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Winning the Battle Against Global Climate Change

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1. INTRODUCTION

With the entry into force of the Kyoto Protocol international efforts to combat climate change enter a new phase. The EU has begun reducing its greenhouse gas emissions and now needs to develop its medium and long term strategies for winning the battle against climate change, inside the EU and together with the international community. Several EU Member States have already announced or proposed national mid- and long-term climate targets. This Communication responds to the request of the European Council at its March 2004 meeting for "a cost benefit analysis which takes account both of environmental and competitiveness considerations", as preparation for a discussion on "medium and longer term emission reduction strategies, including targets". On the basis of the analysis undertaken by the Commission, it recommends a number of elements which should be included in the EU's future climate change strategies and proposes dialogue with key partners during 2005 in order to prepare the EU's position for future international negotiations. It is accompanied by a working document setting out in greater detail the review of scientific evidence and the scenarios which have been analysed to underpin the information presented here.

2. THE CLIMATE CHALLENGE

Climate change is happening. Over the 20th century, the global average temperature has risen by about 0.6°C, and the mean temperature in Europe increased by more than 0.9°C. Globally, the 10 warmest years on record all occurred after 1991. Greenhouse gas concentrations are higher now than at anytime in the past 450 000 years, and are projected to keep rising.

The overwhelming scientific consensus is that the cause is emissions of greenhouse gases from human activity. Because of lags in the climate system, past emissions will lead to an additional rise in the temperature during the 21st century, and emissions, are expected to increase further in the coming decades. As a consequence, global temperatures are expected to increase by 1.4 to 5.8°C by the year 2100 (compared to 1990 temperatures) and by 2.0 to 6.3°C in Europe.

Climate change needs to be slowed down and eventually halted. On the basis of the 2nd Assessment Report of the Intergovernmental Panel on Climate Change (IPPC) the EU Council of Ministers stated in 1996 that it "believes that global average temperatures should not exceed 2 ºC above pre-industrial level"[1]. The 2°C objective needs to be translated technically into policy terms. Often it is presented in terms of atmospheric concentration of greenhouse gases and expressed in parts per million (ppmv). Recent research indicates that a level of 550 ppmv (CO_2 equivalents) offers at most a one in six chance of respecting the 2 ºC target, while if the concentration were to rise to 650 ppmv there is a one in sixteen chance of meeting the target. Consequently, limiting the temperature rise to 2 ºC would very probably require greenhouse gas concentrations to be stabilised at much lower levels. As the

[1] 1939th Council Meeting, Luxembourg, 25 June 1996.

concentration is already over 400 ppmv and is rising at an average rate of 0.5 % per year, achieving the 2 ºC target will require significant global cuts in emissions.

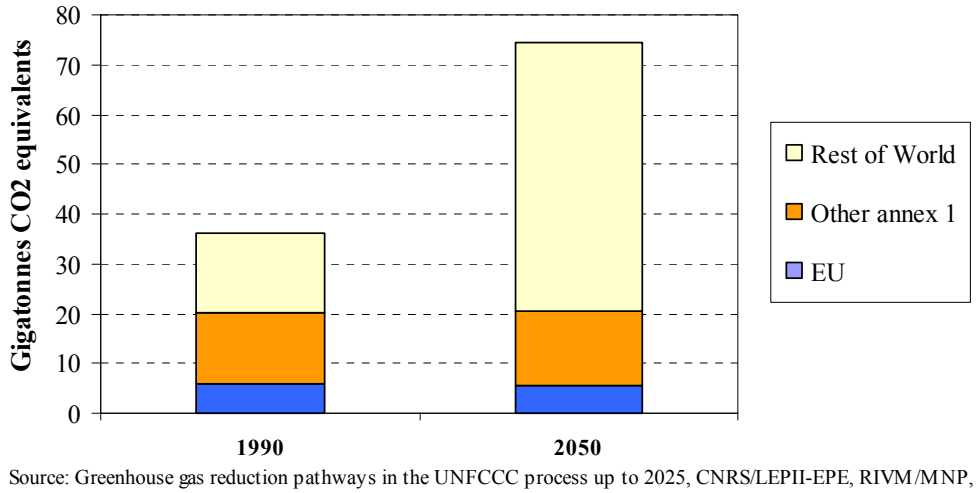
3. BENEFITS AND COSTS OF LIMITING CLIMATE CHANGE

There is increasing scientific evidence that the benefits of limiting the global average temperature increase to 2 °C outweigh the costs of abatement policies (for detailed summaries see Annexes 1 and 2). If temperatures continue to rise beyond 2 °C a more rapid and unexpected response of the climate becomes more likely and irreversible catastrophic events may occur. The Commission has carried out an analysis of the costs and benefits (see staff working paper for detail) which shows that the costs of abatement policies and competitiveness effects can be minimized if all sectors and greenhouse gases are included, participation in reducing emissions is broadened to include all major emitting countries, emissions trading and project based mechanisms are fully used, and if synergies with other policies are fully exploited (e.g. Lisbon Strategy, energy security policy, continuing reform of the Common Agricultural Policy, cohesion policy, and air quality policies).

