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COMMUNICATION FROM THE COMMISSION TO THE COUNCIL, THE EUROPEAN PARLIAMENT, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS

Limiting Global Climate Change to 2 degrees Celsius
The way ahead for 2020 and beyond

{COM(2007) 2 final}
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Impact Assessment

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1. INTRODUCTION

The 2005 Communication "*Winning the Battle against Global Climate Change*"[1] outlined the challenges ahead in tackling global climate change. It provided concrete recommendations for EU climate policies and sets out key elements for the EU's future climate strategy, i.e. to build on the market-based mechanisms of the Kyoto Protocol; broaden participation; include more sectors and gases; foster deployment and development of technologies, and strengthen work on adaptation.

The European Council and the European Parliament have both confirmed the EU's objective to limit average global temperature increase to a maximum of 2°C compared to pre-industrial levels. To meet this objective, atmospheric concentrations of greenhouse gases have to remain well below 550 parts per million volume (ppmv) CO_2 equivalent, requiring global emission reductions of at least 15 % but perhaps as much as 50 % by 2050 compared to 1990 levels. Industrialised countries would have to continue to take the lead and explore options to reduce their greenhouse gas emissions by 15–30 % by 2020 and 60–80 % by 2050. The European Council expressed the need to further explore with other Parties to the UN Framework Convention on Climate Change (UNFCCC) strategies that can deliver these significant emission reductions. It also requested the European Commission to deepen its analysis.

This staff working paper provides the background analysis for the Communication "*Limiting Global Climate Change to 2 degrees Celsius: Policy options for the EU and the world for 2020 and beyond*", which responds to this request. It explores options for international and EU policy instruments to limit global greenhouse gas emissions to a level that would be consistent with the Council request aiming at preventing an average global temperature increase of more than 2°C. It takes stock of the progress on the implementation of the recommendations of the 2005 Communication and provides latest information on the science of climate change and climate impacts. It also gives an update on the costs of inaction and benefits of action in other policy domains. It discusses strategies to reach credible reduction pathways up to 2050 and assesses the global and EU costs of reduction pathways for 2020 and 2030, complementing previous assessments[2]. The issue of adaptation[3] within the EU will be covered in a separate Green Paper.

[1] COM (2005) 35 of 9 February 2005.

[2] Staff working paper annexed to COM (2005) 35 of 9 February 2005.

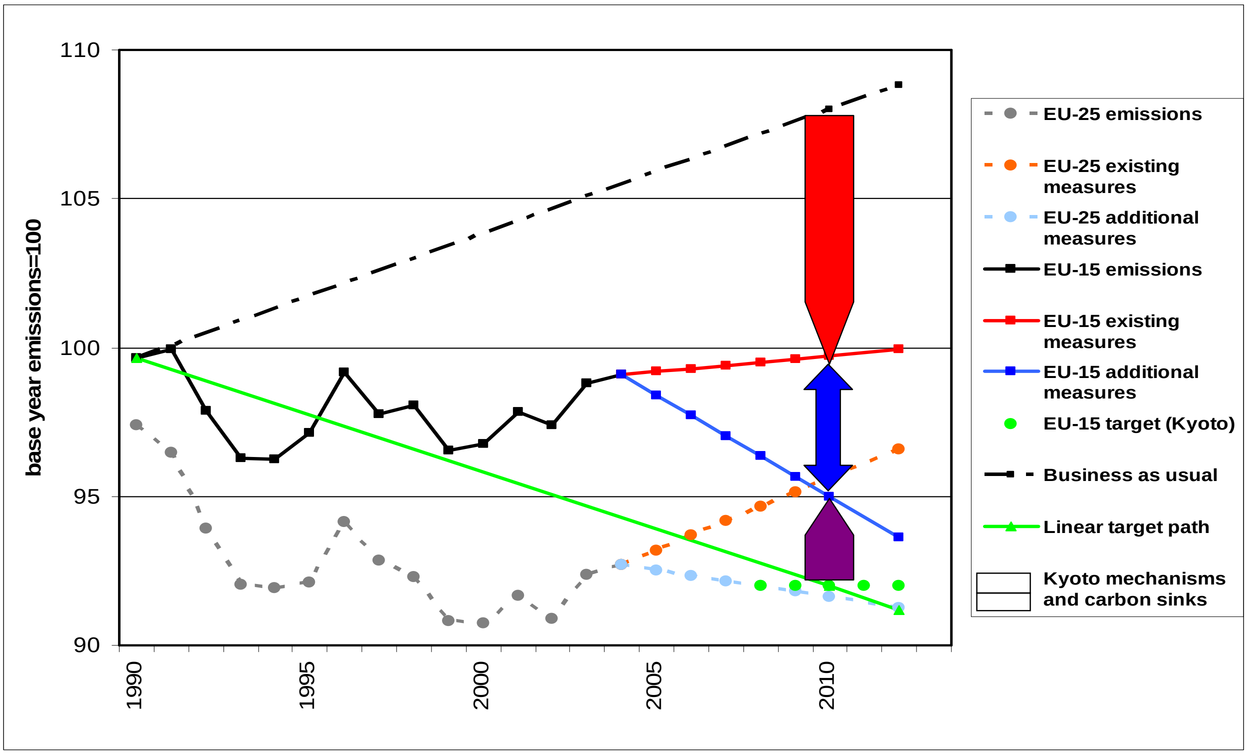
[3] "Adaptation" refers to all measures to adapt to unavoidable climate change impacts, while "mitigation" refers to all measures minimising greenhouse gas emissions and concentrations in the atmosphere

2. TAKING STOCK OF THE RECOMMENDATIONS OF THE 2005 COMMUNICATION

2.1. Immediate and effective implementation of agreed policies to reach the Kyoto Protocol targets

The 15 EU Member States (EU-15) that are part of the EU's "joint fulfilment agreement"[4] have a collective greenhouse gas emissions reduction target of 8 % for the period 2008-2012, compared to their base-year emissions (mostly 1990). The aggregate projections, based on existing domestic policies and measures, show that greenhouse gas emissions of the EU-15 will only be 0.6 % below base-year levels in 2010 (i.e. a 7.4 % distance from the emission reduction commitment). Member States have reported additional measures to the European Commission under the EU greenhouse gas monitoring mechanism that promote electricity generation from renewable energy sources, cogeneration and energy efficiency. These additional domestic measures are projected to reduce the gap by a further 4.0 %, down to 4.6 % by 2010.

Emission reductions achieved through domestic measures alone will not suffice to reach the Kyoto Protocol's target. The use of Kyoto mechanisms is expected to deliver an additional 2.6 % emission reductions and the removal through sinks (Article 3.3 and 3.4 activities under the Kyoto Protocol) in the EU-15 is estimated to add about 32.6 million tonnes CO_2 equivalent reductions per year, corresponding to an additional 0.8 %. Taking this together, the EU-15 is projected to reduce its emissions by 8.0 % over the period 2008-2012 compared to 1990, meeting its Kyoto target.



[4] Council Decision 2002/358/EC of 25 April 2002 concerning the approval, on behalf of the European Community, of the Kyoto Protocol to the United Nations Framework Convention on Climate Change and the joint fulfilment of commitments thereunder, OJ L 130 of 15 May 2002, p. 1.

Figure 1: EU progress towards the reduction commitment under the Kyoto Protocol

The fact that projections suggest that the EU will only just meet its target underlines the importance of Member States' implementation of these additional measures. Following the first European Climate Change Programme (ECCP I) in 2001, several policies were implemented in the energy sector such as Directive 2003/30/EC on the promotion of the use of biofuels or other renewable fuels for transport[5], Directive 2004/8/EC on the promotion of cogeneration[6] , and Directive 2002/91/EC on the energy performance of buildings[7].

The review of the ECCP I, launched at the end of 2005, assessed the stage of implementation of the identified measures and concluded that 30 % of the reduction potential had been reached. It also concluded that the quantitative assessment methods to assess the degree of implementation of these measures needed to be improved.

Directive 2003/87/EC[8] established the EU emissions trading scheme (EU ETS), which accounts for around 45 % of the EU's total CO_2 emissions. This trading scheme is linked to the Kyoto Protocol's project mechanisms through Directive 2004/101/EC[9]. The EU ETS started successfully on 1 January 2005 and the European Commission is currently assessing the National Allocation Plans for the second phase under the scheme, covering the period 2008-2012.

Since early 2005, several other new legislative instruments have been enacted that will contribute to lower greenhouse gas emissions within the Community, for example Directive 2005/32/EC on product eco-design[10], Directive 2006/40/EC to control the use of fluorinated greenhouse gases in air conditioning systems in motor vehicles[11] and Regulation 2006/842/EC concerning the use of similar gases in other products[12].

The European Commission's Green Paper "*A European Strategy for Sustainable, Competitive and Secure Energy*"[13] pointed to the necessity of a renewed focus on sustainable, secure and

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5 Directive 2003/30/EC of the European Parliament and of the Council of 8 May 2003 on the promotion of the use of biofuels or other renewable fuels for transport, OJ L 123 of 17 May 2003.

6 Directive 2004/8/EC of the European Parliament and of the Council of 11 February 2004 on the promotion of cogeneration based on a useful heat demand in the internal energy market and amending Directive 92/42/EEC, OJ L 52 of 21 February 2004.

7 Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the energy performance of buildings, OJ L 1 of 4 January 2003.

8 Directive 2003/87/EC of the European Parliament and of the Council of 13 October 2003 establishing a scheme for greenhouse gas emission allowance trading within the Community and amending Council Directive 96/61/EC, OJ L 275 of 25 October 2003.

9 Directive 2004/101/EC of the European Parliament and of the Council of 27 October 2004 amending Directive 2003/87/EC establishing a scheme for greenhouse gas emission allowance trading within the Community, in respect of the Kyoto Protocol's project mechanisms, OJ L 338 of 13 November 2004.

10 Directive 2005/32/EC of the European Parliament and of the Council of 6 July 2005 establishing a framework for the setting of ecodesign requirements for energy-using products and amending Council Directive 92/42/EEC and Directives 96/57/EC and 2000/55/EC of the European Parliament and of the Council, OJ L 191 of 22 July 2005.

11 Directive 2006/40/EC of the European Parliament and of the Council of 17 May 2006 relating to emissions from air conditioning systems in motor vehicles and amending Council Directive 70/156/EEC, OJ L 161 of 14 June 2006.

12 Regulation (EC) No 842/2006 of the European Parliament and of the Council of 17 May 2006 on certain fluorinated greenhouse gases, OJ L 161 of 14 June 2006.

13 COM (2006) 105 of 8 March 2006.

competitive energy. In addition, the European Commission has recently issued a "*Biomass Action Plan*"[14], a "*Biofuels Strategy*[15], an "*Action Plan for Energy Efficiency: Realising the Potential*"[16] , and the *EU Forest Action Plan (FAP)*[17], and is undertaking the first Strategic EU Energy Review.

2.2. A new phase of the European Climate Change Programme in 2005

The European Commission launched the 2nd phase of the ECCP in October 2005. Its five working groups cover the review of ECCP I, aviation, cars, carbon capture and geological storage (CCS) and adaptation. All groups concluded their work in 2006.[18]

Following up on the results of the 2nd phase of the ECCP, the European Commission has come forward with a number of initiatives, including a proposal to include aviation in the EU emissions trading scheme[19]. The European Commission will also adopt a Communication on next steps to achieve the EU's objectives for reducing CO_2 emissions from cars in early 2007. The European Commission is furthermore planning to release a proposal for regulating Carbon Capture and Geological Storage in the 2nd half of 2007, by establishing an EU legal framework, which ensures that this technology is deployed safely and which provides certainty to investors. The European Commission will also put forward a Green Paper on adaptation that will look into the necessity of Community action in this field.

Following the European Commission Communication on the Review of the EU Emission Trading Scheme[20], the European Commission will also use the ECCP Working Group on the Review of the EU ETS to consult further on the review of the scheme. The report of this working group will feed into a legislative proposal by the European Commission in 2007.

2.3. Increasing public awareness

The European Commission has intensified its awareness raising activities and is providing information to the public in a variety of forms, for example:

– the European Commission's 2005 "Green Week" was entirely devoted to climate change and brought together stakeholders from academia, governments, NGOs and private sector[21];

– a series of workshops and conferences on post-2012 climate strategies in the new Member States during 2006;

14 COM (2005) 628 of 7 December 2005.
15 COM(2006)34
16 COM(2006)545 of 19 October 2006.
17 COM(2006) 302 of 15.06.06.
18 Final reports and documents for the meetings can be found at: http://forum.europa.eu.int/Public/irc/env/eccp_2/library.
19 Commission Proposal for a Directive of the European Parliament and of the Council amending Directive 2003/87/EC so as to include aviation activities in the scheme for greenhouse gas emission allowance trading within the Community, COM(2006)818final, 20 December 2006.
20 Commission Communication "Building a global carbon market – Report pursuant to Article 30 of Directive 2003/87/EC", COM (2006) 676 of 13 November 2006.
21 See: http://ec.europa.eu/environment/greenweek2005/index_en.htm.

– an awareness raising campaign "you control climate change" in all 25 Member States. This aims to inform individuals about their role in controlling climate change[22].

Figure 2: European awareness raising campaign: http://www.climatechange.eu.com

2.4. More and better focussed research

As recommended in the 2005 Communication "Winning the battle Against Global Climate Change", the forthcoming 7th European Community Framework Programme for research, technological development and demonstration activities (FP7) has a significantly increased budget for research on climate change, energy and transport technologies from 2007 to 2013[23].

FP7 builds upon the themes of FP6 and aims to enhance progress towards the goals of the Lisbon Strategy in promoting economic growth, whilst at the same time ensuring social progress and environmental sustainability. For the theme 'Sustainable development, global change and ecosystems' (including research in the area of energy and transport), some € 300m were spent in FP6 while the FP7 will have an estimated € 500m at its disposal, putting a significantly stronger emphasis on direct climate research and also a strong increase in the related energy and transport parts. The thematic areas linked to climate change (with their indicative budgets) are:

Energy (€ 2300m): to support transformation of the current fossil-fuel based energy system into a more sustainable system, based on a diverse portfolio of energy sources and carriers combined with enhanced energy efficiency. It aims to address the pressing challenges of security of supply and climate change, whilst increasing the competitiveness of Europe's energy industries. Key activities will focus upon:

– hydrogen and fuel cells;

– renewable electricity generation;

– renewables for heating and cooling;

22 See: http://www.climatechange.eu.com.

23 Climate change related research under the 6th Framework programme was covered under the Theme 'Sustainable development, global change and ecosystems (including research in the area of energy and transport) which had a budget of € 2.120bn from 2002-2006 with Sustainable energy systems - € 800m, Sustainable surface transport - € 600m environmentally friendly and competitive transport systems and global change and ecosystems - € 700m.

