctic changes will, in turn, impact the planet as a whole, therefore people outside the Arctic have a great stake in what is happening there. For example, climatic processes unique to the Arctic have significant effects on global and regional climate. The Arctic also provides important natural resources to the rest of the world (such as oil, gas, and fish) that will be affected by climate change.

Whether a particular impact is perceived as negative or positive often depends on one's interests, for instance, the reduction in sea ice is very likely to have devastating consequences for polar bears, ice-dependent seals, and local people for whom these animals are a primary food source. On the other hand though, reduced sea ice is likely to increase marine access to the region's resources, expanding opportunities for shipping.

It is important to realize that changes in the Arctic will not only affect people and species locally: they have global consequences as well. In other words, biodiversity on a global scale may be threatened as local habitats for migratory species disappear. Arctic tundra is the main breeding habitat for more than 20 million individual geese and waders that over-winter in the mid-latitudes of Europe, Asia, and North America. Many of these species will be severely impacted by the loss of tundra ecosystems projected for a rise in temperatures of 2°C.

The Risk of a Collapse of the Atlantic Thermohaline Circulation

The Atlantic Thermohaline Circulation (ATHC) is driven by temperature (thermo) and salt (haline) forcing over the ocean surface. The ATHC currently transports poleward about 1 petawatt (10¹⁵ W) of heat, that is, a million billion Watts. As a result of this enormous northward heat transport, Europe is up to 8°C warmer than other longitudes at its latitude, with the largest effect in winter. It is this comparatively mild European climate, as well as the inter-related climates elsewhere, that has created concern about the possible effect of a collapse of the ATHC, in terms of political and economic instability and the onset of an ice age.

If this circulation were to collapse, as it appears to have done in the past, the climate of Europe, and the whole Northern Hemisphere, could change rapidly. This event is normally classified as a 'low probability/high impact' event. However, comprehensive Global Climate Models (GCMs) suggest a slowdown of the ATHC in response to global warming over the next century, in the range 0–50%. The amount of ATHC change is likely to be an important factor in determining the magnitude of warming

throughout the Northern hemisphere but no GCMs have shown a complete shutdown, or a net cooling over land areas, hence a shutdown during the 21st century must be regarded as unlikely.

Acidification of the Oceans

The world's oceans contain an enormous reservoir of carbon, greater than either the terrestrial or atmospheric systems and the oceans have taken up around 50% of the total carbon dioxide (CO₂) released to the atmosphere via fossil fuel emissions and other human activities in the last 200 years. Whilst this has slowed the progress of climate change, CO₂ ultimately results in acidification of the marine environment. CO₂ in the atmosphere is relatively inert, but when dissolved in seawater it becomes highly reactive due to its reaction with seawater to form carbonic acid, and takes part in a range of chemical, physical, biological and geological reactions.

Ocean pH has already fallen and will continue to do so as the oceans take up more anthropogenic CO₂. Even though acidification has only recently emerged as a serious issue, it has the potential to affect a wide range of marine biogeochemical and ecological processes. Plus, the oceans' capacity to absorb more CO₂ decreases as they take up CO₂.

There has been an increase in atmospheric carbon dioxide from 280 ppm in AD1800 to 380 ppm at the present day, which is due to a supply of anthropogenic CO₂ to the atmosphere. Predictions of atmospheric CO₂ concentrations, due to the unrestricted release of fossil fuel, by 2100 are 700 ppm and by 2300 are 1900 ppm.

ISSUE: The effect of high CO₂ on tropical coral reefs has received particular attention because calcification rates in corals decline under elevated CO₂ conditions. Predictions are that coral calcification rates may decrease by 21–40% over the period 1880–2065 in response to changes in atmospheric CO₂ concentrations. Following this, a reduction in coral calcification can result in declining coral cover and loss of the reef environments which is a serious threat, because Coral reefs are oases of high productivity, such that they produce 10–12% of the fish caught in the tropics and 20–25% of the fish caught by developing nations. Such issues are important as the sea contributes about 90% of the animal protein consumed by many Pacific Island countries.

The potential impacts of Global Climate Change at various Annual Mean Global Temperatures

Summary of the climate change impacts on the earth system, human systems and ecosystems for different amounts of Annual Global Mean Temperature Change (AGMTC) relative to pre-industrial times. Currently, temperature has already risen by AGMTC of 0.6°C and effects of climate change are already being observed globally.

At AGMTC of 1°C, world oceans and Arctic ecosystems are damaged.

At AGMTC of 1.5°C Greenland Ice Sheet melting begins.

At AGMTC of 2°C agricultural yields fall, billions experience increased water stress, additional hundreds of millions may go hungry, sea level rise displaces millions from coasts, malaria risks spread, Arctic ecosystems collapse and extinctions take off as regional ecosystems disappear. Serious human implications exist in Peru and Mahgreb.

At AGMTC of 2–3°C the Amazon and other forests and grasslands collapse.

At AGMTC of 3°C millions at risk to water stress, flood, hunger and dengue and malaria increase and few ecosystems can adapt.

The thermohaline circulation could collapse in the range AGMTC of 1–5°C, whilst the West Antarctic Ice Sheet may commence melting and Antarctic ecosystems may collapse. Increases in extreme weather are expected.

Climate Change and Water Resources: A Global Perspective

FACT: climate change will affect precipitation patterns

In some parts of the world – predominantly in high latitudes and some tropical regions – there will be additional rainfall, whilst in other large parts of the world, rainfall would decrease. Climate change therefore has the potential to increase water resource stresses through increasing flood risk in some areas and increasing the risk of shortage in others: some parts of the world may see increased flood risk in one season and increased risk of shortage during another.