4. THE PARTICIPATION CHALLENGE

The importance of broadening international participation in efforts to tackle climate change cannot be overestimated. In the coming decades, the share of EU-25 emissions in world greenhouse gas emissions is expected to decline to less than 10 %, while those of developing countries will expand to more than half of the total. Even when considering historic and future emissions together, the cumulative contributions of developed and developing countries are projected to reach parity between 2030 and 2065.

Figure 1: Projected development of greenhouse gas emissions in different regions of the world



Source: Greenhouse gas reduction pathways in the UNFCCC process up to 2025, CNRS/LEPII-EPE, RIVM/MNP, ICCS-NTUA, CES-KUL (2003).

Thus, even if the EU were to cut its emissions by 50 % by 2050, atmospheric concentrations would not be significantly affected, unless other major emitters also

made substantial emission cuts. Therefore, effective action to tackle climate change requires widespread international participation on the basis of common but differentiated responsibilities and respective capabilities.

Although developing countries are more vulnerable than industrialised countries to the damages of climate change, they are concerned that reducing emissions will harm their economic development. However, the experience of the new Member States during the economic recovery in the second half of the 1990's shows that this needs not to be the case. Developing countries will be more likely to adopt climate policies if these are designed to contribute to wider development goals. Moreover, tackling climate change also provides other benefits that almost exclusively accrue to those countries that undertake the effort. For instance, significant improvements in energy efficiency and the introduction of low carbon energy sources are possible and will contribute to sustaining rapid growth. The health benefits which come from better air quality could also be a major driving force for cutting emissions. In fact, some countries already implement a number of such policies. The recently adopted EU Action Plan on Climate Change and Development[2] will be instrumental in supporting developing countries addressing these issues.

Developing countries could be further encouraged to take part in international efforts to reduce emissions. For instance, if companies located in developing countries could participate in emissions trading it would open the possibility for them to benefit from effective emission reductions. Devising incentives for developing countries to take part in international emissions reductions may also be a way of achieving wider participation by developed countries. The US has argued that the absence from the requirements of the Kyoto Protocol of developing countries that are by now major greenhouse gas emitters makes it environmentally ineffective and risks undermining the competitiveness of US industry. Developing countries in turn are reluctant to constrain their emissions. The EU should support efforts to resolve this impasse. Indeed a relatively small group – EU, US, Canada, Russia, Japan, China and India – accounts for about 75 % of world greenhouse gas emissions. It might be worthwhile to try to accelerate progress at the global level by discussing reductions among this smaller group of major emitters in a forum similar to the G8, in parallel with vigorous efforts to reach agreement in the UN context.

5. THE INNOVATION CHALLENGE

The innovation challenge over the coming five decades will be considerable. Substantial changes in how the world produces and uses energy will be required. Some of these changes in energy use can be expected to occur in any event. Factors such as rising prices for fossil fuels are likely to lead to a partial shift away from fossil fuels. Despite these developments, additional technological change in all economic sectors will be required, in addition to measures to reduce non-CO_2 greenhouse gases and to maintain or enhance carbon sinks. Achieving this progress will require a combination of "push" and "pull" policies.

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[2] Council document 15164/04.

Pulling technological change

The more prices truly reflect external costs and the more demand reflects better consumer climate awareness, the more investments in climate friendly technology will increase. Establishing a market value for greenhouse gases, for instance through emissions trading or taxation, will provide a financial incentive curbing demand, promoting the widespread use of such technologies, and encourage further technological development. Similarly, the abolition of environmentally harmful subsidies will help to create a level-playing field between different energy sources. In 2004, the European Environment Agency estimated annual energy subsides in the EU-15 for solid fuels, oil and gas amounted to more than € 23.9 billion and for renewable energy to € 5.3 billion. International transport such as aviation and maritime transport are almost entirely excluded from taxation.

Market-based instruments can be complemented with smart and cost-effective policies that encourage the adoption of new technologies promoting their early deployment as foreseen in the context of the Lisbon strategy. They are particularly suitable at an early stage of commercialisation by helping to overcome barriers to their introduction and facilitating demonstration. The European experience shows that active support policies have helped to radically reduce unit costs of producing electricity from renewable energy sources in the years 1980-1995 (-65 % for photovoltaics, -82 % for wind power, -85 % for electricity from biomass). Such efforts must continue at accelerated speed. In addition, policies should exploit possible co-benefits, for instance in terms of air quality or urban transport policies. The actions proposed in the EC Environmental Technology Action Plan can provide guidance for national and European action.