- Carbon Capture and Geological Storage technologies for zero emission power generation;
- clean coal technologies;
- smart energy networks;
- energy efficiency and savings, and
- knowledge for energy policy making.

Environment (including Climate Change) (€ 1900m): for a more sustainable management of the environment and its resources through the improvement of our knowledge of the interactions between the biosphere, ecosystems and human activities, and the development of new technologies, tools and services, in order to address global environmental issues in an integrated way. Emphasis will be placed on prediction of climate, ecological, earth and ocean systems changes. Key activities will focus on:

- climate change, pollution and risks, in particular looking at the core climate issues, on the pressures on the environment, and on the additional impacts and links to health and natural hazards;
- sustainable Management of Resources;
- environmental Technologies for observation, prevention, mitigation, adaptation, remediation and restoration of the natural and man-made environment, and
- earth observation and Assessment tools including modelling and predicting environmental phenomena, modelling links between economy, environment and society, including market based instruments, as well as contributing to the Global Earth Observation System of Systems (GEOSS).

Transport (including aeronautics) (€ 4180m): to develop integrated, "greener" and "smarter" pan-European transport systems for the benefit of citizens and society, respecting the environment and natural resources while securing and further developing the leading role of European industries in the global market. Key activities will focus on:

- the greening of air transport – including emissions reductions, alternative fuels, traffic management etc;
- the greening of surface transport – including reduction of pollution, promotion of efficient engines, hybrid technology and alternative fuels;
- encouraging modal shift and decongesting transport corridors, and
- ensuring sustainable urban mobility.

In addition, **the European Commission's Joint Research Centre (JRC)**, which provides science-based support to the policy making, has Climate Change as well as Energy and Transport as priorities in its FP7 work programme. In particular, the JRC establishes European and global datasets needed to assess the feasibility of options for mitigation and adaptation and it engages in scenario modelling to investigate the effectiveness of these options.

2.5. Stronger co-operation with third countries

The 2005 Communication recommended the strengthening of co-operation on climate change with third countries. This recommendation was strongly supported by the Council, most recently in the conclusions of the European Council in December 2005 and the Environment Council of March 2006. As a result, the European Commission and the Member States have significantly stepped up their outreach to and cooperation with third countries through actions such as the following:

– regular high-level policy dialogue;

– filling the knowledge gaps through cooperation on climate science and policy modelling;

– exchange of experiences on domestic climate change, air quality and energy policies, optimal design of environmental policy instruments, including market based instruments and legislative approaches;

– technology co-operation on reducing greenhouse gas emissions, including through energy efficiency, renewable and clean energy, methane capture, agriculture/forestry, and waste management and CCS technologies;

– international initiatives to better understand hemispheric transport of air pollution, which raise awareness on the global character of air pollution, and its links to climate change;

– exchange of views on impacts and adaptation, plus capacity building on adaptation;

– strengthening the implementation of the Kyoto Protocol's Joint Implementation (JI) and Clean Development Mechanism (CDM);

– implementation of commitments under the United Nations Framework Convention on Climate Change (UNFCCC) and its Kyoto Protocol, and

– demarches carried out jointly by the European Commission and the Member States in the run-up to all major international climate change conferences since 2004.

Efforts to increase third country participation in the 6th European Community Framework Programme for research have been significantly stepped up since the 2005 Communication. In 2006, an additional call for proposals was launched. This call, with a total budget of € 20m, specifically invited proposals for research projects to facilitate and enhance international cooperation on dealing with major technical and non technical barriers to hydrogen and fuel cell deployment and CCS technologies. A further call for proposals with a budget of € 20m was opened to increase participation of third country partners in existing projects. International Cooperation on energy research will be further increased in the 7th Framework Programme, including the specific programme on 'Cooperation' that will be open to participation from third countries. The European Commission is also currently preparing a European strategy on international science and technology cooperation that will strengthen the EU's external relations in this field.

The 7th Framework Programme should also stimulate cooperation in support of the aim of the EU Energy Initiative for poverty eradication and sustainable development launched at the World Summit on Sustainable Development in 2002 (WSSD), with the aim of providing reliable and affordable access to sustainable energy for the poor.

Several Ministerial meetings were organised for the Johannesburg Renewable Energy Coalition (JREC, also launched at WSSD) and the EU Energy Initiative. These dialogues inspired concrete Community sponsored initiatives such as the Global Renewable Energy Policies Database developed by the International Energy Agency, the € 220m EU Energy Facility, and the recently launched € 100m Global Energy Efficiency and Renewable Energy Fund (GEEREF)[24] that has already received pledges for additional funding from several Member States. GEEREF is a financing partnership that mobilises substantial commercial funding by offering new risk sharing to co-financing options to public and private investors. It will make risk capital available in energy efficiency and renewable energy projects in developing countries and economies in transitions, also at the level of small and medium-sized enterprises. GEEREF will actively engage in the creation of regional funds covering Africa, Asia, Latin America, and European Neighbouring countries.

The JRC has also given more space to the global dimension in its FP7 work programme, in particular for issues related to climate change and development.

A further direct result of the EU's commitment to reinforce its cooperation in the field of climate change with third countries is the agreement on a series of climate change partnerships with key third countries.

China

The EU-China Partnership on Climate Change was launched in the context of the EU-China Summit in September 2005. This Partnership established a political dialogue between China and the EU on actions to tackle climate change and focuses the concrete cooperation efforts between the EU and China in the area of climate change and energy.

Key results of the Partnership include the agreement to set up a demonstration near-zero-emissions coal fired power plant using carbon capture and geological storage in China. Memoranda of Understanding between China, the European Commission and the United Kingdom have been agreed. Total funding from the United Kingdom and the European Community for the first phase of this project amounts to around € 10m.

The Partnership also led to the initiative by the European Investment Bank to set up a € 500m financing facility aimed at supporting investment projects in China that mitigate climate change. These efforts come in addition to the EU-China Energy and Environment Programme, which promotes sustainable energy use in China, in particular in the area of energy policy development, energy efficiency, renewable energy and natural gas. The EEP is running from May 2003 until May 2008 with a total budget of € 42.9m, of which the contribution of the European Commission is € 20m.

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[24] Commission Communication "*Mobilising public and private finance towards global access to climate-friendly, affordable and secure energy services: The Global Energy Efficiency and Renewable Energy Fund*", COM(2006) 583 of 6 October 2006.

The partnership has furthermore led to a series of activities to strengthen China's participation in the CDM, including through a joint workshop on the CDM and market based mechanisms, the European Community's support for the Asia Carbon Expo in Beijing in October 2006 and a number of new projects to strengthen China's capacity to implement CDM projects. The partnership has furthermore strengthened the cooperation between China and the EU in the area of adaptation.

India

The EU and India adopted their Action Plan at the EU-India Summit in September 2005. This Action Plan contains a chapter on Clean Development and Climate Change, establishing an EU-India Initiative on Clean Development and Climate Change. This partnership focuses on cooperation in the area of clean technology and the Kyoto Protocol’s CDM, as well as on cooperation on adaptation to climate change and the integration of adaptation concerns into sustainable development strategies. The Initiative has strengthened the political dialogue on international action to tackle climate change between India and the EU.

Russia

Following Russia's ratification of the Kyoto Protocol in February 2005, EU climate co-operation with Russia has progressed significantly. Bilateral workshops with EU and Russian experts on Kyoto implementation have been organised regularly since 2003. At the Environment Permanent Partnership Council 10 October 2006, the EU and Russia agreed on the terms of reference for a bilateral Environment Dialogue and established seven expert sub-groups, including one on climate change involving the European Commission and the Russian authorities that will drive forward co-operation into areas such as adaptation and mitigation policies, future action, reporting and research.

The EU launched a € 2m TACIS-funded project on Kyoto implementation in June 2005, covering issues of capacity building in Russia for monitoring and reporting, inventory of greenhouse gas emissions, and development of the national emission registry system.

Since 2005, the EU has increased its efforts to promote energy efficiency as a means to stimulate modernisation of the energy sector in Russia. The framework of the EU-Russia Energy Dialogue foresees an Action Plan on energy efficiency. The plan stresses the role of the Kyoto Protocol's flexible mechanisms in promoting energy efficiency.

Ukraine

Ukraine ratified the Kyoto Protocol in 2004. EU-Ukraine climate change co-operation has developed slowly due to the latter's frequent changes of government in recent few years. Since 2004, the EU has provided Ukraine with technical assistance for implementing the Kyoto Protocol, including support for monitoring and reporting as well as inventories of greenhouse gas emissions. Ukraine is participating in the Kyoto mechanisms as a host country for JI projects. The EU and Ukraine have a bilateral working group on climate change which met most recently on 12 December 2006.

Because of its dependence on energy imports, Ukraine has a strong interest in making its economy more energy efficient. An EU-Ukraine working group on energy efficiency and renewable energy was established in July 2006 in order to enhance bilateral cooperation in these areas.

Brazil

The European Commission has recently agreed with Brazil to set up a European Commission-Brazil Dialogue on the Environment and Climate Change dimension of Sustainable Development. This will encompass a Working Group on Climate Change. This newly established cooperation is expected to develop into a broader EU-Brazil Partnership.

United States of America

At the June 2006 EU-US Summit the decision was taken to set up a High Level Dialogue on Climate Change, Clean Energy and Sustainable Development, which met for the first time in November 2006.

Other countries/regions

Concrete initiatives for closer cooperation are also planned with South Africa, Mexico and South Korea. In addition to the bilateral work, the EU has strengthened its cooperation in the area of climate change with various regional organisations. Climate and energy issues featured high on the agenda of the 2006 EU-Latin America and Caribbean, ACP and ASEM Summits. Finally, the EU-Gulf Cooperation Council Joint Cooperation Committee agreed to intensify dialogue on environmental topics, in particular climate change.

3. RECENT SCIENTIFIC FINDINGS ON CLIMATE CHANGE

In March 2005, the Exeter Conference on Avoiding Dangerous Climate Change gathered leading climate scientists in order to present the latest scientific results (Tirpak et al. 2005). This was the most comprehensive exercise since the Inter-Governmental Panel on Climate Change (IPCC) published its Third Assessment Report in 2001. Latest research results confirm that the climate is actually changing with direct impacts on ecosystems and mankind. There are indications that these changes have accelerated even faster. In many cases the risks also seem to be more serious than previously thought. The IPCC is currently preparing the 4th Assessment Report that will include scientific findings until the end of 2006, to be published in November 2007.

3.1. Current observations of climate change: the physical system

- 2005 was the warmest year on record (NASA, 2005). Globally, the 10 warmest years on record have all occurred after 1990. Another study concludes that, because of a rapid warming trend over the past 30 years, the Earth is now reaching and passing through the warmest levels in the current interglacial period, which has lasted nearly 12,000 years. This warming is forcing migration of plant and animal species toward the poles (Hansen 2006).

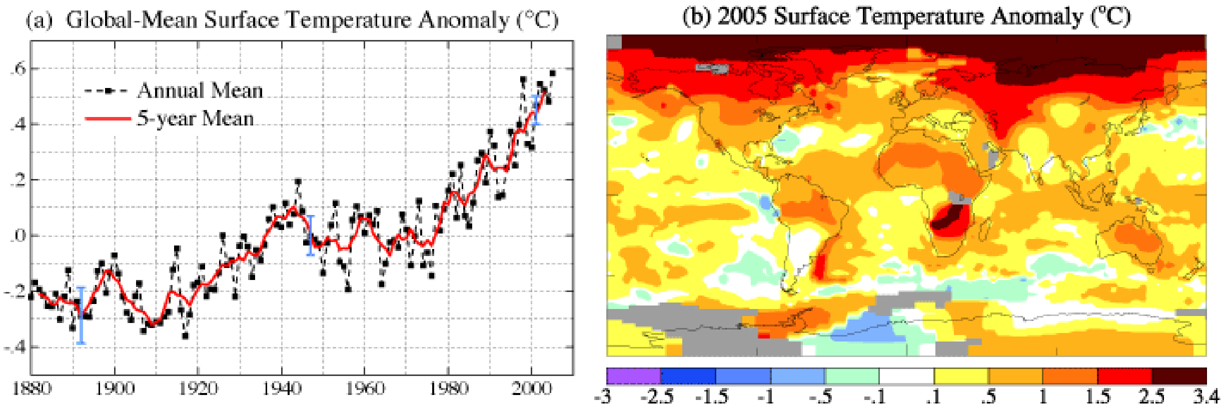

Figure 3: (Left) Global annual surface temperature relative to 1951-1980 mean based on surface air measurements at meteorological stations and ship and satellite measurements for sea surface temperature. Error bars are estimated 2σ (95% confidence) uncertainty. (Right) Temperature anomaly for 2005 calendar year. Grey areas indicate a lack of station data within 1200km. Source: NASA Goddard Institute for Space Studies Surface Temperature Analysis

- The ice cores, sampled and analysed by the European Project for Ice Coring in Antarctica (EPICA), reveal the long-term glacial-interglacial cycles of the climate and provide records of atmospheric carbon dioxide, methane, and nitrous oxide for the time period. Today's methane and carbon dioxide levels are unmatched by any record during the last 650,000 years (Siegenthaler, 2005).

- Acceleration in sea-level rise has been observed. A recent study found a sea-level rise from January 1870 to December 2004 of 195 mm, equal to an average sea-level rise of 1.7 ± 0.3 mm per year in the 20th century. This yearly rise is also increasing by 0.013 ± 0.006 mm per year. This is an important confirmation of climate change simulations, which projected this acceleration (Church, 2005).

