eoi escuela de negocios

INTERNATIONAL MASTER IN SUSTAINABLE DEVELOPMENT

MODULE: **ATMOSPHERIC POLLUTION**

SUBJECT: **Atmospheric Pollution**

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7. INTEGRATED POLLUTION PREVENTION AND CONTROL

CHAPTER I

1. INTRODUCTION TO THE ATMOSPHERIC POLLUTION

1.1 Definition

According to the European Environment Information and Observation Network (EIONET) the Atmospheric Pollution is defined as the presence in the air of one or more contaminants in such a concentration and of such duration as to cause a nuisance or to be injurious to human life, animal life or vegetation.

2. ATMOSPHERIC POLLUTANTS: ITS CHARACTERISTICS, ORIGIN AND EFFECTS

2.1 Introduction

A variety of air pollutants have known or suspected harmful effects on human health and the environment. In most areas of Europe, these pollutants are principally the products of combustion from space heating, power generation or from motor vehicle traffic. Pollutants from these sources may not only prove a problem in the immediate vicinity of these sources but can travel long distances, chemically reacting in the atmosphere to produce secondary pollutants such as acid rain or ozone.

2.2 An overview of the principal pollutants produced by industrial, domestic and traffic sources

2.2.1 Sulphur Dioxide (SO_2)

Sulphur dioxide is a corrosive acid gas which combines with water vapour in the atmosphere to produce acid rain. Both wet and dry deposition have been implicated in the damage and destruction of vegetation and in the degradation of soils, building materials and watercourses. SO_2 in ambient air is also associated with asthma and chronic bronchitis.

The principal source of this gas is power stations burning fossil fuels which contain sulphur. Major SO_2 problems now only tend to occur in cities in which coal is still widely used for domestic heating, in industry and in power stations. As some power stations are now located away from urban areas, SO_2 emissions may effect air quality in both rural and urban areas. Since the decline in domestic coal burning in cities and in power stations overall, SO_2 emissions have diminished steadily and, in most European countries, they are no longer considered to pose a significant threat to health. Of particular concern in the past was the combination of SO_2 and black smoke and particulate matter; current EC Directive Limit Values for SO_2 are defined in terms of accompanying black smoke levels, although these are likely to change.

2.2.2 Particulate Matter

Airborne particulate matter varies widely in its physical and chemical composition, source and particle size. PM_{10} particles (the fraction of particulates in air of very small size (<10 µm)) are of major current concern, as they are small enough to penetrate deep into the lungs and so potentially pose significant health risks. Larger particles meanwhile, are not readily inhaled, and are removed relatively efficiently from the air by sedimentation. Particles are often classed as either primary (those emitted directly into the atmosphere) or secondary (those formed or modified in the atmosphere from condensation and growth).

A major source of fine primary particles are combustion processes, in particular diesel combustion, where transport of hot exhaust vapour into a cooler tailpipe or stack can lead to spontaneous nucleation of “carbon” particles before emission. Secondary particles are typically formed when low volatility products are generated in the atmosphere, for example the oxidation of sulphur dioxide to sulphuric acid. The atmospheric lifetime of particulate matter is strongly related to particle size, but may be as long as 10 days for particles of about 1mm in diameter.

The principal source of airbourne PM_{10} matter in European cities is road traffic emissions, particularly from diesel vehicles. As well as creating dirt, odour and visibility problems, PM_{10} particles are associated with health effects including increased risk of heart and lung disease. In addition, they may carry surface-absorbed carcinogenic compounds into the lungs.

Concern about the potential health impacts of PM_{10} has increased very rapidly over recent years. Increasingly, attention has been turning towards monitoring of the smaller particle fraction $PM_{2.5}$ capable of penetrating deepest into the lungs, or to even smaller size fractions or total particle numbers.

2.2.3 Carbon Monoxide (CO)

Carbon monoxide (CO) is a toxic gas which is emitted into the atmosphere as a result of combustion processes, and is also formed by the oxidation of hydrocarbons and other organic compounds. In European urban areas, CO is produced almost entirely (90%) from road traffic emissions. CO at levels found in ambient air may reduce the oxygen-carrying capacity of the blood. It survives in the atmosphere for a period of approximately 1 month but is eventually oxidised to carbon dioxide (CO_2).

2.2.4 Nitrogen Dioxide (NO2)

Nitrogen oxides are formed during high temperature combustion processes from the oxidation of nitrogen in the air or fuel. The principal source of nitrogen oxides - nitric oxide (NO) and nitrogen dioxide (NO_2), collectively known as NO_x - is road traffic, which is responsible for approximately half the emissions in Europe. NO and NO_2 concentrations are therefore greatest in urban areas where traffic is heaviest. Other important sources are power stations, heating plants and industrial processes.

Nitrogen oxides are released into the atmosphere mainly in the form of NO, which is then readily oxidised to NO_2 by reaction with ozone. Elevated levels of NO_x occur in urban environments under stable meteorological conditions, when the airmass is unable to disperse.

Nitrogen dioxide has a variety of environmental and health impacts. It is a respiratory irritant, may exacerbate asthma and possibly increase susceptibility to infections. In the presence of sunlight, it reacts with hydrocarbons to produce photochemical pollutants such as ozone (see below). In addition, nitrogen oxides have a lifetime of approximately 1 day with respect to conversion to nitric acid. This nitric acid is in turn removed from the atmosphere by direct deposition to the ground, or transfer to aqueous droplets (e.g. cloud or rainwater), thereby contributing to acid deposition.

2.2.5 Ozone (O3)

Ground-level ozone (O_3), unlike other primary pollutants mentioned above, is not emitted directly into the atmosphere, but is a secondary pollutant produced by reaction between nitrogen dioxide (NO_2), hydrocarbons and sunlight. Ozone can irritate the eyes and air passages causing breathing difficulties and may increase susceptibility to infection. It is a highly reactive chemical, capable of attacking surfaces, fabrics and rubber materials. Ozone is also toxic to some crops, vegetation and trees.

Whereas nitrogen dioxide (NO_2) participates in the formation of ozone, nitrogen oxide (NO) destroys ozone to form oxygen (O_2) and nitrogen dioxide (NO_2). For this reason, ozone levels are not as high in urban areas (where high levels of NO are emitted from vehicles) as in rural areas. As the nitrogen oxides and hydrocarbons are transported out of urban areas, the ozone-destroying NO is oxidised to NO_2, which participates in ozone formation.

Sunlight provides the energy to initiate ozone formation; near-ultra-violet radiation dissociates stable molecules to form reactive species known as free radicals. In the presence of nitrogen oxides these free radicals catalyse the oxidation of hydrocarbons to carbon dioxide and water vapour. Partially oxidised organic species such as aldehydes, ketones and carbon monoxide are intermediate products, with ozone being generated as a by-product.