Smart and cost effective 'pull' policies should take advantage of normal capital replacement cycles. Gradual transformation will require a stable, long term policy framework. Given the need for the renewal and expansion of the global capital stock in the electricity industry in the coming three decades, such a framework needs to be established as early as possible. Such opportunities cannot be missed as investments in the power sector, industry, transport infrastructure or buildings will determine CO_2 emissions for several decades ahead. In Europe alone around 700 GW of electricity generation (equivalent to the currently installed capacity) needs to be installed (investment cost: € 1.2 trillion) by 2030. Planning for these decisions is being done some 5 to 10 years ahead and must be based on the necessities of long-term climate policies.

Many technologies to reduce greenhouse gas emissions either exist already or are at an advanced pilot stage. A recent study identified the 15 most promising of such technologies (see Annex 3). Taking all 15 options together this would amount to a reduction potential of more than 54 Gt CO_2 eq. per year in 2050. If used to its fullest extent, the major part of the projected baseline emissions in 2050 could be avoided. Five of those options concern energy efficiency. Thus, one central pillar of any future energy strategy for the EU must be cost effective energy efficiency improvements and energy savings. Action in this field further complements the Lisbon strategy, strengthens the security of energy supply, and creates significant numbers of new jobs in Europe and a more competitive industry consuming less energy. Estimates show that in the EU-15 it would be economically feasible to realise energy savings of

up to 15 % over the coming decade, while a technical potential of up to 40 % exists. Carbon capture and storage is another important area.

Pushing technological change: Invest in the knowledge economy

Future technologies for widespread use in the second half of this century still need to be developed. Unfortunately, since the early 1980's IEA Members have halved their energy-related research and technology development budgets. This trend needs to be reversed in the EU if it wants to improve its competitiveness in these markets. Therefore, budgets for climate, energy, transport and production and consumption research need to be increased significantly in the upcoming 7th Framework Programme. International co-operation to develop breakthrough technologies must be enhanced with the help of public-private partnerships.

Technology innovation: giving Europe a competitive edge in a low carbon future

In the context of the Lisbon strategy, the Kok report stresses that the EU can gain a first mover advantage and can create a competitive edge by focusing on resource-efficient climate friendly technologies that other countries will eventually need to adopt. As an example, the countries that have taken the lead in promoting wind energy now have 95% of the rapidly growing wind turbine industry. Looking forward, this kind of phenomenon could also emerge in other countries and other sectors, such as in cars or aviation. Competitive advantages will be enhanced if participation in a future international climate agreement is broadened and deepened.

6. THE ADAPTATION CHALLENGE

Scientific evidence indicates that even meeting the 2°C target will require significant preventive and remedial adaptation efforts around the globe. As yet, few Member States have examined the need to reduce vulnerability and to increase their resilience to the effects of the climate change.

Adaptation to climate change will require further research to predict the impacts at regional level in order to enable local and regional public and private sector actors to develop cost-effective adaptation options. Particularly vulnerable to climatic changes are low-lying areas close to the coast and in river catchments, mountainous areas, and areas with high risks of increasing numbers of storms and hurricanes.

Economic sectors dependent on weather like agriculture, fisheries, forestry and tourism are more at risk than other sectors, and thus have a greater need to adapt to climate change. In this context, developing countries are the most vulnerable given their high dependence on these climate-sensitive economic sectors and their low capacity to adapt. Strengthening their adaptive capacity would contribute to their development.

Another important aspect of adaptation is the early prediction of more frequent and more damaging natural disasters. The Commission is already involved in an EU-wide early warning system for floods and forest fires. This will improve responses to natural disasters and assist in preventing damage. Earth observation can provide reliable tools for both prevention and adaptation. Private insurance might not

adequately cover damages and losses of private property or might even be reduced over time. Governments will have to step in, either by requiring the provision of adequate coverage or providing solidarity funding.

7. CONCLUSIONS

Climate change is happening. Science tells us that we should be aiming to limit the future global average temperature increase to 2°C above pre-industrial levels in order to limit the damage. The 2°C target implies that policies are needed both to adapt to climate change and to mitigate climate change. Despite the implementation of already agreed policies, global emissions are likely to grow within the next two decades and global reductions of at least 15 % in emission by 2050 compared to 1990 levels would seem to be necessary, and will take significant effort.

Doing nothing is not a sensible option. The more action is postponed, the greater the risk of irreversible climate change, as options to stabilise greenhouse gas concentrations at lower levels are closed off. The science of climate change continues to develop and future evidence may show that change is taking place even faster than is apparent today. Therefore, a rational medium- and long-term climate policy should be based on a 'keeping the door open' strategy. Such a strategy would allow moving even to a lower than initially targeted concentration level in future, if new scientific knowledge points to the necessity to do so.