- Climate change is affecting precipitation and hydrological cycles (Dore, 2005). One of the expected impacts of climate change is that snow and ice levels reduce and that snowmelt occurs earlier in the spring season. Wet regions increasingly experience higher levels of precipitation, and arid areas reduced levels, becoming drier. New studies show that hydrological changes are already observable.

- Scientific findings conclude that there has been an increase in hurricane intensity and attribute this trend in part to climate change, while it is still uncertain whether the number of hurricanes per year is correlated. Scientists also are drawing a link between climate change and the first-ever South Atlantic hurricane, which hit southern Brazil in Spring 2004 (Pezza et al., 2005).

- Given damages associated with intense storms over the recent past (for example, reports by Munich Re and others indicate weather-related damages over the past 25 years at about $ 1.5 trillion), capacity will need to be increased to deal with damages to coastal communities and ecosystems.

3.2. Current observation of climate change: impact on ecosystems

- Species are already migrating out of their historic ranges to avoid changing climate conditions. Plants and animals associated with certain geographic regions are moving — or dying. Habitats are becoming reduced as a result of temperature increases. Food chains have changed. Further alterations in ecosystem provisioning services, including wood products, drinking water supply, and agriculture productivity can be expected as climate change continues to alter entire ecosystems (ecological systems including interlinked fauna, flora and the physical framework in which they live). Observed changes are already significant. The North Sea waters have warmed by 1.1°C over the past 30 years. Sea temperature rise is causing fish species in the North Sea to shift their ranges northward in latitude and/or deeper to find colder waters. Changes in North Sea fisheries, already under stress from over-fishing, are likely to accelerate with climate change (Perry, 2005).

- Scientists have documented a shift in the habitat of Spanish butterflies due to the changing climate. Models had projected that species are likely to move upwards in elevation and/or move north as a result of temperature rise. In this study it is estimated that the species' habitat has already decreased by one-third and is likely to decrease by 50 to 80 % during the next 100 years if climate change is left unabated (Wilson, 2005).

- Climate change will alter the supply of European ecosystem services over the next century (Schröter, 2005). While climate change will result in enhancements of some ecosystem services, a large portion will be adversely impacted because of drought, reduced soil fertility, fire, and other climate change-driven factors. Europe can expect a decline in arable land, a decline in Mediterranean forested areas, a decline in the terrestrial carbon sink and soil fertility, and an increase in the numbers of basins with water scarcity. This will all increase the loss of biodiversity.

- Glaciers are retreating, ice sheets are melting and collapsing, and early snowmelt is augmenting warming rates. A study measured glacial cover over several decades and found that 87 % of the 244 Antarctic glaciers have retreated. These results confirm modelling predictions (Cook, 2005).

- The European Alps could lose some 80 % of their glacier cover by the end of this century if summer air temperatures rise by 3°C and become almost completely ice-free by 2100, in the case of a temperature increase of 5°C (Zemp et al., 2006).

- Loss of ice from Greenland doubled between 1996 and 2005, as its glaciers flowed faster into the ocean in response to a generally warmer climate, according to a NASA/University of Kansas study (Buis, 2006). The researchers estimated the ice mass loss resulting from enhanced glacier flow increased from 63 cubic kilometres in 1996 to 162 cubic kilometres in 2005.

- "Ocean acidification" describes a process whereby increased CO_2 in ocean waters leads them to become more acidic. This could cause dramatic changes in the marine environment in the decades to come. Since the industrial revolution began, ocean pH has dropped by approximately 0.1 units, and it is estimated that it will drop by a further 0.3 – 0.4 units by 2100 as the ocean absorbs more anthropogenic CO_2. While the full ecological consequences of these changes in calcification are still uncertain, it appears likely that calcifying species, including in particular coral reefs, will be adversely affected (Orr, J. et al., 2005).

- A study conducted by the FAO and IIASA using spatial soil and climate data reveals that climate change will significantly impact the global food supply (FAO 2005). The results project a loss of 11 % of arable land in the developing world due to climate change, including a loss of cereal production in 65 developing countries (for these countries, the loss equates to roughly 16 % of agricultural GDP in 1995 dollars). The study also suggests that some of the losses would be offset: “new” land available at high latitudes could become available in Russia, Northern Europe, and North America. However, the distributional effects would, overall, be negative.

3.3. Climate model projections

- There is now even greater clarity and reduced uncertainty about the impacts of climate change. Climate models project continued increases in both greenhouse gas concentrations and global temperature with increased impacts unless considerable emission reductions are taken. These impacts increase significantly when global temperatures rise 2°C or more above today’s levels.

- Current greenhouse gas concentrations are higher than 380 ppmv CO_2 (corresponding to approximately 425 ppmv CO_2 equivalent) and rising about 2 ppmv per year. Recent studies point to an increasing risk of exceeding 2°C above pre-industrial levels, with stabilisation levels of greenhouse gas concentrations far beyond 450 ppmvCO_2 equivalent (Meinshausen, 2005).

- Critical temperature levels and rates of change relative to pre-industrial times vary for the globe, specific regions and sensitive ecosystems. For example, a regional increase of 2.7°C above present levels may be a threshold that triggers melting of the Greenland ice-cap, while an increase in global temperatures of about 1°C is likely to lead to extensive coral bleaching. Serious risk of large scale, irreversible disruption, such as reversal of the land carbon sink and possible destabilisation of the Antarctic ice sheets is more likely above 3°C. Such temperature levels are well within the range of climate change projections for the 21st century (Tirpak et al., 2005).

- Aerosol pollution ("global dimming"), which blocks a certain amount of solar radiation, may have shielded us from climate change impacts. Necessary improvements in air quality and successes in abating pollution will increase the incoming radiation and the Earth's warming (Wild, 2005). However, improvements in air quality may reduce warming by tropospheric ozone (Dentener et al., 2006).

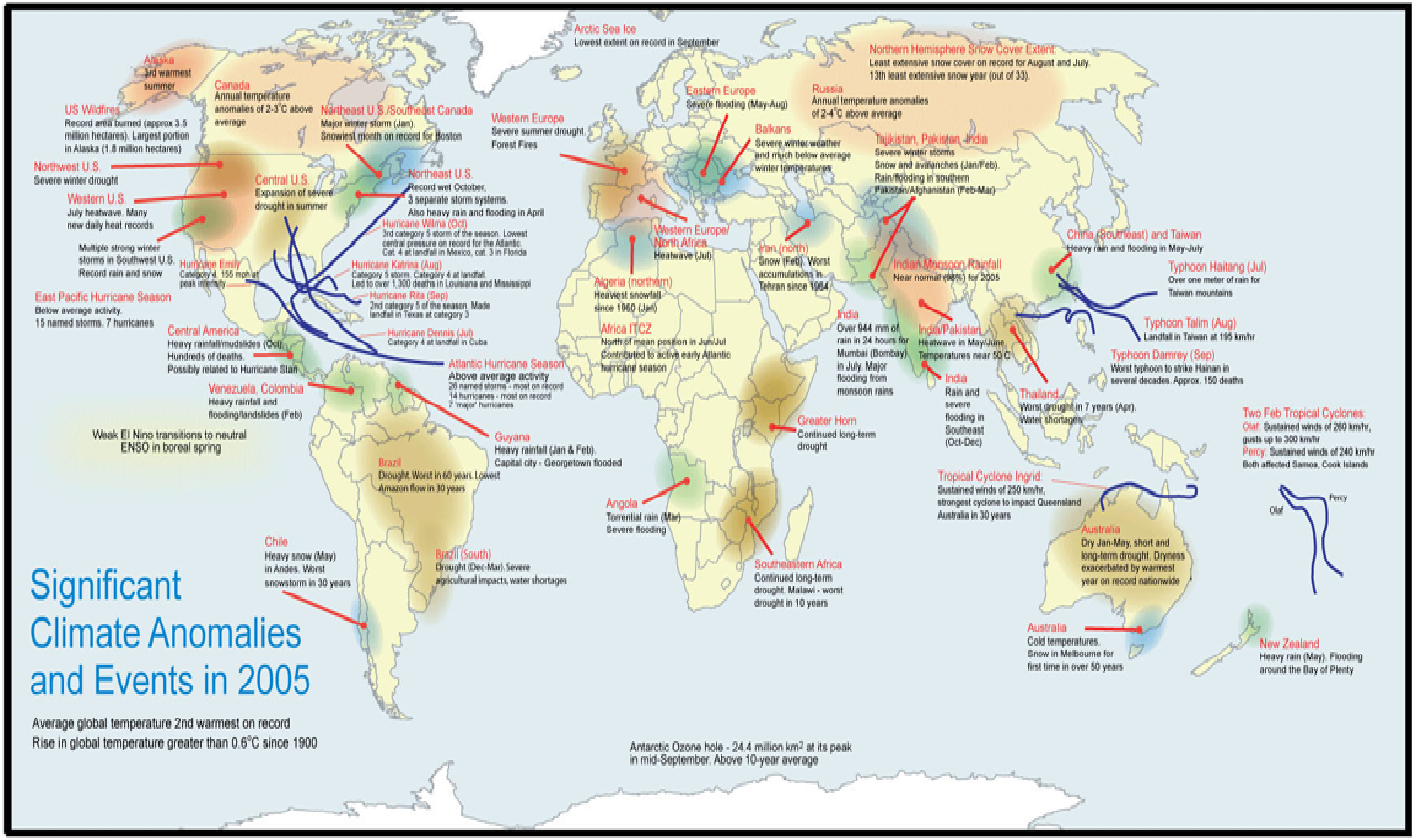

Figure 4: SOURCE: National Oceanic and Atmospheric Administration, National Climatic Data Center, Asheville, North Carolina, , United States)

4. COSTS OF INACTION FOR EUROPE

4.1. The Peseta Study

Incomplete scientific methodologies and gaps in data still do not allow for a systematic and complete economic analysis of the costs of inaction for the EU, particularly when integrating adaptation measures. The on-going PESETA study, coordinated by the Joint Research Centre of the European Commission (DG JRC), will fill some of the knowledge gaps[25]. The PESETA project assesses the expected impacts of climate change in Europe for the time horizons 2011-2040 and 2071-2100, giving a quantitative model-based assessment of physical impacts for certain key sectors. It considers impacts on agriculture, human health, tourism, river basins and coastal systems by using common climate scenarios and consistent underlying socio-economic scenarios. Two global scenarios have been selected from the IPCC's Special Report on Emissions Scenarios (SRES), belonging to the A2 and B2 scenario storyline. This choice partly covers the range of uncertainty associated with the driving forces of global emissions: demographic change, economic development and technological change. In the A2 scenario, where the storyline focus is on national enterprise, global greenhouse gas emissions are assumed to increase more significantly leading to approximately a tripling of average CO_2 concentrations by the end of this century compared to the pre-industrial concentration. The B2 storyline focuses on local stewardship and results in approximately a doubling of the atmospheric CO_2 concentration. More background information on the PESETA study is given in Annex 2. The following paragraphs summarise some of the preliminary results of the PESETA study in relation to agriculture, health, coastal protection, river flood risk and tourism.

4.2. Agriculture

In the PESETA agriculture case study, climate change impacts in the form of European crop yield changes have been modelled for 2020 and 2080 in nine agro-climatic zones. Grain crop productivity decreases in Southern Europe are caused by a shortening of the growing period, with subsequent negative effects on grain filling. Crop suitability and productivity is projected to increase in Northern Europe caused by a lengthened growing season and longer frost-free period. The results, although subject to considerable uncertainties, are consistent with the results of previous studies. Modelled yield changes ranging from +2.8 to +70 % for certain northern regions and decreases ranging from -1.9 to - 22.4 % for southern regions should be taken as indicative estimates. The next phase of the PESETA study will place an economic value on these physical effects of climate change.

[25] Another important research activity, the ADAM project (adaptation and mitigation), will also contribute to filling key knowledge gaps, but is yet in an early stage of work.

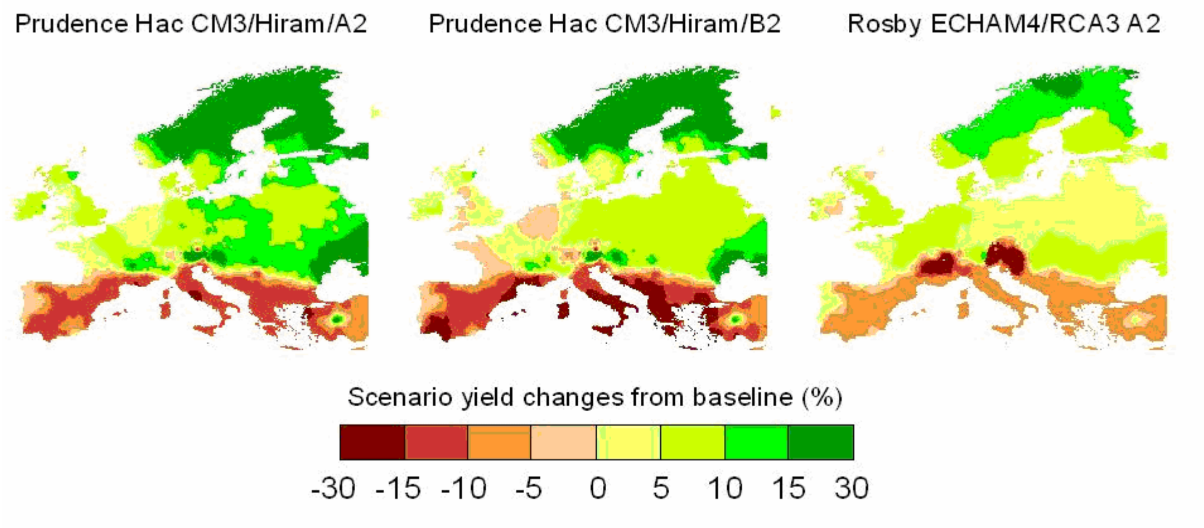

Figure 5 : Crop yield changes under the HadCM3/HIRHAM A2 and B2 scenarios for the 2080s and for the ECHAM4/ RCA3 A2 scenario for the 2020s compared to baseline

4.3. Health

Health effects are one of the key impacts of climate change. The most important, likely health effects of future climate change include:

- Increases in summer heat related mortality (deaths) and morbidity (illness);
- Decreases in winter cold related mortality and morbidity ;
- Changes in the disease burden e.g. from vector-, water- or food-borne disease;
- Increases in the risk of accidents from extreme weather events (storms and floods).
- Impact on mortality, morbidity, disability, health systems, and health economics of extreme events (storms and floods)

The PESETA health project attempts to quantify all the above effects, but has initially concentrated on cold and heat related mortality. The preliminary results indicate that at an overall European level, the increase in the number of heat related deaths could be larger than the reduction in cold related deaths for the 2080s. The analysis shows almost 86,000 net extra deaths per year under a scenario A2 with a global mean temperature increase of 3°C in 2071-2100 relative to 1961-1990. Under scenario B2 with a global mean temperature increase of 2.2°C in 2071-2100 relative to 1961-1990, this number of net extra deaths per year halves to 36,000.