Since ozone itself is photodissociated (split up by sunlight) to form free radicals, it promotes the oxidation chemistry, and so catalyses its own formation (ie. it is an autocatalyst). Consequently, high levels of ozone are generally observed during hot, still sunny, summertime weather in locations where the airmass has previously collected emissions of hydrocarbons and nitrogen oxides (e.g. urban areas with traffic). Because of the time required for chemical processing, ozone formation tends to be downwind of pollution centres. The resulting ozone pollution or “summertime smog”may persist for several days and be transported over long distances.

2.2.6 Hydrocarbons

There are two main groups of hydrocarbons of concern: volatile organic compounds (VOCs) and polycyclic aromatic hydrocarbons (PAHs - see section below on TOMPs). VOCs are released in vehicle exhaust gases either as unburned fuels or as combustion products, and are also emitted by the evaporation of solvents and motor fuels. Benzene and 1,3-butadiene are of particular concern as they are known carcinogens. Other VOCs are important because of the role they play in the photochemical formation of ozone in the atmosphere.

2.2.7 Benzene

Benzene is an aromatic VOC which is a minor constituent of petrol (about 2% by volume). The main sources of benzene in the atmosphere in Europe are the distribution and combustion of petrol. Of these, combustion by petrol vehicles is the single biggest source (70% of total emissions) whilst the refining, distribution and evaporation of petrol from vehicles accounts for approximately a further 10% of total emissions. Benzene is emitted in vehicle exhaust not only as unburnt fuel but also as a product of the decomposition of other aromatic compounds. Benzene is a known human carcinogen.

2.2.8 1,3-Butadiene

1,3-butadiene, like benzene, is a VOC emitted into the atmosphere principally from fuel combustion of petrol and diesel vehicles. Unlike benzene, however, it is not a constituent of the fuel but is produced by the combustion of olefins. 1,3-butadiene is also an important chemical in certain industrial processes, particularly the manufacture of synthetic rubber. It is handled in bulk at a small number of industrial locations. Other than in the vicinity of such locations, the dominant source of 1,3-butadiene in the atmosphere is the motor vehicle. 1,3 Butadiene is also a known, potent, human carcinogen.

2.2.9 TOMPs (Toxic Organic Micropollutants)

TOMPs (Toxic Organic Micropollutants) are produced by the incomplete combustion of fuels. They comprise a complex range of chemicals some of which, although they are emitted in very small quantities, are highly toxic or carcinogenic. Compounds in this category include:

- PAHs (PolyAromatic Hydrocarbons)
- PCBs (PolyChlorinated Biphenyls)
- Dioxins
- Furans

2.2.10 Lead (Pb) and Heavy Metals

Particulate metals in air result from activities such as fossil fuel combustion (including vehicles), metal processing industries and waste incineration. There are currently no EC standards for metals other than lead, although several are under development. Lead is a cumulative poison to the Central Nervous System, particularly detrimental to the mental development of children.

Lead is the most widely used non-ferrous metal and has a large number of industrial applications. Its single largest industrial use world-wide is in the manufacture of batteries (60-70% of total consumption of some 4 million tonnes) and it is also used in paints, glazes, alloys, radiation shielding, tank lining and piping.

As tetraethyl lead, it has been used for many years as an additive in petrol; most airborne emissions of lead in Europe therefore originate from petrol-engined motor vehicles. With the increasing use of unleaded petrol, however, emissions and concentrations in air have declined steadily in recent years.

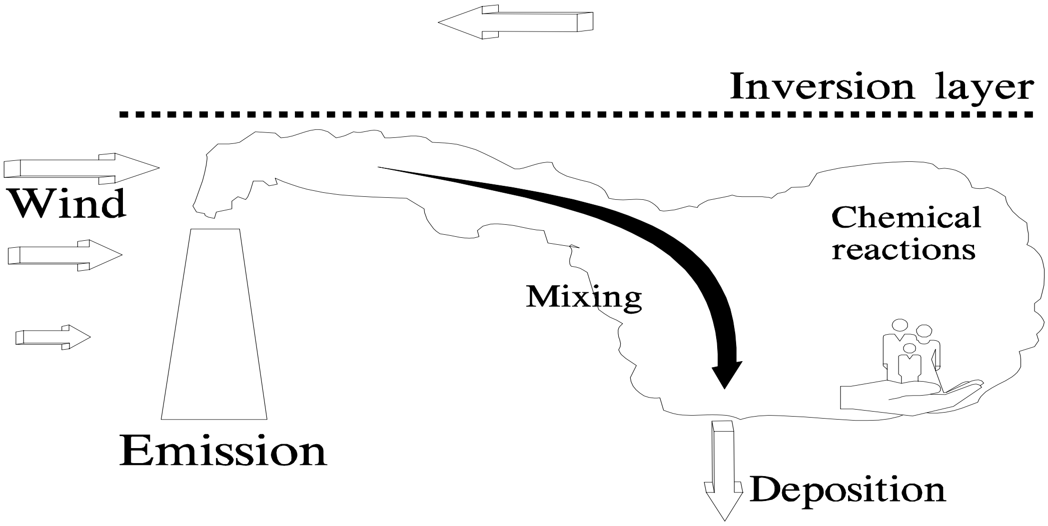
2.2.11 Acid Deposition

Acidification of water bodies and soils, and the consequent impact on agriculture, forestry and fisheries are the result of the re-deposition of acidifying compounds resulting principally from the oxidation of primary SO_2 and NO_2 emissions from fossil fuel combustion. Deposition may be by either wet or dry processes, and acid deposition studies often need to examine both of these acidification routes.

3. APPROACHING TO EMISSION AND IMMISION CONCEPTS

3.1 Emission Concept in the Atmospheric Pollution Context

Discharge of pollutants into the atmosphere from stationary sources such as smokestacks, other vents, surface areas of commercial or industrial facilities and mobile sources, for example, motor vehicles, locomotives and aircrafts.



3.2 Immission Concept in the Atmospheric Pollution Context

Pollution that occurs in cities from the burning of fossil fuels, the emissions of industrial processes and other sources. The normal or average prevailing quality of the surrounding air in a given area in terms of the type and amounts of various air pollutants present.

CHAPTER II

4. TROPOSPHERIC AND STRATOSPHERIC OZONE

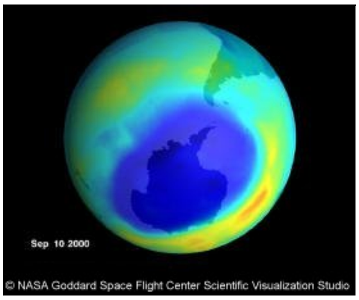
4.1 Tropospheric ozone

Tropospheric ozone is the one in the atmosphere, see 2.2.5.