Mitigation involves significant adjustments to our societies and economies, such as the restructuring of energy and transport systems. It is therefore imperative to use the most efficient and least-cost mix of adaptation and mitigation actions over time to meet our environmental objectives while maintaining our economic competitiveness. The future climate change strategy of the EU needs to include the following elements:

(1) **The broadening of participation:** The EU will continue to play a leadership role in the multilateral approach to climate change, but wider participation on the basis of common but differentiated responsibilities is urgently required. Realistic progress towards the 2°C target is only within reach if more countries in the world take effective actions. In order to minimise negative economic impacts further policy efforts by the EU need to be accompanied by similar action of other major emitting nations. Moreover, policies to tackle climate change must be consistent with and contribute towards other important objectives (e.g. poverty reduction), accommodating the rather diverse conditions of current and future major emitters.

The EU negotiating strategy should include an international process of negotiated actions to reduce emissions, with the aim of involving and committing all large emitters. These actions could consist of specific projects or programmes to improve energy efficiency or to promote low-carbon technologies as well as more comprehensive policies, including targets.

(2) **The inclusion of more policy areas:** The scope of international action must be widened to cover all greenhouse gases and sectors. In particular, the fast growing emissions from aviation and maritime transport should be included.

A fresh look will have to be taken at how to halt deforestation of the world's forests. Addressing this problem as a specific issue in some regions is necessary as almost 20 % of global greenhouse gas emissions are currently emitted due to land use changes.

(3) **Enhanced innovation:** The required transformation of energy and transport systems presents a major innovation challenge. Within the context of the Lisbon strategy, a technology policy employing an optimal mix of 'push' and 'pull' policy instruments should be developed to underpin the restructuring process. Placing an emphasis on cost-effective emission abatement would be essential. A portfolio of low emission technologies is already available and needs to be disseminated more widely. More research is needed to bring new technologies closer to the market.

(4) **The continued use of market based and flexible instruments:** Successful structural elements of the Kyoto Protocol should be maintained in any new system post 2012. These include emissions trading, as introduced by the European Union, on the basis of emission limitations and project based mechanisms as building blocks to a truly international carbon market, the rules for monitoring and reporting on emissions, and a multi-lateral compliance regime.

While continuing to promote the concept of targets and timetables, the scope of international negotiations has to be broadened so as to concretely link climate change issues with research, development, deployment and diffusion of new technologies, improving energy efficiency and developing low-carbon sources of energy and development policy. This broadening of the scope for negotiation has to be understood as a way of creating incentives and motivation for more countries to participate in actions against climate change.

Developing countries will make huge investments into their energy infrastructure over the coming decades. Public funds that are channelled by the World Bank, EIB, EBRD and other development banks need to be used to leverage developing countries' own savings towards climate-friendly investments, particularly in the energy sector. The potential of a global low-carbon energy programme and technology transfer and diffusion funds focusing on major emerging economies needs to be explored.

(5) **The inclusion of adaptation policies:** More resources need to be allocated in the EU to adapt effectively to climate change. The adaptation efforts of the poorest and worst-affected countries should be financially supported.

8. RECOMMENDATIONS FOR EU CLIMATE POLICIES: THE NEXT STEPS

The European Council intends to discuss "medium and longer term emission reductions strategies" at its next meeting. This discussion will lay the foundations for future EU climate change policy and will shape the way in which the Union engages with its international partners. In the light of the analysis and the conclusions contained in this Communication and in the accompanying staff working paper, the Commission has identified a number of elements which, in its view, should be

included in the EU's future climate change strategy. The Commission recommends that the European Council endorse the following approach on which to base the development of the Union's climate change policy:

- **Immediate and effective implementation of agreed policies:** the EU has succeeded in reducing its emissions by 3% below the 1990 level, but much more needs to be done to reach the 8% emission reduction targets agreed in the Kyoto Protocol. Measures identified in the Green Paper on the security of energy supply and the White Paper on Transport Policy such as infrastructure charging, the revision of the Eurovignette Directive and measures encouraging a modal rebalancing towards rail and waterborne transport, such as those included in the Transeuropean Transport Network policy, need to be fully implemented. The removal of bottlenecks preventing the deployment of existing or promising new technologies and new initiatives (e.g. the assessment of the potential of an EU market for green certificates, the swift implementation of Environmental Technology Action Plan) should also be pursued. A key element will be strengthened support for investment in climate-friendly technologies under different headings in the new Community budget for the period 2007 to 2013. In addition, a major new effort throughout Europe is necessary to make real progress in energy efficiency: a new European-wide Energy Efficiency Initiative.