These results are preliminary and do not assume acclimatisation and do not yet separate out the impact of non-climate changes (socio-economic changes in age structure or population movements). Nonetheless, assuming a range of values of statistical life of from € 1-2m, they do show that potential economic costs of climate change are large – measured in € billions as an annual cost already in the second half of the 21st century.

4.4. Coastal protection

The preliminary modelling results of the physical impacts and costs of sea-level rise in the EU show significant damages, in particular where adaptation would not be undertaken (e.g. through enhanced coastal protection). Adaptation can reduce the total costs in the medium term by 7 to 50% and in the long run by more than 70%. But significant total costs will still be incurred due to expenditure on adaptation measures and residual climate change impacts. Significant populations are threatened with displacement by flooding and to a lesser extent coastal erosion.

Table 1: The impact of adaptation measures on residual damage of low and high sea level rise

Global sea-level rise for low, medium and high climate sensitivities, at 2100, for the A2 and B2 SRES storylines and associated greenhouse gas emissions.

	Socio-Economic Scenario	
Sea-Level Rise Scenario	A2	B2
Low (m)	0.22	0.17
Medium (m)	0.47	0.36
High (m)	0.96	0.74

Adaptation options considered in the PESETA analysis.

No Adaptation	No increase in flood defence dike heights from baseline No beach nourishment.
Adaptation – based on cost benefit analysis	Increase in flood defence dike heights. Application of beach nourishment.

Scenario "low sea-level rise" (B2)	**Time**	**Residual damage** € billion /year	**Adaptation cost** € billion /year	**Total cost** € billion /year
No adaptation	2020	4.4	0.0	4.4
	2080	9.3	0.0	9.3
With Adaptation	2020	1.0	1.3	2.3
	2080	0.9	1.3	2.2

Scenario "high sea-level rise" (A2)	**Time**	**Residual damage € billion /year**	**Adaptation cost € billion /year**	**Total cost € billion /year**
No adaptation	2020	5.9	0	5.9
	2080	42.5	0	42.5
With Adaptation	2020	1.4	4.0	5.4
	2080	1.8	9.3	11.1

The results show the potential benefits of timely adaptation for climate change in Europe’s coastal zones using standard protection measures like dike construction and beach nourishment. However, even with adaptation, costs remain high and coastal ecosystems are significantly reduced, especially under the high sea-level rise scenario. Climate change raises significant challenges for wider coastal management in Europe.

4.5. River flood risk

The number of great flood disasters (those requiring international and inter-regional assistance) in the period 1990 to 1998 was higher than over the entire the period from 1950 to 1985. Consequently, the costs of flood disasters have increased considerably (Munich Re, 2005). For the coming decades, it is projected that the magnitude and frequency of extreme weather events will increase due to climate change and that floods will likely be more frequent and severe in many areas across Europe.

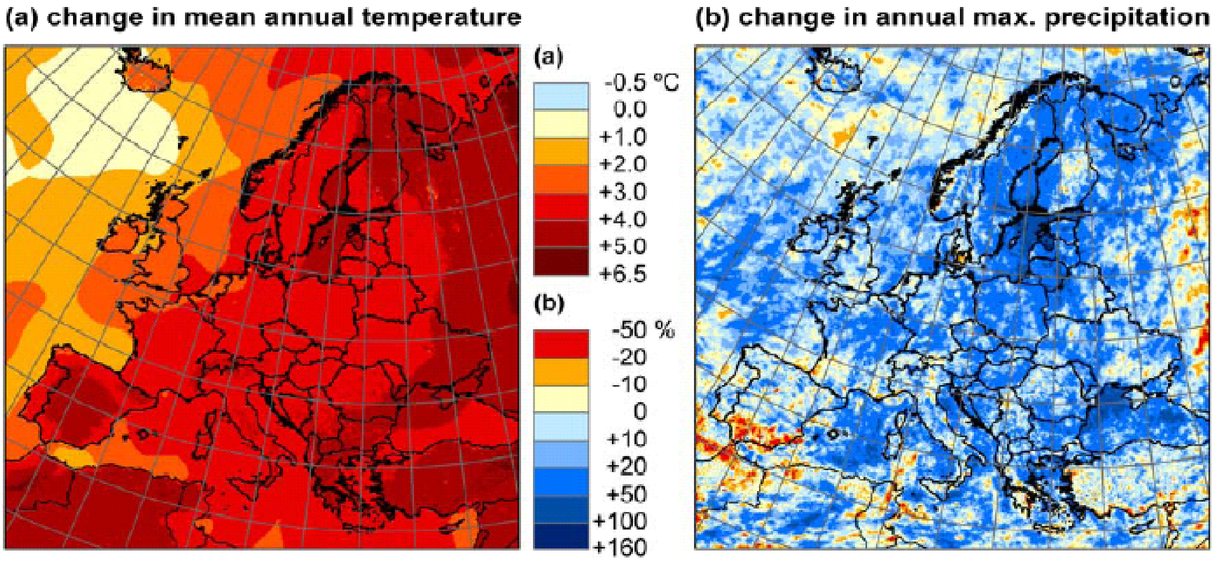

Figure 6: Absolute change in mean temperature (a) and relative change (scenario divided by control) in annual maximum precipitation (b) over Europe as simulated by the regional climate model HIRHAM (scenario A2, resolution 12 km).

Due to time and data constraints, it is not feasible for the PESETA project to make assessments for all of Europe. Preliminary results of two pilot river basins, the Upper Danube and the Meuse (upstream of Borgharen) allow, however, to draw consistent conclusions:

For the Upper Danube (~130,000 km2) the estimated total damage of a 100-year flood in the higher emission scenario A2 is projected to rise from € 47.5 to € 66bn, an increase of ~40 %. For the lower emission scenario B2 the projected increase is ~19 %. The number of people affected in the Upper Danube is projected to increase by 242,000 (~11 %) for the A2, and 135,000 (~6 %) for the B2 scenario. For the Meuse catchment (~22,000 km2), the total damage of a 100-year flood is projected to increase by ~14 % for the A2 scenario and ~11 % for the B2 scenario.

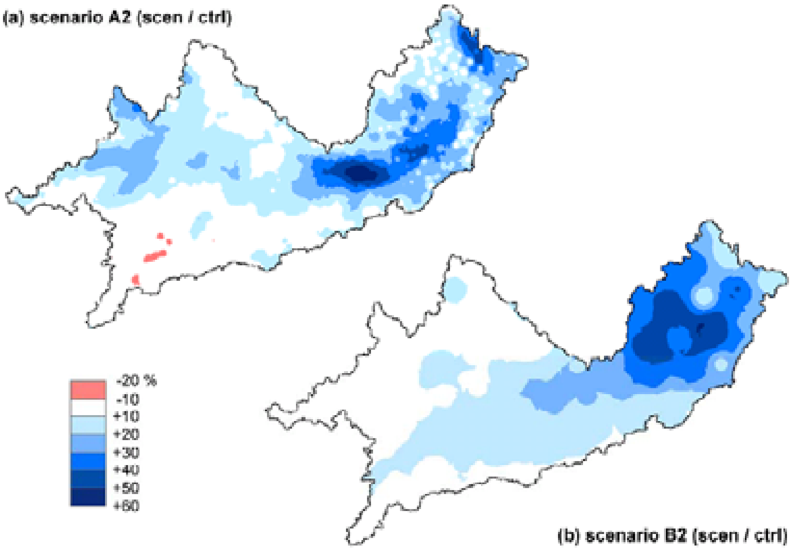

Figure 7: Relative change in the average annual maximum 5-daily precipitation amount for the Upper Danube: (a) emission scenario A2, 12 km resolution;(b) emission scenario B2, 50 km resolution.

The projected changes in extreme precipitation and in temperature indicate that other areas in Europe are also likely to see changes in flood risk. Results for the Upper Danube and Meuse catchment may be indicative of expected changes in costs and people affected in regions with similar projected changes in climate, hydrological and socio-economic conditions.

4.6. Tourism

The annual migration of northern Europeans to the countries of the Mediterranean coast in search of the traditional summer 'sun, sand and sea' holiday is the single largest flow of tourists across the globe, accounting for one-sixth of all tourist trips in 2000. This large group of tourists, totalling around 100 million per annum, spends an estimated € 100bn per year. Any climate-induced change in these flows of tourists and money would have very large implications for the destinations involved. The PESETA tourism case study focuses on the tourism segments most climate-dependent and sensitive to climate change; initial results are based on thermal comfort for beach tourism.

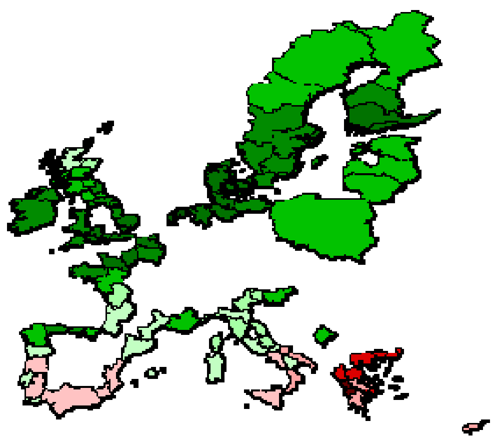

Figure 8: Net vulnerability scores for the tourist industry in the coastal regions of the European Union. Net 'positive opportunities' (green) and 'negative vulnerabilities' (red) scores for the tourist industry in the coastal regions of the European Union

The pattern of summer conditions may well change dramatically in the course of this century as a result of climate change. The zone with excellent conditions, which is currently located around the Mediterranean (in particular for beach tourism), will shift towards the north, perhaps as far as the North Sea or the Baltic Sea. The same holds probably for the inter-linkages between tourism development and water availability.

However, conditions in spring and autumn will improve. Much will therefore depend on the tourists' response to these changes. The more tourists stay home, or switch to different destinations, the larger the distributional impact in Europe will be. How large these distributional effects will be, depends on the adaptation of tourists, tourist businesses and entire societies. The largest impact will probably be realised if the dominant form of adaptation for tourists is travelling to other destinations. In this case, many destinations (in particular in southern Europe) will suffer, although others will gain.

5. BENEFITS OF CLIMATE ACTION IN OTHER POLICY DOMAINS

5.1. Air quality

Integrated approaches to reduce air pollution and abate greenhouse gas emissions offer significant co-benefits, particularly in terms of health impacts as well as reduction of abatement costs. There are strong inter-linkages between climate change policy and air pollution. The energy and transport sectors, large emitters of CO_2, emit at the same time other air pollutants such as nitrogen oxides (NOx), particulate matter (PM) and sulphur dioxide (SO_2). Measures to reduce emissions of CO_2 through improved energy efficiency, fuel switching and increased biomass use also have an impact on the emissions of other air pollutants. Measures to reduce emissions, including from agriculture, of nitrous oxide (N_2O) and methane (CH_4), two powerful greenhouse gases, also have an impact on air quality. In the agricultural sector measures to reduce the emissions of N_2O from soils through the use of various fertilisers and agricultural practices can influence atmospheric emissions of ammonia (NH_3) as well.

The cost of inaction on air pollution in terms of health impacts is high due to the strong impact of PM on life expectancy and ozone (O_3) on premature deaths and morbidity. Assessments for the Thematic Strategy on Air Pollution estimate that present levels of air pollution by PM2.5 in the EU are causing a loss of life expectancy of over 8 months. Without further air pollution legislation, the health effects would still be large in 2020, with a loss of life expectancy of around 5.5 months. In addition, O_3 would be causing some 21,000 premature deaths in the EU by 2020. The estimated value of the damage to human health by 2020 is in the range from € 162bn to € 587bn. The range reflects different methods and valuation of life years lost.

O_3 is also known to cause damage to vegetation, leading to a loss of agricultural productivity and a decrease of terrestrial carbon uptake in general. Ongoing research at the JRC indicates that the current yearly loss in EU agricultural productivity of four crops (wheat, corn, soybean, rice) may be in the range € 200m to € 2bn corresponding to an average yield loss of 3%. Emerging economies like China and India are estimated to loose 0.3 – 2% of their present GDP merely through ozone damage to crops. Furthermore, O_3 is estimated to cause a mean reduction in annual net primary production of 2.6 – 6.8% in the US (Felzer et al., 2004), an effect large enough to be considered in the global carbon budget.

The inter-linkages between climate change policies and air pollution were studied in the preparation of the European Commission's Thematic Strategy on Air Pollution[26]. Measures to reduce CO_2 emissions reduce for instance the use of coal in primary energy production, simultaneously generating substantial reductions for other air pollutants, in particular for SO_2, PM and NO_x. Co-benefits of climate change policies are estimated to be substantial (AEA Technology Environment 2006)[27]. Reducing CO_2 emissions by almost 10% compared to baseline emissions in 2020 reduces impacts on human health, implying benefits of between €8.5bn and €27.8 bn. Reducing CO_2 emissions by 22% compared to baseline emissions in 2020 reduces impacts on human health, with benefits between €27.8bn and €48.1bn.

The costs for achieving climate change and air pollution objectives jointly have been estimated for the EU in 2020, using the joint greenhouse gas and air pollution model GAINS[28]. Reducing CO_2 emissions by 10 percent as compared to baseline emissions would cost about € 12bn per year. However, considering that the policy also reduces the emissions of other air pollutants, the overall costs to achieve both climate change and air pollutants objectives would decrease with about € 2.5bn by 2020 due to the reduction in abatement costs for traditional air pollutants.