4.2 The Ozone Layer

Although ozone (O_3) is present in small concentrations throughout the atmosphere, most ozone (about 90%) exists in the stratosphere, in a layer between 10 and 50km above the surface of the earth. This ozone layer performs the essential task of filtering out most of the sun's biologically harmful ultraviolet (UV-B) radiation. Concentrations of ozone in the atmosphere vary naturally according to temperature, weather, latitude and altitude. Furthermore, aerosols and other particles ejected by natural events such as volcanic eruptions can have measurable impacts on ozone levels.

4.3 The Ozone Hole



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In 1985, scientists identified a thinning of the ozone layer over the Antarctic during the spring months which became known as the "ozone hole". The scientific evidence shows that human-made chemicals are responsible for the creation of the Antarctic ozone hole and are also likely to play a role in global ozone losses. Ozone Depleting Substances (ODS) have been used in many products which take advantage of their physical properties (e.g. chlorofluorocarbons (CFCs) have been used as aerosol propellants and refrigerants).

CFCs are broken down by sunlight in the stratosphere, producing halogen (e.g. chlorine) atoms, which subsequently destroy ozone through a complex catalytic cycle. Ozone destruction is greatest at the South pole where very low stratospheric temperatures in winter create polar stratospheric clouds (PSCs). Ice crystals formed in PSCs provide a large surface area for chemical reactions, accelerating catalytic cycles. The destruction of ozone also involves sunlight, so the process intensifies during spring time, when the levels of solar radiation at the pole are highest, and PSC's are continually present.

Although ozone levels vary seasonally, stratospheric ozone levels have been observed to be decreasing annually since the 1970s. Mid-latitudes have experienced greater losses than equatorial regions. In 1997 the Antarctic ozone hole covered 24M km^2 in October, with an average of 40% ozone depletion and ozone levels in Scandinavia, Greenland and Siberia reached an unprecedented 45% depletion in 1996.

4.4 Environmental and Health Effects

The amount of UV reaching the earth's surface has been shown to correlate with the extent of ozone depletion. In 1997 UV-B levels continued to rise at a rate of 2% per annum. Increased UV levels at the earth's surface are damaging to human health, air quality, biological life, and certain materials such as plastics. Human health effects include increases in the incidence of certain types of skin cancers, cataracts and immune deficiency disorders. Increased penetration of UV results in additional production of ground level ozone, which causes respiratory illnesses. Biologically, UV affects terrestrial and aquatic ecosystems, altering growth, food chains and biochemical cycles. In particular, aquatic life occurring just below the surface of the water, where plant species forming the basis of the food chain are most abundant, are adversely affected by elevated levels of UV radiation. The tensile properties of certain plastics can be affected by exposure to UV radiation. Depletion of stratospheric ozone also alters the temperature distribution in the atmosphere, resulting in indeterminate environmental and climatic impacts.

4.5 Future Perspective

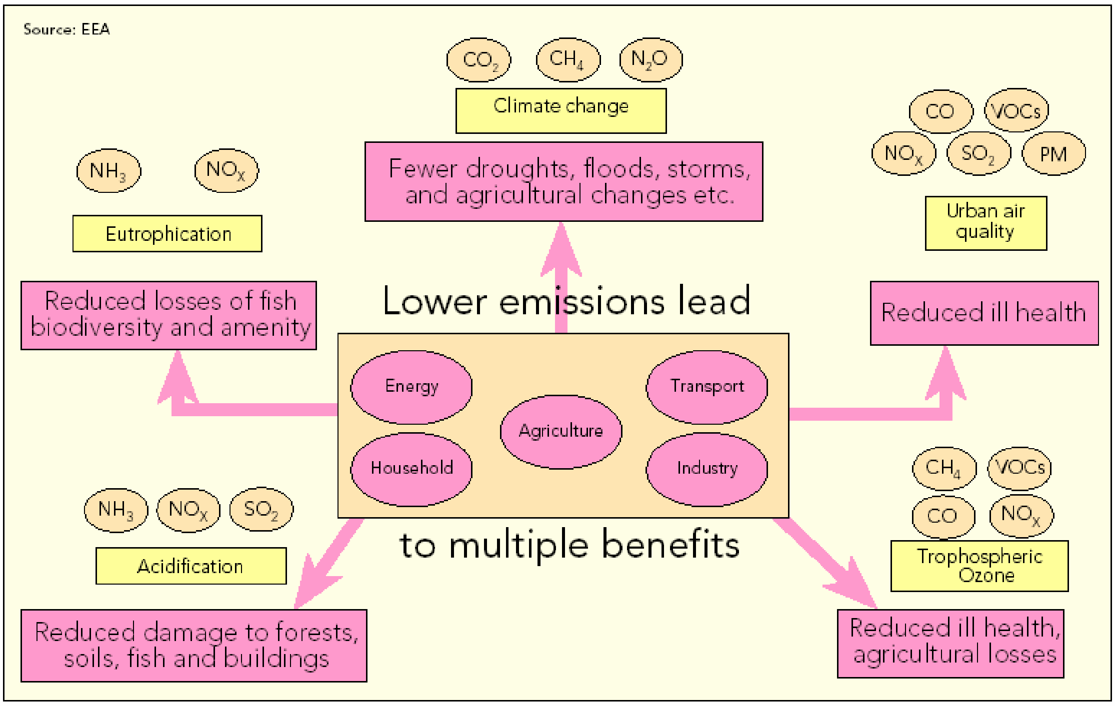
Despite existing regulation of ODS, there continues to be severe ozone depletion and maximum stratospheric levels of chlorine and bromine are predicted to occur only during the next decade. Without further measures the ozone hole will continue to exist beyond 2050. However, the success of the Montreal Protocol has already been observed in terms of changes in the concentrations of man-made chlorine-containing chemicals in the troposphere (i.e. the rates of release of ODS to the atmosphere have been reduced). Additional measures are currently being proposed by the European Commission to accelerate the phase out of various ODS and thereby to provide much-needed additional protection for the ozone layer.

5. TRANSBOUNDARY POLLUTION

5.1 Definition

According to the European Environment Agency "*Transboundary Pollution*" is defined as "Polluted air and water, or any other contaminated waste, that is generated in one country and transmitted to others".

Figure 5.2.1 Multi-pollutants, Multi-effects



5.2 Introduction

Transboundary air pollution (generated in one country and impacting in others) makes a major contribution to acidification and summer smog (caused by tropospheric ozone), and also to eutrophication of soil and water and dispersion of hazardous substances.