- **Increased public awareness** should be fostered through a strategic programme to sensitise the general public to the climate change significance of their actions, i.a through the launching of an EU-wide awareness campaign.

- **More and better focussed research** should be directed to further improving knowledge on climate change, including the links to ocean processes, to addressing global and regional impacts, developing cost-effective adaptation and mitigation strategies, including non CO_2 gases. This could be done through a significant increase in EU spending under the 7th Framework Programme for climate-friendly technology research and development, in particular in the energy and transport sectors, but also in agriculture and industry.

- **Stronger co-operation with third countries** could be promoted through a strategic programme for enhanced technology transfer (incl. technology diffusion funds) and scientific R&D cooperation on low greenhouse gas technologies in the field of energy, transport, industry and agriculture. Climate friendly development policies should be drawn up in co-operation with developing countries, in particular in the areas of energy and air quality. In implementing these recommendations, coherence between the internal and external dimension of the EU climate change policies needs to be ensured. For instance, the European Neighbourhood Policy could emphasise early transposition and implementation of the climate related 'acquis' promoting convergence with the EU's climate policy. The same approach should be followed in the pre-accession strategies. Strengthening the adaptive capacity, particularly of the most vulnerable developing countries, should become an integral part of development assistance.

- **A new phase of the European Climate Change Programme in 2005:** The Commission will review progress and explore new actions to systematically exploit cost effective emission reduction options in synergy with the Lisbon

strategy. Attention will be paid in particular to energy efficiency, renewable energy, the transport sector (including aviation and maritime transport), and carbon capture and storage. The role of the EU in reducing vulnerability and promoting adaptation should be explored with the involvement of the EU insurance industry.

In building support for further multilateral action against climate change the EU should engage in real dialogue with its international partners. The Commission recommends that the EU explore options for a post-2012 strategy with key partners during 2005 before deciding on the position it will take in the upcoming negotiations. In bilateral contacts with interested countries, including the large emitters, actions should be identified that they are ready to take within specified time horizons and conditions. In this way, the EU should use its international leadership role on climate change to pursue an action oriented approach at the international level.

The outcomes of bilateral discussions could then be fed into the UNFCCC negotiations, through commitments to act or to meet targets. The objective is to establish a multilateral climate change regime post-2012 with meaningful participation of all developed countries and the participation of developing countries which will limit the global temperature increase to 2 °C, and which is considered as a fair sharing of effort by all key players. The reduction commitments that the EU would be willing to take under such a regime should depend on the level and type of participation of other major emitters. Therefore, the Commission is not recommending the adoption of a specific EU target at this stage.

Drawing on the analysis and ideas set out in this Communication, the EU should make clear its continuing commitment to winning the battle against global climate change and to honouring its existing commitments. The EU should show its determination to take on deeper and longer term reductions in its greenhouse gas emissions in the context of an international agreement on a future strategy post-2012 which will deliver global reductions commensurate with the 2°C target. Depending on the outcome of international consultations during 2005 the Commission will make further proposals to the Council to develop the EU's negotiating strategy for the next round of global climate change negotiations.

ANNEXES

Annex 1: Effects of Continuing Climate Change

Sea level rise: By 2100, sea levels rise of 0.09 to 0.88 m, with a central value of 0.48 m, is predicted to occur. Sea level rise will cause flooding, coastal erosion and the loss of flat coastal regions. Coastal protection is possible, though this leads to adaptation costs. Rising sea level increases the likelihood of storm surges, enforces landward intrusion of salt water and endangers coastal ecosystems and wetlands. Estimates in the European Union, where the coastline is about 89,000 km long, indicate some 68 million people could be affected by sea level changes.

At a global level, the effect is potentially more extreme. Populations that inhabit small islands and/or low-lying coastal areas (e.g. small island states such as the Maldives, the Bangladesh delta) are at particular risk of severe social and economic effects from sea-level rise and storm surges. The loss of these areas (e.g. for those living on small island states) will have potentially important secondary effects through migration and potential socially contingent effects.

Agriculture: Parts of Europe, particularly in mid and northern Europe, are expected to potentially benefit from increasing CO_2 concentrations and rising temperatures. The cultivated area could be expanded northwards, and growing seasons extended. In southern parts of Europe, agriculture may be threatened by climate change due to increased water stress. During the heat wave in 2003, many southern European countries suffered drops in yield of up to 30%, while some northern European countries profited from higher temperatures and lower rainfall. Bad harvests could become more common due to an increase in the frequency of extreme weather events (droughts, floods, storms, hail), and pests and diseases.

Global projections estimate EU agricultural yield increases for up to 2°C temperature rise, but a decline beyond this level. But in subtropics/tropics damages, increased heat stress is already projected for 1.7°C temperature increase. Higher average temperatures of 2.5°C in 2080 could result in 50 million additional people at risk of hunger.