Similar or larger co-benefits are anticipated in developing countries, where urban areas experience particularly high local air pollution levels. Nine out of the 10 large cities (defined as 5 million inhabitants or more) worst affected by PM10 pollution are located in Asia, the other one is in Africa (World Bank, 2006). A study in Shanghai (China) suggests that the implementation of an energy scenario with CO_2-tax could prevent more than 10,000 PM10-related avoidable deaths in 2020 and it could also decrease substantial cases of other relevant diseases. A recent case study for the Beijing area (Integrated Environmental Strategies, 2005) showed the huge potential for active energy policies to reduce pollutants. They estimate that an ambitious energy policy, to more than halve business as usual emissions of SO_2, NOx and PM10 by 2030 in the Beijing area, would also decrease business as usual CO_2 emissions by a third. Of the analysed policies, energy efficiency is one of the most cost-effective among the groups of policies in reducing CO_2 emissions. The local benefits of these measures outweigh local costs. By 2030 the monetized health benefits are projected to be 7 to 8 times larger than the cost of implementing these policies.

Methane, one of the key greenhouse gases, also acts as a precursor for ground-level ozone. Reducing methane emissions reduces ground-level ozone. Recent research for instance suggests that a 20 % cut in methane emission can reduce ozone related mortalities globally between 2010 and 2030 by 370,000 cases (West et al., 2006). Also a study of the EC Joint Research Centre and IIASA showed that the reduction potential for methane is large, application of all available abatement techniques would bring down ozone worldwide and bring ground level ozone levels below air quality standards and at the same time substantially reduce climate forcing by ozone (Dentener et al, 2006).

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[26] Thematic Strategy on Air Pollution, COM (2005) 446 final.

[27] AEAT/ED48763001/CAFE-CBA update, November 2006. Issue 2 "An update on cost-benefit analysis of the CAFÉ programme (http://www.cafe-cba.org/ (under heading "reports")).

[28] More information on the GAINS model can be found through http://www.iiasa.ac.at/rains/gains/index.html; See also the results of the Conference on Air Pollutant and Greenhouse Gas Emission Projections for 2020: http://ec.europa.eu/environment/air/conf_air.htm.

5.2. Energy security

5.2.1. Global outlook

Recent geopolitical and socio-economic developments have again drawn attention to the volatility of international energy markets. In the coming decades more countries will become more dependent on energy imports. By 2030 most large economies (including the US, Japan, China and India) will import over 70 % of their domestic oil consumption (International Energy Agency 2006). Imports will by then cover more than 80 % of the EU's gas needs and more than 90 % of its oil needs.[29] China's petroleum imports are expected to grow manifold in the coming decades, with much of the increase coming from Persian Gulf suppliers. (US Energy Information Administration, 2006). These shifts towards more energy dependency can occur rapidly. The United Kingdom, for instance, was practically self sufficient for its gas consumption at the beginning of this decade, but could import 40 % by 2010, increasing to 80 % and more by 2020 (DTI, 2006).

Not only will there be more energy imports in the future, they will also become more expensive. Long term oil price estimates by the International Energy Agency have increased substantially recently. In 2004 price estimates for 2030 were equal to US$ 29 per barrel (in 2000-US$, WEO 2004). In 2005 this estimate already increased to US$ 39 per barrel (in 2004-US$, WEO 2005) and it increased again in this year to US$ 55 by 2030 (in 2005-US$, WEO 2006).

High and volatile energy prices and increased future dependency on energy imports have highlighted the need for a renewed focus on energy security policies to ensure a sustainable high growth of our global economy. The G8 summit of July 2005 appealed in its Gleneagles Plan of Action to take action forward that delivers on climate change mitigation, clean energy and sustainable development.

This call for action comes at a period of time that will see investments in the global energy system at an unrecorded scale. Rapid economic growth in developing countries and an ageing infrastructure in developed countries will require massive investments in the energy system in the coming years. The International Energy Agency (IEA, World Energy Outlook 2006) estimates that between now and 2030 just over US$ 20 trillion needs to be invested in the energy sector. This estimate has been substantially increased since their projections in 2005, due to increases in unit capital costs. The main sector to receive investments is the electricity sector with US$ 11 trillion of which over $ 5 trillion will be invested into more than 5000 GW of new generation capacity equal to an average of US$ 200bn a year. OECD countries will need to install around 2000 GW of new capacity and developing countries 2700 GW. The remainder will be built in economies in transition such as Russia. China and India are expected to build together 1100 GW of new power installations, which is equivalent to one new 900 Megawatt power plant coming online every week between now and 2030.

Investment needs in the energy sectors in developing countries up to 2010 are estimated by the World Bank (World Bank 2006) to require about € 130bn per year[30] and increasing thereafter. More recent estimates by the IEA put the total required average yearly investment up to 2030 as high as € 200bn. This potential investment creates a window of opportunity for

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[29] Commission "*Green Paper on a European Strategy for Sustainable, Competitive and Secure Energy*", COM (2006) 105, 8 March 2006.

[30] At an exchange rate of € 1 = US$ 1.27.

switching to a low carbon, clean and sustainable future with limited additional costs on a global scale.

Choosing a low-carbon pathway is much cheaper when a replacement or extension of the infrastructure is needed than replacing functioning capital stock prematurely. A bottom-up analysis by the World Bank estimates that to significantly de-carbonise power production would require incremental investments of up to € 25bn per year in non- OECD countries (i.e., beyond the basic needs for electricity generation), at the same time reducing their energy bills substantially.

The IEA has shown that many of the carbon efficient technologies have higher upfront investment costs than incumbent technologies, but offer cost savings on a life-cycle basis because of lower fuel or other variable costs, particularly for demand-side technologies (Energy Technologies Perspectives 2006). None of the technologies identified by the IEA that could bring emissions in 2050 back down to the level of today are expected to have an incremental investment cost of more than €20 per tonne of avoided CO_2 emissions, when fully deployed. However, there is a degree of uncertainty. Other modelling calculations suggest carbon prices in excess of €30.

A future world of rapid economic growth and increased global interactions should allow for rapid capacity building within developing economies, helping them to leap-frog historical development pathways. This can dramatically shorten the transition period from an agrarian society into a full grown service and information economy. Such an economic and societal pathway also allows for the swift introduction of new efficient and low carbon technologies, putting the global economy on a sustainable emission pathway. The IPCC’s Special Report on Emissions scenarios already indicated in 2000 that, under these conditions, global CO_2 emissions could peak in a baseline scenario before 2050 and decrease by 2100, even without specific focus on climate change policies.

5.2.2. The EU's energy security

Energy security has also become a major concern within the EU due to recent price and political developments. The March 2006 Green Paper "*A European Strategy for Sustainable, Competitive and Secure Energy*" addressed these major energy challenges. It has put forward three policy options that are critical in terms of tackling the fundamental challenges of energy security as well as climate change: energy efficiency, renewable energy and carbon capture and geological storage (CCS).

The Strategic EU Energy Review and accompanying scenario analysis further explores the potential role of these options as part of the EU energy system. Recently, the European Commission released its "*Action Plan for Energy Efficiency"*. This plan recognises the huge, cost efficient energy saving potential that remains within the EU and aims for efficiency improvements of 20 % by 2020.

An assessment of the potential of energy efficiency and renewable energy within the EU has been carried out by the European Commission (European Energy and Transport: Scenarios on energy efficiency and renewables, 2006[31]). The aim was to identify the potential impacts of strong effective policies for energy efficiency and renewables on energy security and

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[31] For more information see: http://ec.europa.eu/dgs/energy_transport/figures/index_en.htm

greenhouse gas emissions. These include, for instance, the full implementation of existing directives[32], measures that improve customers' perception of real cost of energy and increase their financial foresight and measures permitting effective integration of greater volumes of small-scale, local generation into the electricity grid.

The projections of the business as usual case are unsustainable from a strategic energy security perspective. The EU's oil imports would rise by around 25 % between 2000 and 2030. Natural Gas imports would more than double in 30 years time. Overall import dependency would even increase to 65 % by 2030, up from 44.7 % in 2000. At the same time the energy mix would remain dominated by fossil fuels, increasing EU CO_2 emissions slightly above 1990 levels. Both impacts are inconsistent with the EU's policy objectives to improve security of supply and mitigate against climate change.

The impacts of increased energy efficiency and renewables penetration on energy security and greenhouse gas emissions are substantial. Overall energy demand decreases rapidly and the share of renewables increases substantially (see figure 9). This allows for a reduction in CO_2 emissions compared to 1990 of 21 % by 2020 and even 29 % by 2030. The impact on energy security is also significant. By 2020 oil and gas imports would be reduced by more than 15% compared to the business as usual case. Continued policies up to 2030 would see net imports of oil starting to reduce and stabilise gas imports. By 2030 growth this would translate in halving the expected growth of natural gas imports compared to the business as usual case.

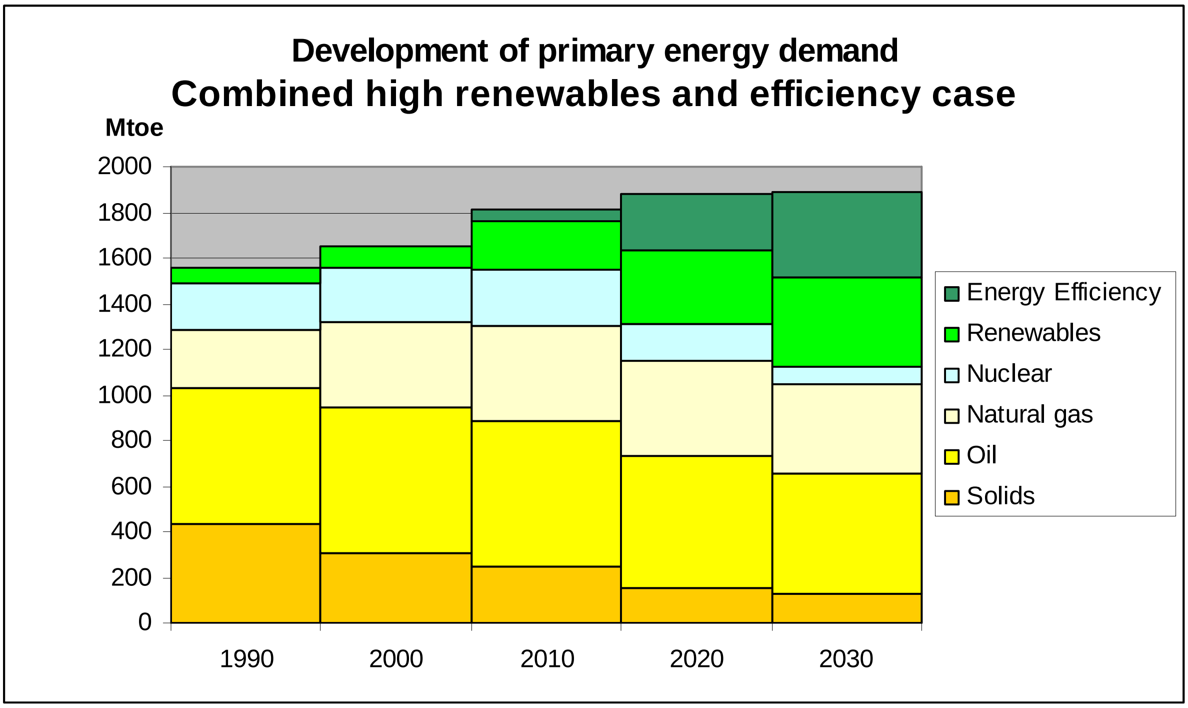

Figure 9: Impact of the strong renewable energy and energy efficiency penetration on the EU's primary energy demand (PRIMES modelling results)

32 For example, Directive on building performance, Directive on end-use energy efficiency and energy services, eco-design Directive, Directive on electricity from renewables, Directive on bio-fuels, all referred to at the beginning of this paper.

This assessment, using the Primes European energy model, focused only on the potential for efficient deployment of energy efficiency and renewables in the EU, two crucial low or zero emission technologies. As indicated in the 2005 Commission Communication "*Winning the Battle against Global Climate Change*" and in the 2006 Green Paper "*A European Strategy for Sustainable, Competitive and Secure Energy*", CCS provides a third option for near zero emission technology. Projections by the POLES model on ambitious global greenhouse gas reduction scenarios foresee an important role for CCS in the fight against climate change, capturing in the EU 4.5 % of CO_2 emissions of the fossil fuel power plants by 2020, rapidly increasing to 30 % by 2030.

In an increasingly carbon constrained world, CCS offers a significant energy security benefit. First, it provides for the continued use of coal, which is considered an abundant and secure energy source, including for the EU. Around 40 % of total energy consumption in the 10 new Member States is supplied by coal. Of the EU15, Denmark, Greece, Germany and Finland still rely on coal for around 20 % or more of their total energy consumption on coal. CCS is an attractive prospect for major energy consuming countries that are currently heavily dependent on coal and consider it a strategic resource. Second, as an end-of pipe technology, it can more easily be deployed in line with the existing energy infrastructure, thereby requiring less structural changes. Thirdly, in combination with enhanced oil recovery it will increase domestic oil production in depleting oil fields like those in the North Sea. Fourthly, in combination with gasification, CCS opens up the prospect of 'multi-purpose' hydrogen plants that capture CO2 while producing hydrogen for, various applications, including for the transport sector in case fuel cell technology would become an economically viable option.

The simultaneous pursuit of these three energy policy options in an efficient way is mutually beneficial for climate change policies and energy security. It would enable the EU to develop an energy system which is largely freed from the structural deficiencies it is perceived to have today. Future energy and climate policies must further develop such options.

5.3. Employment

Many climate change policies are known to create new employment. The impact assessment for the Biomass Action Plan[33] estimated that achieving the aims of this plan could potentially create some 250,000 to 300,000 additional jobs, directly, inside the EU-25, mostly through using biomass for electricity production and bio-fuels for transport. Wind Energy is a rapidly growing sector in Europe already employing for instance 64,000 people in Germany; around 21,000 in Denmark and 35,000 in Spain (EWEA, 2006). The European Trade Union Confederation is undertaking a study on the impact of climate change and climate change policies on employment. While the impact of climate change policies on jobs can be positive or negative, intermediate results show that most studies available on climate change and employment agree that climate change policies in total can be positive for employment (e.g. Ecotec study on renewable energies 1999, OECD Workshop on the Benefits of Climate Policy 2003, Study from the Bureau Fédéral du Plan 2006, Syndex study on the power sector in Europe 2006).