The main sources of this pollution are energy use and transport in which international shipping is of growing importance. The cost-effectiveness of measures to reduce emissions from ships has been demonstrated by the European Commission in its strategy to combat acidification. However, sufficient measures are yet to be implemented.

Major emission reductions for sulphur dioxide and nitrogen dioxide adopted under the Convention on Long-Range Transboundary Air Pollution (CLRTAP) and EU legislation have reduced the harmful effects of transboundary air pollution. Projected further reductions fall short of EU targets for 2000 and 2010 and further intiatives are needed in the framework of integrated abatement strategies.

Projections for 2010 suggest that, despite the projected emission reductions, areas of the EU and (especially) the Accession Countries will continue to be affected by acid and nitrogen deposition above the level defined as the ‘critical load’. Ecosystems in the EU still receive 7% acid deposition and 39% nitrogen deposition above their critical loads. European countries where over 70% of ecosystems will still be affected by excess nitrogen deposition include the Czech Republic, Lithuania, Poland, the Slovak Republic and Switzerland.

With respect to ozone, despite the considerable efforts in precursor emission reductions, the long-term objective for protection of crops is expected to be reached only in the north-west parts of Europe (Ireland, Scandinavia). The health-related ozone threshold concentration will continue to be exceeded 50 days per year. The highest number of exceedances will be found in the more densely-populated north-western part of Europe (Netherlands, Belgium and northern France).

Moreover, despite reductions in precursor emissions, smog will remain a health threat due to increases in ozone worldwide: this calls for action on a global scale to reduce emissions of carbon dioxide, nitrogen oxides and methane.

5.3 Effects on flora and fauna

The assessment of adverse effects on vegetation caused by ozone exposure is based on the critical level concept. In a series of international workshops organised under the auspices of UNECE CLRTAP, critical levels of ozone were agreed upon to prevent damage to the most sensitive crops, forests and natural vegetation.

The UNECE International Co-operative programme on assessment and monitoring of air pollution effects on Forests (ICP Forest) has observed the forests of Europe where tree crown condition has been deteriorating on a large scale over several years.

Distinct areas with heavily damaged trees exist in various parts of Europe. The deterioration is most severe in the regions of central Europe where sulphur and nitrogen depositions are highest. In some of those regions, Scots pine recovered after a decrease in air pollution and improved weather conditions. Crown conditions are affected by many stress factors and the trends of the most common species are related to soil and humus types. However, large-scale deterioration over more than a decade is not readily explicable by natural stresses alone (UNECE, 1998). On a large scale, air pollution is considered as a predisposing or triggering factor.

Nitrogen deposition affects ecosystems in particular in nutrient-poor areas. The increasing domination of grass species on many lowland dry-heathlands in western Europe can largely be attributed to the effect of excess nutrient deposition. There is in fact growing evidence that excess nitrogen input increases frost and drought sensitivity of heather.

Transboundary transport and deposition of heavy metals lead to accumulation of these metals in the ecosystem. Acidification also increases the bio-availability of metals. The long-term accumulation of metals in the topsoil and vegetation also leads to increased concentrations in animals. It may be concluded that high concentrations of cadmium and lead found in birds and mammals (reindeer, moose) in remote areas are attributable to long-range transport. The reported concentrations are below the lowest acute effect-levels but sub-lethal effects (impaired vision, co-ordination and body movement) might well occur (AMAP, 1997).

The tendency of persistent organic pollutants to bio-accumulate and bio-magnify results in significant exposure levels for organisms at highest trophic levels, such as humans and marine mammals. It is known that POP exposure affects reproduction either by diminishing survival of offspring or by disrupting reproductive function and reproductive cycles of adult animals.

Short-term exposure of crops during smog episodes may lead to visible injuries. However, the largest effect on agricultural crops is caused by chronic exposure during the growing season which might lead to reduction in crop yield. For the Netherlands alone, it is estimated that a 30% reduction in average ozone concentrations during the growing season will yield an annual benefit of 200 million euros. This compares with an estimated cost of half a million euros per year.

5.4 Damage to ecosystems and health

Under the baseline scenario, significant improvements in the area of ecosystems which are protected against acidification (change in an environment's natural chemical balance caused by an increase in the concentration of acidic elements) and eutrophication (the excessive enrichment of waters with nutrients, and the associated adverse biological effects) will be achieved. The acidification impact reductions are concentrated in northern Europe: the UK, northern France, Belgium, the Netherlands, Germany, Poland, Czech Republic, Slovak Republic and Austria. For eutrophication, the improvements are more dispersed across Europe.

In the EU, ecosystems that receive acid deposition above their critical loads could decrease from 25% of the total (38.6 million ha) in 1990 to 7% in 2010 (10.6 million ha). Ecosystems in several countries, such as France, Ireland, Italy, Spain are virtually no longer exposed to exceedances of critical load. Other countries, where the proportion of ecosystems affected by acidification was high in 1990 show considerable improvement.

In 2010, the two countries with the highest proportion of ecosystems affected by acidification remain Germany and the Netherlands, although considerable improvement will be experienced; there will be reductions from 84% above critical loads to 33% in Germany and 89% to 45% in the Netherlands.

In the AC10, the area of ecosystems with a deposition above the critical load for acidification could decrease from 44% of all natural and semi-natural ecosystems (18.1 million ha) to 6%. In Norway and Switzerland, these improvements are from 25% to 13% and from 38% to 4% respectively. Very 149 Transboundary air pollution large improvements in the impact of acidification are projected for some Accession Countries. For example, the proportion of ecosystems adversely affected by acidification drops from 91% to 19% in the Czech Republic, from 44% to 4% in Lithuania, and from 73% to 8% in Poland.

In the EU, the area of ecosystems that receives nitrogen deposition above critical loads for eutrophication could decrease from 55% (68.0 million ha) in 1990 to 39% in 2010 (48.8 million ha). Countries where a high proportion of ecosystems remains adversely affected by eutrophication in 2010 include Belgium, France, Germany, Luxembourg and the Netherlands.

Eutrophication impact levels, however, remain high in most of the EFTA countries and in the AC10. In the AC10, the eutrophication indicator improves to a lesser degree from 84% of the area (33.4 million ha) having a nitrogen deposition exceeding the critical load to 72%. Countries where over 70% of ecosystems will still be affected by excess nitrogen deposition include the Czech Republic, Lithuania, Poland, the Slovak Republic and Switzerland.