Energy: Energy use is likely to change with new average temperatures ranges, with a combination of increases and decreases in demand for heating (both in terms of overall energy supplied, and to meet peak demands). Benefits from increased winter temperatures that reduce heating needs may be offset by increases in demand for summer air conditioning, as average summer temperatures increase.

Health - thermal stress: More than 20,000 additional deaths attributable to heat, particularly among the aged population, occurred in western and southern Europe during the summer of 2003. Heat waves are projected to become more frequent and more intense during the twenty-first century and hence the number of excess deaths due to heat is projected to increase in the future. However, rising temperatures will lead to reduce deaths in winter. Globally it is estimated that an average temperature rise above 1.2°C will cause an increase in premature mortality by several hundred thousands without accounting for extreme event like heat waves.

Health - infectious disease: In Europe tick-borne encephalitis cases increased in the Baltic region and central Europe between 1980 and 1995, and have remained high. Ticks can transmit a variety of diseases, such as tick-borne encephalitis (TBE) and Lyme disease (in Europe called Lyme borreliosis). It is not clear how many of the 85,000 cases of Lyme borreliosis reported annually in Europe are due to the temperature increase over the past decades. At a global level, the rising temperatures will bring many additional people at risk of suffering from diseases like Malaria, dengue and schistosomiasis. For instance it is projected that 2°C increased will result in 210 million people more at risk of malaria and an epidemic potential increase of 30 to 50 % for dengue.

Ecosystems: Significant impacts on ecosystems and water resources are likely between 1 and 2°C, and the risks of net negative impacts on global food production occur between 2 to 3°C global warming. Recent studies[1] for instance indicate that a rise of up to 1°C above pre-industrial levels up to 10 % of ecosystem areas worldwide will shift. Some forest ecosystems will exhibit increased net primary productivity, increased fire frequency and pest outbreaks. Some hotspots with high biodiversity and protected areas of global importance will begin to suffer first climate-change induced losses. Coral reefs will suffer increased bleaching. Range shifts of species and higher risk for some endangered species are likely. Most of these impacts can already be observed today.

An increase of 1 to 2°C above pre-industrial levels will shift up to 15 to 20 % of ecosystem areas worldwide. Some protected areas of global importance and hotspots are likely to suffer severe losses of both area and species. Wildlife of arctic ecosystems will be harmed (e.g. polar bear, walrus). Bleaching events will likely be so frequent that coral reef recovery is insufficient to prevent severe losses of biodiversity.

Increase of more than 2°C above pre-industrial levels: The global share of ecosystems shifting due to climate change will likely be above 20 %, and much more in some regions. Global losses of coastal wetlands may exceed 10 %. At a global scale, reefs will undergo major disruptions and species loss, but will possibly not disappear completely. A large number of species will be endangered by range shifts. There is a risk that some protected areas of global importance will lose most of their area due to climate change.

Water resources, water supply and water quality: Above 2 to 2.5°C global average temperature increase it is projected that additional 2.4 to 3.1 billion people will be at risk of water stress.

Floods: Between 1975 and 2001, 238 flood events were recorded in Europe. Over this period the annual number of flood events clearly increased. The number of people affected by floods rose significantly, with adverse physical and psychological human health consequences[1]. With 2.0 to 6.4°C temperature increase the damage from riverine floods will be several times higher than in the no climate change case. With 1.4°C temperature increase coastal floods are projected to increase the number of people at risk by 10 million, 3.2°C will bring 80 million at risk.

Impacts from storm damage and extreme weather: Extreme weather events are also likely to increase, with cold spells, heat waves, drought, floods, storms and tropical cyclones. Changes in both frequency and severity are possible, though these may not be linearly dependent on average climate. In Europe, 64 % of all catastrophic events since 1980 are directly attributable to weather extremes: floods, storms and droughts / heat waves. 79% of economic losses caused by catastrophic events result from these weather related events. Economic losses resulting from weather related events have increased significantly in the last 20 years, from an annual average of less than US$ 5 billion to about US$ 11 billion. This is due to wealth increase and more frequent events. Four out of the five years with the largest economic losses in this period have occurred since 1997. The average number of annual disastrous weather related events in Europe doubled over the 1990s compared with the previous decade, while non-climatic events such as earthquakes remained stable. Projections show an increasing likelihood of extreme weather events. Thus, growing damages are likely.

Regional conflicts, famines, large scale migration: There is an emerging consensus that widespread climate change may increase socially contingent effects[1], due to multiple stresses coming together. This is unlikely to affect Europeans directly, but may well have effects on Europe. The combination of stresses from climate change from the above effects may converge on a number of vulnerable areas, for example in Africa, leading to potential regional conflict, poverty or famine, migration, etc.