The actual impacts of climate change on water resource availability depend not only on the assumed spatial pattern of climate change and, from the 2050s, the assumed rate of climate change, but also on the economic and demographic state of the world. (i.e. increasing population totals, changing patterns of water use and an increasing concentration of population and economic activities in urban areas) are likely to increase further pressures on water resources. Changes in catchment land cover, the construction of upstream reservoirs and pollution from domestic, industrial and agricultural sources have also the potential to alter the reliability and quality of supplies.

By the 2050s, between 1.1 and 2.8 billion water-stressed people could see a reduction in water availability due to climate change under the most populous future world, but under less populated worlds the numbers impacted could be between 0.7 and 1.2 billion. These impacted populations are largely in the Middle East and central Asia, Europe, southern Africa and parts of central, north and south America. Stabilisation at 550 ppmv (resulting in an increase in temperature since pre-industrial times below the EU's 2°C target), could reduce the numbers of people adversely affected by climate change by between 30% and 50%, depending on the unmitigated rate of change and future state of the world.

FACT: approximately a third of the world's population lives in countries deemed to be 'water-stressed' (World Meteorological Organization, 1997), where withdrawals for domestic, industrial and agricultural purposes exceed 20% of the available average annual runoff.

FACT: Around 1 billion people currently lack access to safe drinking water, approximately 250 million people suffer health problems associated with poor quality water, and each year river floods claim thousands of lives.

There are critical thresholds of water availability below which tropical forests cannot persist and are replaced by savanna systems, often around 1,200–1,500 mm rainfall per annum. Consequently, changing precipitation patterns may cause shifts in vegetation from carbon-dense tropical forests, to lower carbon savanna systems, if thresholds are crossed.

FACT: Rainfall has reduced dramatically over the Northern Congo basin over the past two decades and this current drying trend is of unknown cause. These forests are already relatively dry for tropical forests and may become savanna if current trends continue, leading to large carbon fluxes to the atmosphere. If the current drying trend is caused by climate change, this could lead to a positive feedback with the climate system exacerbating forest losses and carbon fluxes to the atmosphere.

Even though there is considerable uncertainty concerning the future trajectory of the tropical forest biome, it is likely that

- continued deforestation will undoubtedly lead to major Carbon additions to the atmosphere,
- the Carbon sink contribution of remaining intact tropical forests, which we currently think to be around 15% of global fossil fuel emissions, appears unlikely to continue for the rest of this century.

Land Carbon Cycle

Vegetation and soil contain about three times as much carbon as the atmosphere, and they exchange very large opposing fluxes of carbon dioxide with it. Currently the land is absorbing about a quarter of anthropogenic CO₂ emissions, because uptake by plant photosynthesis is outstripping respiration from soils. However, these opposing fluxes are sensitive to climate, so the fraction of emissions taken up by the land is likely to change in the future.

Meeting the EU 2°C Climate Target

The IPCC TAR concluded that the climate sensitivity was likely to be in the range of 1.5 to 4.5°C and limiting global mean temperature change to around 2°C above pre-industrial levels, could be interpreted as a reasonable level to avoid some of the most dangerous risks of climate change. The EU and several EU member states have decided on a maximum temperature increase target of 2°C. Previous literature concentrated on stabilization of the CO₂ concentration at 450 ppmv CO₂, in order to comply with the 2°C target, however more recent literature points out that stabilization at much lower levels might be necessary to make it 'likely' to stay below the 2°C target.

Indications show that a reduction of energy intensity, (i.e. energy saving), is required particularly for developing countries, while a reduction of carbon intensity, (i.e. CO₂ capture and storage), is particularly required for developed countries. As a result, differences in reduction options between developed and developing countries, would be more beneficial to the latter by making them more economically competitive under these emission reduction schemes.

The main conclusion is that general technological change alone seems unlikely to lead to decarbonisation. Improvements in energy efficiency are partly offset in their effects on CO₂ emissions by the effects of higher growth in exports, incomes and therefore the demand for energy.

Increases in renewable generation are also planned and there is the additional possibility of nuclear replacements being built. However, the 1999 EU Energy Outlook to 2020 suggests that, despite anticipated increases in energy generation from renewable sources, up to 80% will still be accounted for by fossil fuels.

If political justification for significant carbon dioxide emission reductions in the UK emerges from global post-Kyoto negotiations, large reductions in CO₂ emissions from the UK electricity generation could be achieved as early as 2020. Both the technical and the political aspects are changing rapidly, and the first clear pointer for the future may only come with the conclusion of the post-Kyoto negotiations. Carbon Capture and Storage (CCS) technologies also have considerable potential for future emission reductions worldwide, especially in regions where large numbers of new fossil fuel power plants are being built within 500 km of sedimentary basins.

In recent years, emissions of carbon dioxide from the UK electricity generation sector have stayed constant or increased slightly. Values from recent UK Department of Trade and Industry updated energy projections show a decrease over the next two decades, but at a reduced rate compared with the 1990s. A 60% CO₂ emission reduction by 2050 was recommended by the Royal Commission on Environmental Pollution and subsequently endorsed by the Energy White Paper.

Climate Change and Finance

It is thought 2004 has been the fourth warmest year on record and the worst year thus far for weather-related disaster claims – though the devastation in the US Gulf Coast from intense hurricanes in the summer of 2005 could well set a new record for disaster spending. Munich Re, the largest reinsurer in the world, recently stated that it expects natural-disaster-related damages to increase ‘exponentially’ in the near future and it attributes much of these damages to anthropogenic climate change. Thomas Loster, a climate expert at Munich Re, says: ‘We need to stop this dangerous experiment humankind is conducting on the Earth’s atmosphere’.