With respect to ozone, the reductions in precursor emissions will lead to a reduction of about 25% in AOT40 levels for crops. Despite the considerable efforts in emission reductions, the long-term objective of 6 000 µg/m3.h will only be reached in the north-west outskirts of Europe (Ireland, Scandinavia). The target value of 16 000 µg/m3.h will still be exceeded in seven EU Member States. The reduction in the number of days with ozone above the health-related threshold of 120 mg/m3 varies over Europe. Under the assumption of the most unfavourable meteorological conditions, the number of days above the health-related threshold falls from 67 in 1990 to 49 in 2010. There is however, a shift in location: in 1990 the highest numbers of exceedances were found in southern Italy; in 2010 the highest number are found in the more densely populated north-western part of EU (the Netherlands, Belgium, and northern France).

5.5 Transboundary pollution: Is our cultural heritage more in danger than our ecosystems?

Exposure to acidifying and photo-oxidant air pollution increases the corrosion rate of materials. Gaseous SO2 has been considered to be the main explanatory factor for corrosion damage to buildings and building materials. Ozone also affects materials such as natural and synthetic rubbers, coatings and textiles. Recently, synergistic effects of ozone in combination with the acidifying components SO2 and NO2 have been reported to lead to increased corrosion. This affects in particular the materials most widely used in our cultural heritage, such as marble, calcareous stone and rendering, medieval glass, copper, bronze and most construction metals.

Recent results (ETSU, 1996) indicate that the average cost of material damage is approximately 1 130 euros per tonne SO2 emitted, which implies a total damage cost of 13.5 billion euros per year for the EU in 1995. This probably underestimates the cost of the damages if the enhanced corrosion levels resulting from the combined exposure to O3 and acidifying compounds were to be considered. There are two main reasons for this expected underestimation. First, the combination of SO2 and O3 increases the actual corrosive attack on materials. Second, the geographical distribution of potential corrosion is expected to change when synergetic effects are considered. Introducing the effect of ozone will probably enhance the corrosion levels in southern Europe, that is, in areas with an extensive cultural heritage where the impact of corrosion will cause more damage. The distribution of copper corrosion rates illustrates well the above-mentioned geographical effect of the combined exposure to SO2 and O3 air concentrations. Copper corrosion has been calculated from 1996 European levels of SO2, NO2 and O3. The actual corrosion levels have been compared to the corrosion caused by exposure to background air concentration. Corrosion rates approximately 25% higher than background corrosion are considered acceptable, above this corrosion levels are considered damaging. Acceptable corrosion rates are exceeded all over Europe, and decay rates are doubled in most central European regions. The substantial emission reductions during recent years have reduced corrosion damage in Scandinavia. In central Europe we still see the effects of high levels of SO2 pollution in areas of Germany, Poland and the Czech Republic where the corrosion rate still is more than three times the general background for Europe. In southern Europe the increased corrosion rate is mostly generated by the high ozone level, although SO2 may still contribute in some areas.

Comparing the geographical distribution of exceedances of acceptable corrosion rates and the distribution of exceedances of critical loads for acidification and eutrophication brings the focus towards southern and eastern Europe. This introduces new elements in the discussion of the harmful effects of transboundary air pollution that will be worth analysing in the future.

6. CLIMATE CHANGE

6.1 What is Climate Change?

The climate of the Earth is always changing. In the past it has altered as a result of natural causes. Nowadays, however, the term climate change is generally used when referring to changes in our climate which have been identified since the early part of the 1900's. The changes we've seen over recent years and those which are predicted over the next 80 years are thought to be mainly as a result of human behaviour rather than due to natural changes in the atmosphere.

Climate change is one of the greatest environmental, social and economic threats facing the planet. During the last century, the Earth’s average surface temperature rose by around 0.6°C. Evidence is getting stronger that most of the global warming that has occurred over the last 50 years is attributable to human activities. In its Third Assessment Report, published in 2001, the Intergovernmental Panel on Climate Change (IPCC) projects that global average surface temperatures will rise by a further 1.4 to 5.8°C by the end of this century. This global temperature increase is likely to trigger serious consequences for humanity and other life forms alike, including a rise in sea levels of an estimated 9 to 88 cm by the end of this century, which will endanger coastal areas and small islands, and a greater frequency and severity of extreme weather events.

Human activities that contribute to climate change include in particular the burning of fossil fuels and deforestation, both of which cause emissions of carbon dioxide (CO_2), the main gas responsible for climate change, as well as other 'greenhouse' gases. In order to bring climate change to a halt, global greenhouse gas emissions must be reduced significantly

The European Union (EU) is at the forefront of international efforts to combat climate change and has played a key role in the development of the two major treaties addressing the issue, the United Nations Framework Convention on Climate Change and its Kyoto Protocol.

The EU is also taking serious steps to address its own greenhouse gas emissions. In March 2000 the Commission launched the European Climate Change Programme (ECCP). The ECCP led to the adoption of a range of new policies and measures, among which the EU’s emissions trading scheme, which will start its operation on 1 January 2005, will play a key role. As a result of the EU’s and individual Member States actions, the latest monitoring data indicates that the European Union has delivered on its long-standing commitment to stabilise emissions of CO_2 at the level of 1990 in the year 2000. The EU-15 is committed to deliver the collective 8% cut in emissions by 2008-2012 to which it signed up under the Kyoto Protocol. Equally the New Member States are determined to meet their individual targets under the Kyoto Protocol.

The Kyoto Protocol is only a first step to address the serious threat of climate change. Further action must be taken after 2012, the end of the Kyoto Protocol’s ‘first commitment period’. In order to prepare for the EU’s input in the further development of the global climate change regime ‘post 2012’, the Commission has started a stakeholder dialogue, inviting stakeholder participation in preparing the EU’s contribution to the shaping the future global climate change regime.

6.2 The Greenhouse Effect

The greenhouse effect is very important when we talk about climate change as it relates to the gases which keep the Earth warm. It is the extra greenhouse gases which humans have released which are thought to pose the strongest threat. But, what is the Greenhouse Effect? Atmospheric scientists first used the term 'greenhouse effect' in the early 1800s. At that time, it was used to describe the naturally occurring functions of trace gases in the atmosphere and did not have any negative connotations. It was not until the mid-1950s that the term greenhouse effect was coupled with concern over climate change. And in recent decades, we often hear about the greenhouse effect in somewhat negative terms. The negative concerns are related to the possible impacts of an enhanced greenhouse effect. This is covered in more detail in the Global Climate Change section of this Web site. It is important to remember that without the greenhouse effect, life on earth as we know it would not be possible.

While the earth's temperature is dependent upon the greenhouse-like action of the atmosphere, the amount of heating and cooling are strongly influenced by several factors just as greenhouses are affected by various factors.