It is highlighted that the disproportionate impact of climate change occurs on developing countries because these countries are more vulnerable to climate change than developed countries: their economies rely more heavily on climate-sensitive activities; they are close to environmental tolerance limits; and they are poorly prepared to adapt to climate change. In contrast, richer societies tend to be better able to adapt and their economies are less dependent on climate. With the upper range of IPCC projections of climate change, the impacts are likely to adversely affect achievement of the Millennium Development Goals (as agreed at the UN Millennium Summit in New York in 2000).

Abrupt climate change: There are also a number of major effects (potentially catastrophic effects or major climate discontinuities) that could occur. These include climate feedbacks that strongly accelerate climate change by exceeding specific temperature thresholds, irreversible changes to the climate system, or result in sudden and rapid exacerbation of certain impacts requiring unachievable rates of adaptation. The temperature changes at which these thresholds would be passed are not all clearly defined as yet, due to uncertainties in the science. At temperature rise above 2°C there is an increase in the risk of a range of severe large scale events, such as shutdown of the ocean thermohaline circulation, but some thresholds may be passed at global average temperature changes below 2°C, such as the irreversible melting of the Greenland Ice sheet leading to a sea-level rise of 0.3 meter per century (to a maximum of 7 meters) at a sustained local warming of 3°C (Arctic warming).

Annex 2: The Benefits and Costs of Limiting Climate Change

The benefits

Reducing greenhouse gas emissions generates benefits in the form of avoided damages from climate change. The potential benefits depend to a large degree on estimates of (i) the availability and costs of adaptation technologies and policies, and (ii) the sensitivity of the climate to rising concentrations of greenhouse gases in the atmosphere. According to the Intergovernmental Panel on Climate Change *"comprehensive, quantitative estimates of the benefits of stabilization at various levels of atmospheric concentrations of greenhouse gases do not yet exist."*

Allowing for scientific and economic uncertainties, the IPCC Second Assessment Report[3] concluded that a 2.5°C rise in global temperature could cost as much as 1.5 to 2.0 % of global GDP in terms of future damage, with significant regional variations[4]. Indeed, the economic consequences of climate change can already be seen today. Over the past 20 years the insurance sector has seen more than a doubling of economic losses (measured in real terms), partly resulting from weather and climate-related events, though other factors such as land use changes increasing pressure on coastal areas and flood plains, and more widespread insurance coverage, have also contributed to this increase. Climate change is hitting poor developing countries hardest as they are most vulnerable and have the least economic means to respond to the negative impacts.

Many different effects of climate change have been studied in detail in recent years, and demonstrate that if climate change is not tackled economic damage will further increase as will the risk of irreversible damage. Impacts include sea level rise, pressure on freshwater resources, water supply and water quality, agriculture, energy use, human health as well as loss of productivity and bio-diversity and the increased likelihood of drought, flooding, storm damage and more extreme weather events. In the long run, as temperatures continue to rise, a more rapid or unexpected response of the climate becomes more likely or irreversible "catastrophic" events such as the shutdown of the Gulf Stream or the collapse of West-Antarctic Ice Sheet may occur.

Not all regions and locations, and not all economic sectors within the European Union or around the world will be equally affected. For instance, the Mediterranean region will suffer most from ever greater pressure on water resources. Agriculture and forestry will be adversely affected by changes in weather patterns as will hydro-electricity production. As a consequence, considerable impacts on the competitiveness of different economic sectors in different regions can be expected.

Avoiding climate change offers also co-benefits that may amount to a substantial proportion of mitigation costs. These co-benefits are significant and lead to lower emissions of other pollutants, lower pollution control costs and lower environmental impacts.

For example, a scenario with 15 % CO_2 reduction in the EU power sector compared to 'business-as-usual" found considerable side-impacts on the emissions of the conventional air

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3 Working Group III report, chapter 6.

4 A significant part of the costs incurred represent reconstruction and repair activities or delocalisation activities because of the negative effects of climate change.

pollutants due to lower consumption of fossil fuels, namely a reduction of the sulphur dioxide emissions by 6% (equivalent to the total SO_2 emissions of Italy), a decline in nitrous oxide emissions (NO_x) emissions by around 1.2 % (comparable to the total emissions of Hungary), and a decline in primary emissions of particle matters smaller than 2.5 micrometers (PM2.5) by 37kt (approximately three times the total emissions of Denmark).

The costs

Estimates of the costs of climate change policies (excluding adaptation efforts) also need to be treated with considerable caution. Whilst the benefits from avoidance of climate change are potentially high, mitigation involves significant adjustment of our societies and economies, such as the restructuring of energy and transport systems. It is therefore essential to find and use the most efficient and least-cost mix of adaptation and mitigation actions over time in order to ensure that climate change mitigation and the Lisbon objective of increasing the EU's economic growth rate are coherent with each other.