An OECD workshop in 2003 concluded that energy efficiency improvements create jobs because the energy saved is often imported and therefore does not affect local and regional employment. Moreover the new, more efficient energy technologies used, also create local

[33] COM (2005) 628 of 7 December 2005.

jobs in support technologies and services. The improvements in energy efficiency generate extra revenues, which can be invested in other economic sectors. According to the studies covered at this workshop, the impact of climate policy on net employment in Germany varied from -0.8 % to +5.5 % with a majority of the results being situated between +0.2 % and +2.2%.

More recently, the Belgian Federal Planning Bureau (Bureau Fédéral Du Plan, 2006) estimated the impact on employment in Belgium of reducing emissions in the EU by 15 to 30 % by 2020 by introducing a carbon price in all sectors across the EU. They projected very limited impact on employment, with even a potential increase of half a percent of total employment in 2020.

5.4. Soil Fertility

Soil organic matter is largely composed of organic carbon originally present in the atmosphere as CO_2. Around 45% of soils in Europe have low or very low organic matter content (0-2% organic carbon) and 45% have a medium content (2-6% organic carbon)[34]. Soil organic matter plays a very important role in keeping soils healthy and fertile. It has a nutritional function and contributes to plant growth. Apart from its importance for soil fertility and structure, its buffering and water retention capacity, and its crucial role in keeping soil biodiversity, soil organic matter is also important in the carbon cycle.

Soil is at the same time an emitter and a major store of carbon. In relation to the role of soils as *emitter*, considerable carbon losses from all types of soils have recently been measured in the UK. If these findings will be confirmed across the EU, this would be a serious concern that would require further action. Further research to clarify this issue and the role of different measures in addressing potential soil carbon loss is needed. In relation to the role of soils as a *store*, it should be noted that carbon sequestration in agricultural soils can be achieved by appropriate land management practices. The first phase of the European Climate Change Programme concluded that in the long term there is a considerably high potential to increase carbon storage in soils, even if constrained by high uncertainty and potentially high monitoring costs. Despite the difficulty and the incertitude surrounding the potential for sequestering carbon of cropland management measures, these are important from a soil conservation perspective, particularly in the view of the risk of carbon losses.[35]

The policy proposed by the Commission in the context of the Thematic Strategy for Soil Protection[36] aims at tackling the loss of organic matter from European soils with a view to reversing unsustainable trends. In doing so, the EU can contribute to maintaining soil fertility with the adoption of appropriate cultural practices and keep or increase carbon levels in the soil, thus avoiding the mineralisation (i.e. its conversion into CO_2) of the soil organic matter.

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34 SEC(2006)620, 22.9.2006, p. 13.

35 The Second European Climate Change Programme, Final Report of the Working Group ECCP Review - Topic Group Agriculture and Forestry.

36 COM(2006)231, 22.9.2006.

6. INTERNATIONAL STRATEGIES TO REACH CREDIBLE EMISSION REDUCTIONS BY 2050

6.1. Emission profiles consistent with the EU's 2°C objective

The European Council and the Parliament have both confirmed the EU's objective to limit average global temperature increase to 2°C compared to pre-industrial levels (see Box 1 below). Recent research, summarised in the Report of the International Scientific Steering Committee of the Exeter conference on Avoiding Dangerous Climate Change, concludes that with a concentration level of 550 parts per million volume CO_2 equivalent (ppmv CO_2 equivalent), global mean temperature increase is unlikely to stay below 2°C, as illustrated in Figure 10 below. A long term stabilisation at 450 ppmv CO_2 equivalent would imply a 50 % chance of staying below 2°C warming.

Box 1: Overview of Council and European Parliament's views on objectives and target "post-2012"

Various Council formations and the European Parliament have over the past few years elaborated their views on objectives and targets for the post-2012 arrangements. This box summarises these views where they relate to concrete emission reductions.

The 2°C was first referred to by the Environment Council in its conclusions in June 1996, where it stated that "the Council believes that **global average temperatures should not exceed 2 degrees above pre-industrial level**". Since then it has frequently been repeated in conclusions of the Environment Council. In March 2005 the 2°C objective was also confirmed by the European Council.

In December 2004 the Environment Council stated that "keeping this long-term objective within reach will require **global greenhouse gas emissions to peak within two decades, followed by substantial reductions in the order of at least 15% and perhaps by as much as 50% by 2050 compared to 1990 levels**". This was again confirmed in subsequent Environment Council Conclusions.

In March 2005 the Environment Council furthermore expressed its intention to explore with other Parties possible strategies for achieving the necessary emission reductions and its belief that **"reduction pathways by the group of developed countries in the order of 15-30% by 2020 and 60-80% by 2050** compared to the baseline envisaged in the Kyoto Protocol should be considered". In March 2005 the European Council stated that "reduction pathways for the group of developed countries in the order of 15-30% by 2020, compared to the baseline envisaged in the Kyoto Protocol, and beyond, in the spirit of the conclusions of the Environment Council, should be considered".

The European Parliament has stressed the importance of the 2°C objective on various occasions, most recently in its resolution on the European Union strategy for the Nairobi Conference on Climate Change, adopted in October 2006, but has also indicated that 2°C may already be too much. The European Parliament has also stated that "strong emission reductions of – 30% by 2020 and 60-80% by 2050 –are to be undertaken by developed countries".

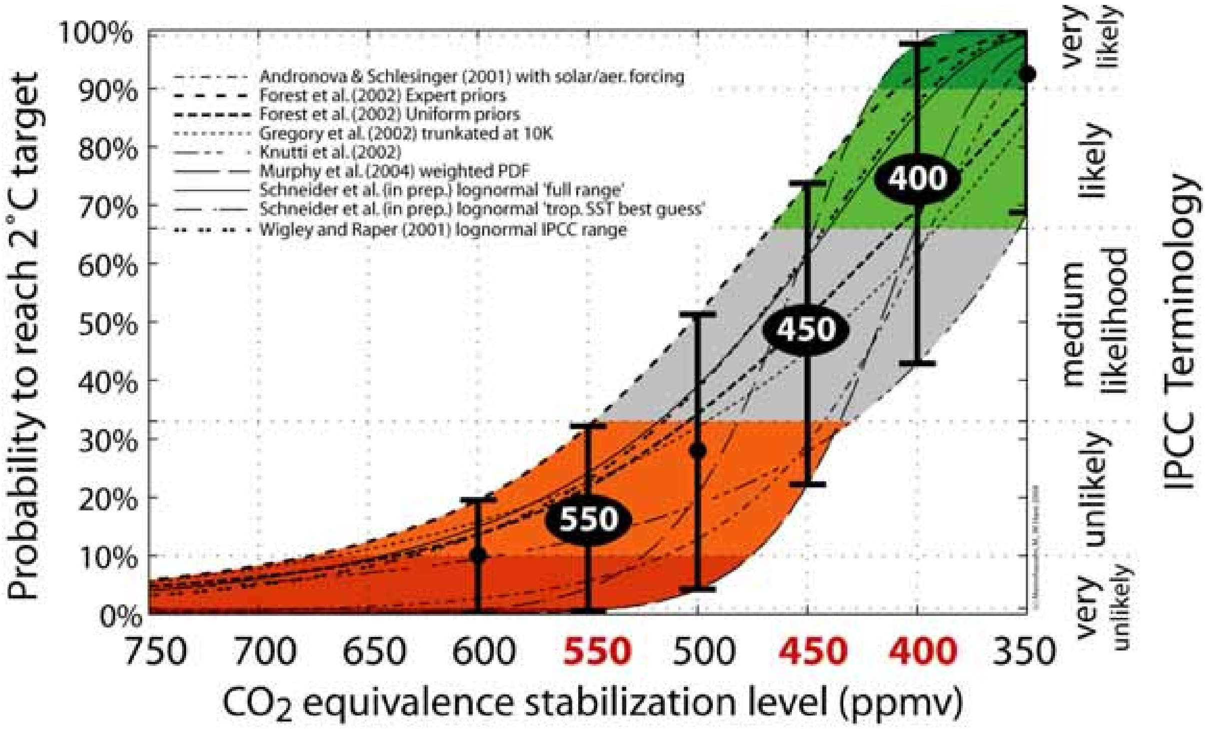


Figure 10: The probability to reach 2 degrees Celsius (Meinshausen, 2005)

Greenhouse gas concentrations in our atmosphere are increasing. In May 2006, the Mauna Loa Observatory in Hawaii reported an average monthly CO_2 emission concentration of almost 385 ppmv[37]. When other greenhouse gases, such as methane and nitrous oxide, are included overall CO_2 equivalent concentrations of greenhouse gases in the atmosphere are already at 420-430 ppmv. The concentration of greenhouse gases in the atmosphere currently increases by about 2 ppmv per year. At this rate of increase, 450 ppmv CO_2 equivalent would be exceeded within the next 10–15 years.

In order to meet the 2°C objective, after exceeding this concentration level in the coming two to three decades, concentrations need to be reduced to 450 ppmv CO_2 equivalent in the long-term. This is also called an "overshooting" scenario. Following such an "overshooting" scenario will require global emissions, including those from land use change, to peak between 2015 and 2020 as illustrated in Figure 11. Land use change emissions, mainly from deforestation, are responsible for approximately 20 % of greenhouse gas emissions, although uncertainty remains high.

[37] For the most recent data see: http://www.cmdl.noaa.gov/ccgg/trends/.

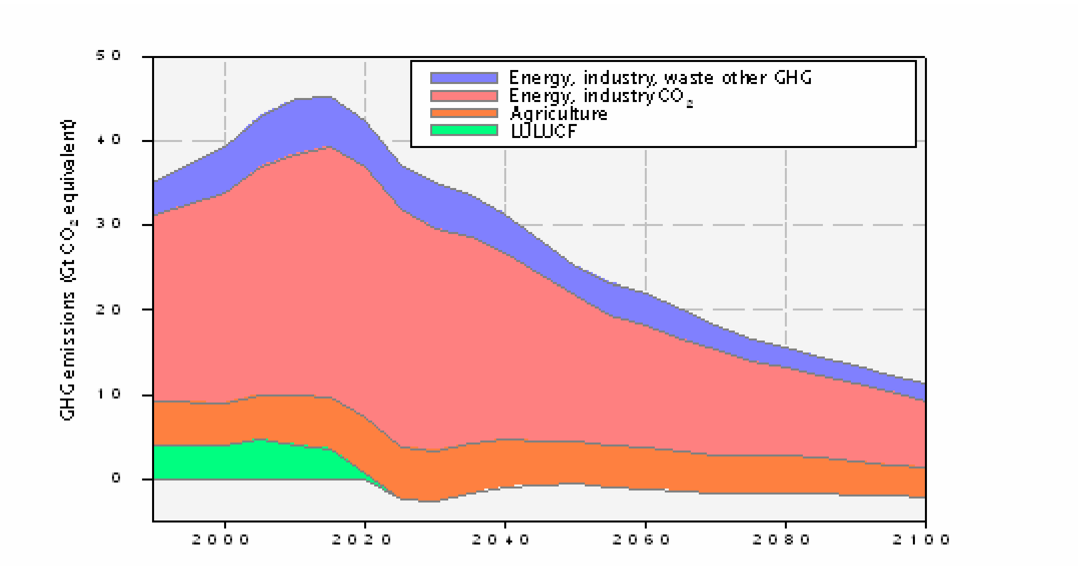


Figure 11: Global greenhouse gas emissions to meet 2 degrees C with 50% probability, (JRC/IPTS)

If emissions from land use change would decrease substantially and reverse by 2020, then greenhouse gas emissions from other sources (e.g. industry, households) would need to decrease by up to 25 % by 2050 compared to 1990 levels (den Elzen et al., 2006) as shown in Figure 12 below.

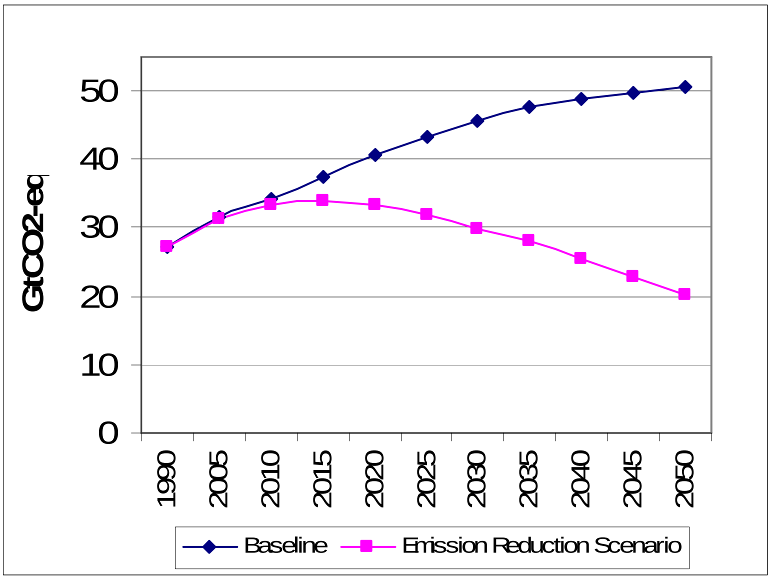


Figure 12: Global emission profile until 2050 excluding land use, land use change and forestry (JRC-IPTS, POLES model)

In March 2005, the Environment Council concluded that in order to keep the 2°C long-term temperature objective within reach, global greenhouse gas emissions will be required to peak within 2 decades, followed by substantial reductions in the order of at least 15 % and perhaps by as much as 50 % by 2050 compared to 1990 levels (see box 1 above). This global emissions path is fully compatible with the views expressed by the Council.

6.2. Assessment of the technical feasibility and economic affordability of deep cuts in global emissions

6.2.1. Main features and assumptions of the scenarios

The European Commission has carried out a cost assessment of a global greenhouse gas emission reduction scenario that would allow reaching in the long-term 450 ppmv CO_2 equivalent of atmospheric greenhouse gas concentrations. Greenhouse gas concentrations would first overshoot 450 ppmv CO_2 equivalent before reducing again. This scenario is similar to the 500 ppmv CO_2 equivalent scenarios in the Stern Review that also overshoot first and then stabilise in the long-term at 450 ppmv CO_2 equivalent. The assessment described in this background document complements the earlier analytical work of the European Commission on scenarios that would reach levels of 550 ppmv and 650 ppmv greenhouse gas concentrations[38].