In the atmospheric greenhouse effect, the type of surface that sunlight first encounters is the most important factor. Forests, grasslands, ocean surfaces, ice caps, deserts, and cities all absorb, reflect, and radiate radiation differently. Sunlight falling on a white glacier surface strongly reflects back into space, resulting in minimal heating of the surface and lower atmosphere. Sunlight falling on a dark desert soil is strongly absorbed, on the other hand, and contributes to significant heating of the surface and lower atmosphere. Cloud cover also affects greenhouse warming by both reducing the amount of solar radiation reaching the earth's surface and by reducing the amount of radiation energy emitted into space.

Scientists use the term albedo to define the percentage of solar energy reflected back by a surface. Understanding local, regional, and global albedo effects is critical to predicting global climate change.

6.3 Greenhouse Gases and its effects in the climate change

Greenhouse gases have been accumulating in the atmosphere since the industrial revolution, almost 250 years ago. Where are these gases coming from? Are they changing the climate?

6.3.1. Carbon Dioxide

Carbon dioxide is the main greenhouse gas emitted by human activity. It is responsible for over half the enhancement of the greenhouse effect. The main sources are shown in Table 1. The largest single contributor to emissions from fossil fuels is power generation. Transport is another major contributor. Table 1 also shows the natural processes (or sinks) which remove CO_2 from the atmosphere. The difference between total emissions and the known sinks is described as the inferred sink, which is probably partly due to the extra growth of plants, stimulated by higher concentrations of CO_2 in the atmosphere.

***Table 1** Annual average carbon budget from human activity for 1980-89*

	Amount (GtC/y)
CO_2 Sources	
1 Fossil fuel combustion and cement production	5.0-6.0
2 Changes in tropical land use (mainly deforestation)	0.6-2.6
3 Total emissions from human activity (1+2)	6.0-8.2
CO_2 Sinks	
4 Storage in the atmosphere	3.1-3.5
5 Ocean uptake	1.2-2.8
6 Northern hemisphere forest regrowth	0.0-1.0
7 Inferred sink 3-(4+5+6)	-0.2-2.8

GtC = 109 tonnes of carbon. Source: IPCC, 1996a

The concentration of CO_2 in the atmosphere has increased from about 280ppmv, before the industrial revolution, to 358ppmv by 1994. The concentration of CO_2 in the atmosphere has been measured in Mauna Loa, Hawaii since the 1950s. The results are illustrated in Figure 1, which shows the regular increase in concentration and the accelerating growth rate.

Figure 1 *CO_2 concentrations measured at Mauna Loa, Hawaii since 1958 showing trends and seasonal cycle*

The natural carbon cycle influences the rate at which CO_2 from human activity accumulates in the atmosphere. Carbon is exchanged over a period of years between the atmosphere, oceans, and terrestrial biosphere; over longer time-scales it is deposited as sediments and eventually, on geological time-scales, as sedimentary rocks, as shown in Figure 2. Carbon dioxide has a long lifetime in the atmosphere, from 50 to 200 years (depending upon which sink is involved). Human activity is responsible for only a fraction of the CO_2 in the carbon cycle but, as can be seen from Figure 1, this is sufficient to alter the concentration of CO_2 in the atmosphere.

Figure 2 *The post-industrial global carbon cycle, showing the major reservoirs and fluxes in (GtC/year)*

6.3.2. Methane

The pre-industrial concentration of methane in the atmosphere was about 700ppbv, less than half the 1994 level of 1,720ppbv. The current growth rate is about 8ppbv/y (IPCC, 1996a). The main sources and sinks of CH_4 are shown in Table 2. Of the fossil fuel sources, 40Mt/y comes from natural gas, 30Mt/y from coal mines, 15Mt/y from the petroleum industry, and a smaller amount from coal combustion. From the difference between emissions and sinks, the extent of further emissions is inferred.

Table 2. *Sources, sinks and the atmospheric increase of methane*

	Amount (Mt(CH_4)/y)
CH_4 Sources	
Natural Sources	160 (110-210)
Human Sources:	
fossil fuel related	100 (70-120)
other e.g. agriculture	275 (200-350)
Total human sources	375 (300-450)
Total identified sources	535 (410-660)
CH_4 Sink	
Sinks of atmospheric CH_4 :	
troposphere OH	490 (405-575)
stratosphere	40 (32-48)
soils	30 (15-45)
Total atmospheric sinks	560 (460-660)
Atmospheric increase	37 (35-40)
Total of sinks + atmospheric increase	597 (495-700)

Source. IPCC, 1996a

As mentioned above, most CH_4 is removed from the atmosphere by reaction with the hydroxyl radical to form CO_2 and water vapour. Because these are also greenhouse gases, CH_4 can be regarded as making both a direct and an indirect contribution to the greenhouse effect. Methane emissions may be exacerbated by climate change. For example, changes in temperature and precipitation will influence emissions from northern wetlands, areas of permafrost and the decomposition of methane hydrates in continental shelf regions.

6.3.3. Nitrous Oxide

There are several nitrogen oxides which contribute to local pollution and problems such as acid rain, but N_2O is the only one that is a significant greenhouse gas. There are many small sources of N_2O. The main human activities that emit N_2O are agriculture, especially the use of nitrogen-based fertilisers, biomass burning, and a range of industrial processes, including production of adipic acid and nitric acid. In the 1980s, human emissions of N_2O were about 3 to 8Mt(N)/y. The main natural sources are the oceans, and tropical and temperate soils. Emissions from natural sources are probably about twice those from human activity. The concentration of N_2O in the atmosphere has increased from a pre-industrial level of about 275ppbv to 312ppbv in 1994. The major sink of N_2O is photolysis in the stratosphere and some is taken up by soils. N_2O has a lifetime of about 120 years in the atmosphere, so even if emissions were held constant, it would be many years before the concentration in the atmosphere stabilised.

6.3.4. CFCs and other halocarbons

CFCs and Halocarbons are strong greenhouse gases, but are present only in low concentrations. Those that contain chlorine and bromine are also implicated in depletion of the ozone layer, so emissions are controlled by the Montreal Protocol and its amendments. As a result, the growth rate of CFCs and some other gases in the troposphere has slowed considerably. Hydrofluorocarbons (HFCs) which are being used as substitutes for CFCs, make only a small contribution to the total enhancement due to human activity. Perfluorocarbons, such as CF_4, have only made a small contribution since pre-industrial times but their lifetime in the atmosphere is over 1,000 years, much longer than that of other greenhouse gases.