The IPCC considered the costs of meeting various targets for atmospheric concentrations under various assumptions about GDP and emissions growth, and based on conservative assumptions as regards technological progress with respect to abatement technologies. They found that, on average, over the period 1990 to 2100, world GDP growth would be slowed by 0.003% per year; the maximum reduction (to reach a very ambitious target in a high growth scenario) was 0.06% per year[5].

The Commission has also studied the possible costs of cutting world emissions consistent with stabilising greenhouse gas concentrations in the atmosphere at 550 ppmv in the long-term. Assuming gradual participation of all countries in an international effort to address climate change and full international emissions trading, the study shows that reducing EU-25 emissions annually by about 1.5 percentage points after 2012 would reduce GDP in 2025 by about 0.5% below the level it would reach in the absence of such a pro-active climate policy. Widespread international participation in lowering the cost of emission reductions is shown to be crucial. If the EU were to unilaterally reduce its emissions by a similar amount while the rest of the world did nothing, the costs could rise by a factor of three or more without the use of the flexible mechanisms of the Kyoto Protocol, with positive environmental effects being negligible.

Alternatively, according to the Commission's analysis, a somewhat less ambitious climate policy, aiming at stabilising greenhouse gas concentrations at 650 ppmv, would come at abatement costs which would amount to only a quarter of the amount to be invested under the first scenario. However, such a policy could, according to this study, lead to global warming about 25 % above the level achieved in the first scenario, leading to additional costs of climate change. Given the huge risk of non-linear responses of the climate to higher greenhouse gas concentrations such a policy is unlikely to be consistent with limiting global average temperature increase to 2 °C above pre-industrial levels.

The studies show that the choice of adjustment path is also crucial. Mitigation costs increase more than proportionally with the speed of adjustment, owing to investment cycles and the relatively long term payback from technology policies. For the EU-25, the costs in terms of GDP vary from 0.2 to 0.5% of GDP by 2025 depending on the adjustment path chosen in the

[5] IPCC Working Group 3 report "Climate Change 2001: Mitigation", technical summary, p. 61.

short-term. In particular, account needs to be taken of the scope for technology policies to encourage the development and deployment of promising technologies that may emerge from 2030 onwards. International co-operation on technology should therefore become a complement to current policies even if one knows that technologies might not emerge as anticipated. Deeper cuts over shorter periods of time might not be compatible with long term investment cycles of costly infrastructure.

Commission studies show that the global costs of mitigation can be minimised under the following conditions:

- the inclusion of all sectors and greenhouse gases (especially non-CO_2 gases, bunker fuels, deforestation).

- the participation of all major emitting countries in an international effort to address climate change.

- the full and unrestricted use of emissions trading and the optimal use of other flexible measures, such as the Clean Development Mechanism. Such schemes supplement emissions trading by allowing access to lower cost abatement opportunities. Commission estimates suggest that such schemes can reduce direct abatement costs by as much as two-thirds.

- the full exploitation of synergies with other important EU policy objectives, in particular the Lisbon strategy, the energy security policy, the sustainable development strategy, the continuing reform of the Common Agricultural Policy, and the thematic strategy on air quality.

Sectoral impacts

The overall effects of mitigation policies on GDP conceal large differences between sectors, and within sectors. For example, while fossil fuel-based energy industries may be expected to face higher compliance costs, increased demand for energy from renewable sources (including energy crops in agriculture) and for electricity generated by nuclear energy is likely. Energy-intensive sectors (chemicals, iron and steel, building materials) will face higher compliance costs, while producers of abatement equipment (energy-saving technologies, carbon storage) will benefit in relative terms. This shift in the structure of the economy will require significant reallocation of capital and labour between sectors, while the presence of emissions trading will keep compliance costs as low as possible.

Annex 3: Fifteen Technology Options - each potentially reducing emissions by 3.6 Gt CO_2 per year by 2050

Efficiency and conservation

(1) Improved fuel economy of vehicles

(2) Reduced reliance on cars

(3) More efficient buildings

(4) Improved power plant efficiency

Decarbonization of Electricity and Fuels

(5) Substituting natural gas for coal

(6) Storage of carbon captured in power plants

(7) Storage of carbon captured in hydrogen plants

(8) Storage of carbon captured in synthetic fuel plants

(9) Nuclear fission

(10) Wind electricity

(11) Photovoltaic electricity

(12) Renewable hydrogen

(13) Biofuels

Natural sinks

(14) Forest management

(15) Agricultural soils management

Source: Pacala, S, Socolow, R. 2004. Science Vol. 305. 968-972