In the following chapters, the business as usual scenario and the global greenhouse gas emission reduction scenario are referred to as "baseline scenario" and as “reduction scenario”, respectively. For the reduction scenario, the main model variants were:

- with vs. without emissions trading
- limited vs. broad participation in international climate policies

The economic analysis assesses mitigation costs up to 2030. The models used for this assessment are:

- **POLES:** a partial equilibrium model that focuses on the energy sector.
- **GEM E3:** a general equilibrium model that can project the impact of a climate policy on the entire economy. The GEM E3 model also includes emissions from agriculture.
- **DIMA (**Dynamic Integrated Model of Forestry and Alternative Land Use): this model was used to look at emissions from deforestation (see chapter 6.5).

For the period between up to 2050 the POLES model was used to project technology paths. This gives insights into key technologies that need to be developed and deployed in the coming decades to reach the EU's 2 degrees Celsius objective. No cost estimates were generated for the time after 2030. When time horizons become too long, assumptions on key variables such as demographic evolution, technological development and overall economic growth become too uncertain for such estimates.

<u>*Baseline Scenario*</u>

The projections in the Baseline Scenario under the POLES model take into account recent developments such as higher projected energy prices and the implementation of the EU Emission Trading Scheme (modelled with a conservative carbon price of € 5/tonne CO_2). The improved energy intensity of global GDP in the baseline is the result of a combination of moderate efficiency improvements due to autonomous technological and price-induced

[38] Commission Staff Working Paper SEC(2005)180 "Annex to the Communication Winning the Battle against global climate change COM(2005)35" of 9.2.2005

changes, together with the on-going structural changes in the economy from energy-intensive industries towards high value-added services. The underlying trend is shown in Figure 13 below.

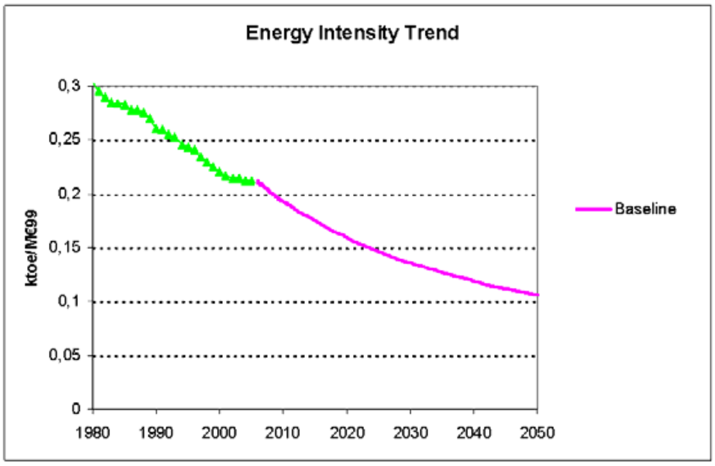


Figure 13: Energy intensity trend in the baseline scenario

Reduction Scenario

The European Commission has assessed a cost efficient reduction scenario that would reach the global greenhouse gas emissions reduction path as shown in Figure 12 above. Emissions (excluding deforestation) would peak at a maximum of 25 % above 1990 emissions by 2020 and then decrease by 25 % by 2050 compared to 1990.

The main assumptions in the cost efficient emissions reduction scenario are:

1. A reduction of the global energy intensity that is realised through energy efficiency policies such as standards. These are motivated by concerns about energy security and high energy prices.

2. Developing countries are not compensated (through instruments like the CDM) for reductions they achieve due to low cost energy efficiency improvements because these generate benefits through reduced energy bills and improved air quality. For instance, in GEM-E3 it is assumed that, in 2020, high income developing countries will reduce emissions by 10 % compared to the baseline scenario due to the introduction of energy efficiency policies.

3. Developed countries take on emission reduction targets in the range as envisaged in the Council conclusions. Variants with and without access to the global carbon market to attain these targets have been calculated.

4. Developed countries set up a trading system such as the EU ETS or similar policy measures that establishes a carbon price in the energy intensive industrial sectors, including the power sector.

5. The POLES model does not assume perfect (i.e. costless) emissions trading. Instead of this, the effective carbon price are assumed to vary between the various regions in the world (see Figure 14). Carbon prices are similar across markets in developed countries by 2015. Economies in transition follow suit but carbon prices would only

be equal as of 2020. Energy intensive sectors in developing countries are exposed to a low carbon price in 2012, simulating the limited penetration or visibility of a carbon price for all individual firms through policy instruments such as the CDM. However, differences in the carbon prices become smaller over time as a result of a strengthened regulatory framework in close relationship with the state of development of the economy. Between 2025 and 2030, these differences in carbon prices become relatively small for all groups of countries apart from low income countries.

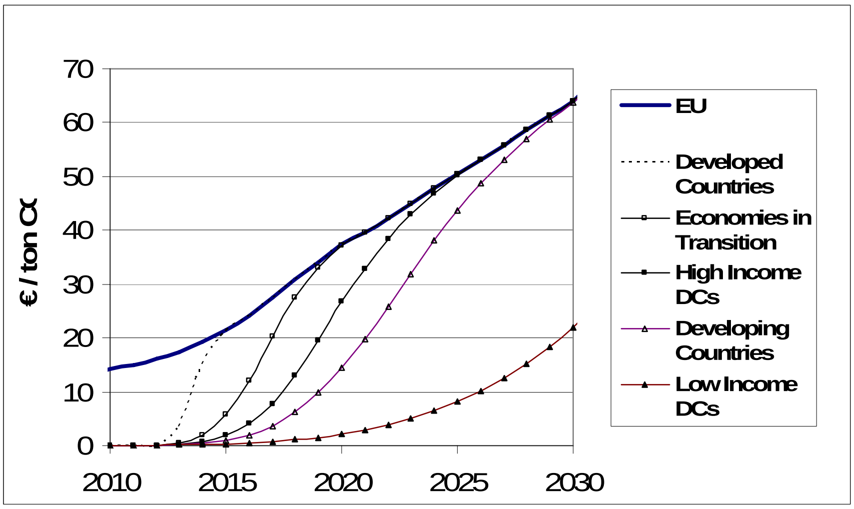


Figure 14: Carbon price differentials between different regions and over time

6. In GEM-E3, transaction costs in the carbon market had to be modelled more restrictively due to the characteristics of the model. For instance, China, Brazil, Latin America and the South African region only enter the carbon market in 2020, and India enters in 2030, but then assuming no transaction costs. Other low income countries enter later.

7. Transport, residential and services sectors do not participate in the global carbon market. For these sectors, developed countries introduce in addition to energy efficiency improvements, policies that reduce emissions at a rate similar to the introduction of a carbon price. In developing countries, only energy efficiency policies are implemented.

8. There is a difference between the mobility of physical capital and monetary capital. Physical capital mobility, i.e. tearing down and moving an industrial installation, can be done in a limited manner within a country but not across countries within the same time period. However, financial capital is assumed to be mobile across countries worldwide. In this way, over time, capital can move across regions through investment and depreciation.

6.2.2. Projections of global greenhouse gas emissions

Under the Baseline Scenario, global greenhouse gas emissions are projected to increase by 86 % in 2050 compared to 1990. Developing countries' emissions would surpass those of developed countries in 2020 (see Figure 15). By 2050 developing countries would emit more than the total global greenhouse gas emissions in 1990. This illustrates that participation of developing countries in the reduction effort is indispensable in order to reach a 25% reduction by 2050 compared to 1990 levels.

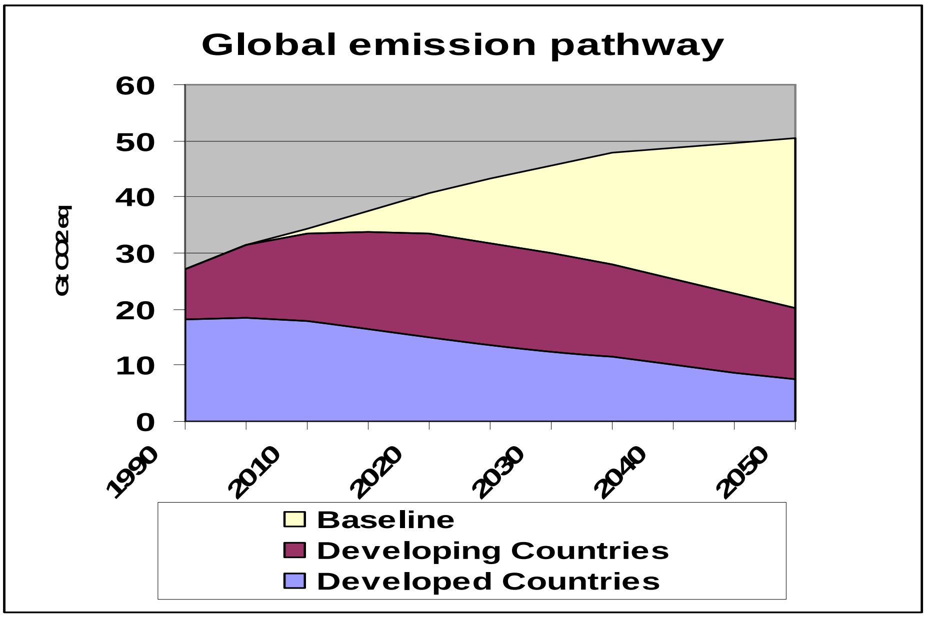
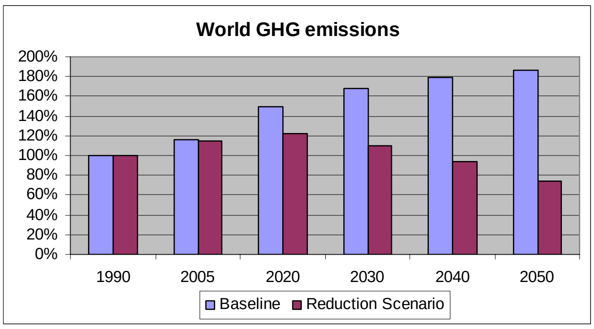


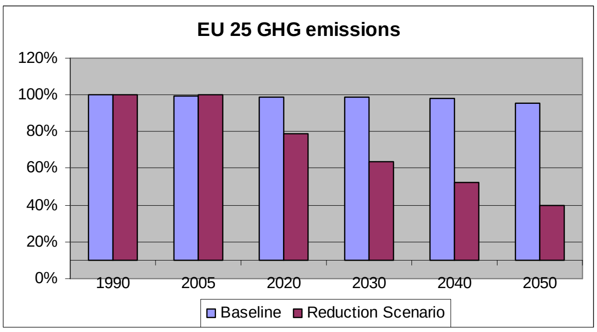
Figure 15: Absolute emissions of developed and developing countries until 2030

As illustrated in Figure 16 below, under the reduction scenario, emissions of developed countries in 2020 are already 18 % below those in 1990. For the EU-25, the reduction would be equal to 21 %. Developing countries' emissions would peak between 2020 and 2025 at a level twice as high as their emissions in 1990.

In 2030, global emissions are reduced to 10 % above the 1990 emissions and continue to decrease. In 2030, developed countries lower their emissions by 32% compared to 1990. The EU's domestic emissions are down by 36 %. Developing countries will succeed in reversing their emissions growth, reducing emissions in 2030 by 5 % compared with their peak level between 2020 and 2025.

By 2050, emissions in developed countries are reduced by 60 % compared to 1990. In developing countries they are still 43 % above 1990 level. Overall, global emissions from energy combustion and industry are then 25 % below emissions in 1990.





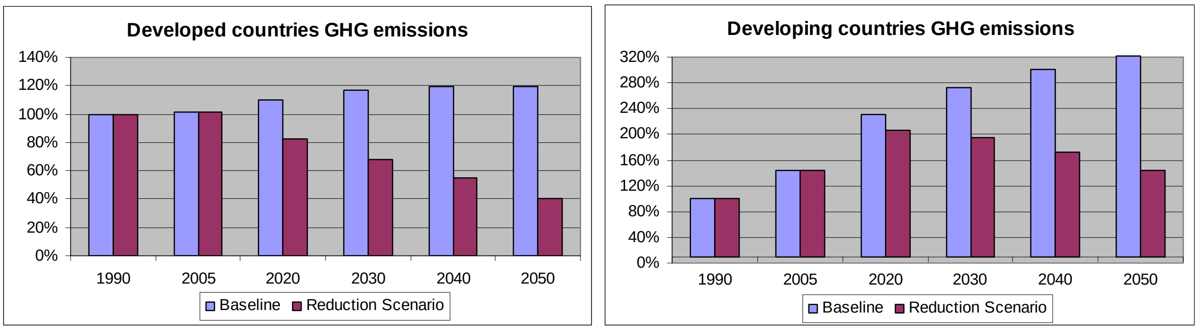


Figure 16: The relative development of greenhouse gas emissions in the world, EU-25, developed and developing countries as compared to 1990 emissions (JRC-IPTS, POLES model)

The underlying carbon price in the global carbon market moves from € 21 by 2015 to € 37 by 2020 to eventually reach € 64 per tonne of CO_2 by 2030.

6.2.3. Technical feasibility of the Reduction Scenario

Reducing emissions by 25 % by 2050 compared to 1990 will require significant changes of the global energy system with respect to both the consumption and the production of energy. The impacts of different actions and technologies in reducing CO_2 emissions are summarised in the figure below[39].