6.3.5 Ozone

Ozone acts as a greenhouse gas in the troposphere and the stratosphere by influencing both solar and infrared radiation. Its concentration in the troposphere may have doubled in the Northern Hemisphere since pre-industrial times, an increase of around 25ppbv. Ozone forms in the troposphere from the reactions of CO, NO_x and non-methane hydrocarbons, and from chemical feedbacks involving methane. Ozone may also move down from the stratosphere. Its contribution to the greenhouse effect is hard to assess as it varies regionally and vertically and has a short lifetime in the atmosphere. Stratospheric ozone depletion will have made a small reduction in the greenhouse effect.

6.3.6. Water vapour

Water vapour makes a large contribution to the greenhouse effect; its spatial distribution is controlled mainly by evaporation, condensation and transport processes (Wuebbles, 1993). On a global scale it is not thought to be affected by human sources and sinks. A warmer atmosphere will hold more moisture, which as a greenhouse gas will further amplify the warming. About half of this feedback depends on water vapour in the upper troposphere. The origin of this water vapour and its response to an increase in surface temperature is not completely understood. However, there is definitely a positive feedback from water vapour in the lower troposphere, and this is probably also true for water vapour in the upper troposphere. Feedbacks caused by changes in temperature with height can partially compensate for the water vapour feedback (IPCC, 1996a). The feedback effect of water vapour is incorporated in climate models.

6.3.7. Aerosols

Aerosols (particles of diameter 0.001-l0 µm) suspended in the atmosphere reflect sunlight and so tend to cool the earth. The main sources of aerosols are fossil fuel combustion, which emits SO_2 (converted to sulphates in the atmosphere) and biomass burning which releases organic and elemental carbon. Aerosols influence the radiative balance by absorbing and scattering solar radiation back to space, and by acting as nuclei for condensation and so influencing the properties of clouds. Aerosols have a short lifetime and vary regionally, so their overall impact on the global climate is hard to assess but it has been concluded that the increase in sulphate aerosols since 1850 has had a cooling effect (IPCC, 1996a).

6.4 Some questions about the Climate Change and its answers.

Has the climate changed due to human activity increasing the emission of greenhouse gases?

The mean global surface temperature has increased by about 0.3° to 0.6°C since the late 19th century - when the instrumental record began - and by about 0.2° to 0.3°C since 1955. The warming occurred largely between 1910 and 1940, and since the mid-1970s. Recent years have been among the warmest since 1860. The warming has been greatest in continental regions between 40° and 70°N. In many areas the daily temperature range has reduced as nights have become warmer. As an average over the northern hemisphere in summer, recent decades appear to be the warmest since at least 1400, from the limited evidence available. Temperature change since 1860 is shown in Figure3.

The IPCC concluded that 'the balance of evidence suggests a discernible human influence on the global climate' (IPCC, 1996a).

Sea level rise is another important consequence of climate change. Global sea level has risen by about 10-25cm over the last 100 years. Increased temperatures will have caused some expansion of the sea water, and the retreat of glaciers and ice caps will have also contributed to the increase.

The IPCC has used emission scenarios and climate models to make projections about future climate change. There are uncertainties that remain in climate modelling, but confidence in the models has increased due to measures such as incorporating the effects of sulphate aerosols. Using the emission scenarios, the IPCC project that the global mean temperature will increase by 0.9 to 3.5°C by the year 2100, relative to 1990 (IPCC, 1996a). The average rate of warming, from these emission scenarios, would probably be greater than any seen in the last 10,000 years. The temperature would continue to increase even after stabilisation of the greenhouse gas concentrations in the atmosphere because of the thermal inertia of the oceans. By 2100, sea level is projected to rise by between 13 and 94cm. There is also the possibility that unusual weather events, such as severe storms, may become more frequent.

If this climate change occurs, what impact will it have?

Ecosystems, agriculture and forestry, and human health are sensitive to the climate. Ecosystems provide many essentials including food, materials, medicines, energy and water resources. Some ecosystems may be unable to adapt to climate change at an adequate rate. Agriculture and fisheries may also be disrupted, with the consequence of food shortages. This may be exacerbated by sea level rise causing widespread flooding. The range of diseases such as malaria could increase. At a more mundane level, demand for heating and for cooling will be changed. Secondary impacts of climate change may include increasing numbers of environmental refugees, altered patterns of tourism and large claims being made on the insurance industry.

If the rate of climate change can be limited to a low level, then natural end human systems will find it easier to adapt. The way to slow the rate of change is to reduce emissions of greenhouse gases.

CHAPTER III

7. INTEGRATED POLLUTION PREVENTION AND CONTROL

7.1 Definition

The Intergovernmental Panel on Climate Change (IPCC) has been established by WMO and UNEP to assess scientific, technical and socio- economic information relevant for the understanding of climate change, its potential impacts and options for adaptation and mitigation. It is open to all Members of the UN and of WMO.

7.2 Introduction

Recognizing the problem of potential global climate change, the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) established the Intergovernmental Panel on Climate Change (IPCC) in 1988. It is open to all members of the UN and WMO.

The role of the IPCC is to assess on a comprehensive, objective, open and transparent basis the scientific, technical and socio-economic information relevant to understanding the scientific basis of risk of human-induced climate change, its potential impacts and options for adaptation and mitigation. The IPCC does not carry out research nor does it monitor climate related data or other relevant parameters. It bases its assessment mainly on peer reviewed and published scientific/technical literature. Its role, organisation, participation and general procedures are laid down in the *Principles Governing IPCC Work*.

7.3 Organisational Structure

The IPCC has three Working Groups and a Task Force

- Working Group I assesses the scientific aspects of the climate system and climate change.
- Working Group II assesses the vulnerability of socio-economic and natural systems to climate change, negative and positive consequences of climate change, and options for adapting to it.
- Working Group III assesses options for limiting greenhouse gas emissions and otherwise mitigating climate change.
- The Task Force on National Greenhouse Gas Inventories is responsible for the IPCC National Greenhouse Gas Inventories Programme.

The Panel meets in plenary sessions about once a year. It accepts/approves/adopts IPCC reports, decides on the mandates and work plans of the Working Groups and the Task Force, the structure and outlines of its reports, the IPCC Principles and Procedures, and the budget. The Panel also elects the IPCC Chair, the IPCC Bureau and the Bureau of the Task Force on National Greenhouse Gas Inventories. The IPCC

Bureau meets two to three times per year and assists the IPCC Chair in planning, co-ordinating and monitoring progress in the work of the IPCC.

The IPCC is managed by the IPCC Secretariat, which is hosted by WMO in Geneva and supported by UNEP and WMO. In addition each Working Group and the Task Force has a Technical Support Unit. These Technical Support Units are supported by the government of the developed country co-chair of that Working Group or Task Force and hosted by a research institution in that country. A number of other institutions provide in kind support for IPCC activities.

7.4 Main Activities and Products

A main activity of the IPCC is to provide in regular intervals an assessment of the state of knowledge on climate change. The IPCC also prepares Special Reports and Technical Papers on topics where independent scientific information and advice is deemed necessary and it supports the UN Framework Convention on Climate Change (UNFCCC) through its work on methodologies for National Greenhouse Gas Inventories. A number of IPCC reports are published commercially. Summaries, CD ROMs and Technical Papers can be obtained free of charge. A limited number of full reports are avaible from the IPCC Secretariat for developing countries and countries with economies in transition.

The First IPCC Assessment Report was completed in 1990. The Report played an important role in establishing the Intergovernmental Negotiating Committee for a UN Framework Convention on Climate Change by the UN General Assembly. The UN Framework Convention on Climate Change (UNFCCC) was adopted in 1992 and entered into force in 1994. It provides the overall policy framework for addressing the climate change issue.

The IPCC has continued to provide scientific, technical and socio-economic advice to the world community, and in particular to the Parties to the UNFCCC through its periodic assessment reports and special reports. Its Second Assessment Report, Climate Change 1995, provided key input to the negotiations, which led to the adoption of the Kyoto Protocol to the UNFCCC in 1997.

The Third Assessment Report (TAR), Climate Change 2001, was completed in 2001. It was submitted to the 7th Conference of the Parties to the UNFCCC and Parties agreed that it should be used routinely as a useful reference for providing information for deliberations on agenda items of the Conference of the Parties.

The IPCC has decided to continue to prepare comprehensive assessment reports and agreed to complete its Fourth Assessment Report in 2007.

7.4.1. Assessment Reports

In accordance with its mandate and as reaffirmed in various decisions by the Panel, the major activity of the IPCC is to prepare in regular intervals comprehensive and up-to-date assessments of policy-relevant scientific, technical and socio-economic information relevant for the understanding of human induced climate change, potential impacts of climate change and options for mitigation and adaptation. The First Assessment Report was completed in 1990, the Second Assessment Report in 1995 and the Third Assessment Report in 2001. Assessment Reports normally consist of the full scientific, technical and socio-economic assessment reports of the IPCC Working Groups and their Summaries for Policymakers, and a Synthesis Report. At its eighteenth session in September 2001 the Panel decided to continue to prepare comprehensive assessment reports and it agreed that the Fourth Assessment Report would be completed in 2007. The Panel at its Twentieth Session in February 2003 decided also to adopt a framework and set of criteria for establishing priorities for Special Reports, Methodology Reports and Technical Papers for the period of the Fourth Assessment to guide, but not prescribe, future decisions by the Panel regarding its work programme.

7.4.2. Special Reports and Technical Papers

The IPCC prepares also, within the overall framework of priorities mentioned above, Special Reports and Technical Papers. Special Reports have been prepared on topics such as aviation and the global atmosphere, regional impacts of climate change, technology transfer, emissions scenarios and issues related to land use, land use change and forestry. They are subject to the same writing, review and approval process as Assessment Reports. Presently two Special Reports are under preparation. Technical Papers are prepared on topics for which an objective international scientific/technical perspective is essential. They are based on material already in the IPCC Assessment Reports and Special Reports and their preparation follows accelerated procedures. Special Reports and Technical Papers are often prepared in response to requests from the Conference of the Parties to the UNFCCC, or from other environmental Conventions, e.g. the Convention on Biological Diversity (CBD), the Convention to Combat Desertification (CCD), or the Vienna Convention on the Protection of the Ozone Layer.

7.4.3. National Greenhouse Gas Inventories Programme (NGGIP)

Within the National Greenhouse Gas Inventories Programme (NGGIP) the IPCC assesses and develops methods and practices for national greenhouse gas inventories and disseminates information related to inventory methods and practices. The Task Force Bureau on National Greenhouse Gas Inventories (TFB) oversees and provides guidance to the programme. The Task Force Bureau is elected by the Panel and is composed of two co-chairs and 12 members.

The NGGIP prepares methodology reports and develops software for the calculation and reporting of national GHG emissions and removals, including an emission factors database. The activities are normally undertaken in response to an invitation by the Conference of the Parties to the UNFCCC and are aimed to meet the inventory reporting requirements of Parties to the UNFCCC. In the year 2003 two methodology reports have been completed. Recently preparations for the the 2006 IPCC Guidelines for National Greenhouse Gas Inventories have started (Outline/List of authors).

7.4.4. Task Group on Data and Scenario Support for Impacts and Climate Analysis (TGICA) & IPCC Data Distribution Center (DDC)

The IPCC Task Group on Data and Scenario Support for Impacts and Climate Analysis (TGICA) is composed of experts in modelling, climate impact assessment and emissions scenarios and is co-chaired by Mr. J. Marengo (Brazil) and Mr. R. Moss (USA) . It was established under a slightly different name (Task Group on Scenarios for Climate and Impact Assessment, TGCIA), following a recommendation made at the IPCC Workshop on Regional Climate Change Projections for Impact Assessment (London, 24-26 September 1996) to facilitate co-operation between the climate modelling and climate impacts assessment communities. The IPCC Data Distribution Centre (DDC) has been established by the Task Group to provide timely information and data to the international climate research community, in particular consistent data sets and guidance material. The DDC contains results from climate change experiments, i.e. data from global climate models (GCMs) produced by different modelling centers. Further types of information provided on the DDC are observed climate datasets for a number of variables, observed environmental data, including concentrations of CO2 and other greenhouse gases, and socio-economic scenario information such as datasets for different SRES (IPCC Special Report on Emissions Scenarios) futures. Guidance material on how the climate scenarios and baseline data can be used in impacts and adaptation assessments and documentation accompany the information on the DDC.

The Panel agreed at it's twentieth session (Paris, February 2003) that role and mandate of the TGCIA be reviewed and that its membership be refreshed. At its twenty-first session (November 2003, Vienna) the IPCC approved the revised mandate and agreed on the new name of the Task Group. The IPCC Bureau at it's thirty-first session (Geneva, April 2004) approved the new membership of the TGICA.

7.4.5. Workshops and Expert Meetings

Workshops and Expert Meetings may be held to support the assessment process when the IPCC, an IPCC Working Group or the Task Force on Inventories decide that they are useful or necessary for the completion of its workplan or task. They are by invitation only. The IPCC may also co-sponsor workshops if the activity will be useful to the work of the IPCC. The proceedings of IPCC workshops and expert meetings are normally published as IPCC supporting material. Summary reports for some of the IPCC expert meetings can be found under official documents/meeting reports. These summary reports have been prepared under the guidance of the IPCC co-chairs responsible for organizing the meeting, but are not IPCC approved documents.