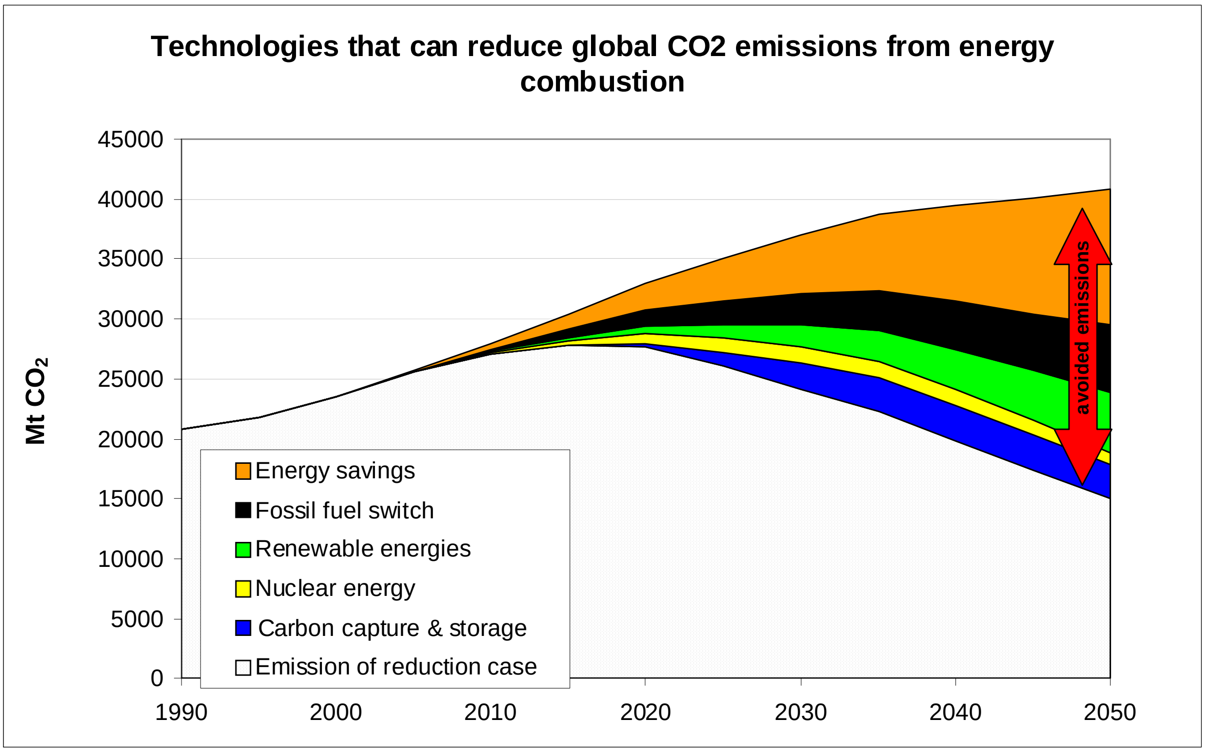


Figure 17: Decomposition of global CO_2 reductions technologies for fossil fuel combustion (JRC-IPTS, POLES model)

<u>*Energy savings*</u>

39 Please note that the decomposition chart should be interpreted with care – the impact of energy savings, for example, does not only relate to dedicated efficiency measures, but also to autonomous improvements through e.g. structural changes. Furthermore, fuel switch often implies an improvement in energy intensity, which is associated with energy savings instead of 'fuel switch'.

Limiting final energy consumption throughout all sectors is a key element in reducing global emissions. The introduction of targeted energy efficiency policies and a carbon price trigger the implementation of additional energy efficiency measures in all sectors. Energy efficiency improvements are projected to happen throughout various sectors as follows:

1. The residential and tertiary sector experience the most important energy savings compared to the baseline projections. These sectors are most sensitive to the introduction of energy efficiency standards for electrical appliances or buildings and thus reduce their consumption by 17 % and 42 % below baseline in 2030 and 2050, respectively (Figure 18). Until 2030 most of the energy savings in this sector can be attributed to dedicated energy efficiency measures.

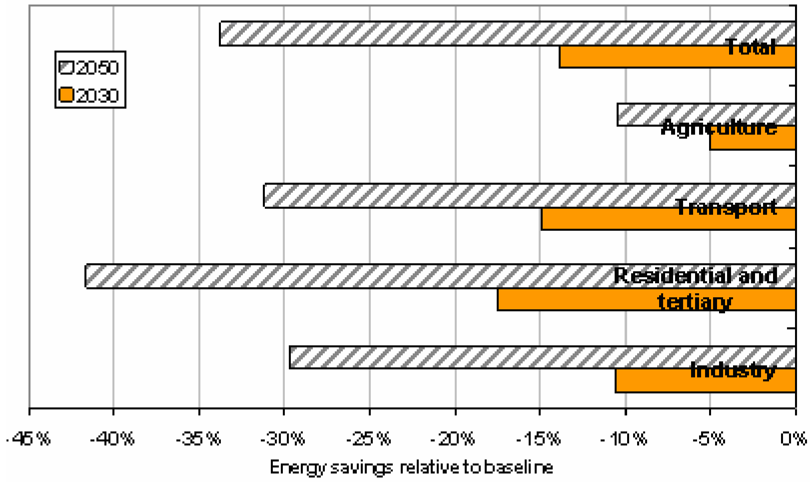


Figure 18: Energy saving per sector relative to baseline (JRC-IPTS, POLES model)

2. In the transport sector, fuel consumption standards are increasingly strengthened. As a result, the specific CO2 emissions of the existing car fleet are projected to decrease substantially between 2005 and 2030. Emission reductions are relatively lower in the EU-25 compared with global trends and this can be explained by already comparably low emissions within the EU in the new road transport stock.

3. Efficiency improvements also occur in the power sector. The efficiency of fossil-fuel fired power plants is projected to increase from 35 % to 46 % in 2030 as a result of the replacement of conventional coal power plants with advanced technologies such as high-efficient, combined-cycle natural gas plants. After 2030, power plant efficiencies are projected not to increase further but to slightly decrease again. This is due to the energy required for the carbon capturing process and the fact that towards 2050, the majority of electricity is generated in power plants that are equipped with Carbon Capture and Geological Storage equipment.

Power sector

The power sector remains a key sector for reducing greenhouse gas emissions. It delivers around 66% of total global reductions compared to baseline by 2030, decreasing to 55 % compared to baseline in 2050 (see figure 19 below). Despite a 74 % rise in electricity consumption between 2005 and 2050 in the emission reduction scenario, the power sector reduces its emissions by almost 80 % over that period. At the same time fossil fuel imports would decrease, improving the energy security and lowering the energy bill. By 2020, the EU would import 14% less fossil fuels. By 2030 this would translate for the EU in 60 % less imports of coal and 20 % less imports of oil and gas than in the baseline.

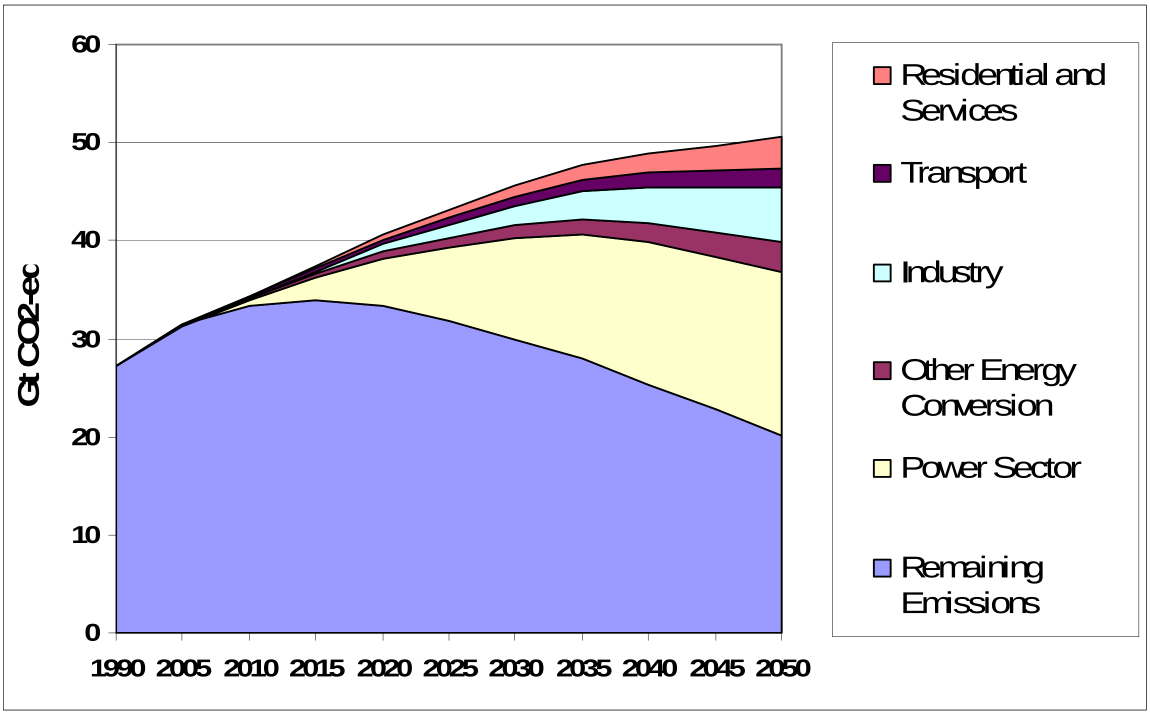


Figure 19: Avoided global greenhouse gas emissions by sector (JRC-IPTS, POLES model)

The reductions in the power sector are mainly due to the following measures:

4. Renewable electricity generation is projected to increase by a factor 4.5 between 2005 and 2050.[40] This brings the share of renewables (including large hydropower) in total electricity generation to 20 % in 2020 and 46 % in 2050 globally. Renewables other than hydro-electric power generation are projected to experience a 24-fold increase.

Table 2: Development of the share of renewables in electricity and total energy consumption until 2050, POLES model

	2020		2030		2050	
	Electric.	Energy	Electric.	Energy	Electric.	Energy
Global	20 %	19 %	27 %	23 %	46 %	40 %
Developed C.	21 %	17 %	29 %	23 %	45 %	40 %
Developing C.	20 %	22 %	25 %	23 %	46 %	40 %
EU-25	23 %	18 %	32 %	25 %	43 %	39 %

It is important to note that the Reduction Scenario does not assume any dedicated policies to support renewables. For that reason, the increase of renewables at a global level compared to the baseline development remains modest in the beginning until an

40 For the calculation of the primary energy consumption equivalent of electricity from nuclear and renewable energy sources an efficiency of 33% has been assumed.

increasing carbon price causes it to rise significantly above baseline values after 2020[41].

Wind electricity production will continue to rise rapidly and is projected to achieve a global share of 7 % (17 %) in 2030 (2050). Of this, 28 % are expected to be generated by offshore wind farms by 2020. Also growth in electricity production based on biomass is substantial, reaching a similar share in global electricity production as wind in 2020.

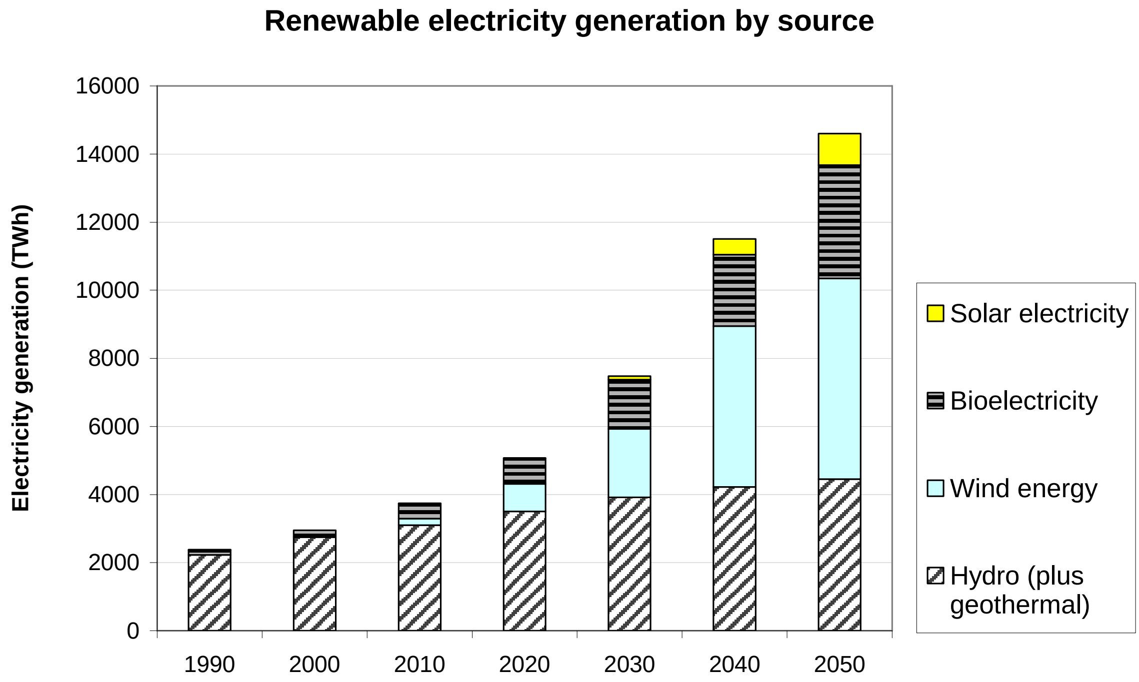


Figure 20: Development of global renewable electricity generation by source (JRC-IPTS, POLES)

5. Carbon capture and geological storage (CCS) will become an important transition technology. In 2050, almost 60 % of CO2 emissions from the power sector are projected to be captured compared to virtually none today and almost 30 % in 2030. Globally, it might contribute 14% of all reductions needed by 2030, going down to 9 % by 2050. This reduced proportion towards 2050 is mainly due to the power sector emissions having a much lower share in total emissions by 2050 (13 % compared to some 40 % in 2005). This is a result of substantial reductions of almost 80 % over the entire time period. Furthermore, CCS is assumed to lead to a net reduction of around 87 % of the specific power plant emissions.

The projections as shown in Figure 21 suggest that CCS will first need to be deployed in developed countries. Soon after, it will be rapidly deployed in developing countries that have ample coal reserves, such as China and countries in South Asia. In China, almost 40 % of total emissions from the power sector are projected to be captured by 2030, rising to two thirds in 2050. Also in the developed

41 For example, the share of renewables in electricity production in the EU-25 in the baseline is 19 %, 22 % and 26 % in 2020, 2030, 2050, respectively.

countries more than 50% of all power sector emissions will have to be captured by 2050, with a higher share in Russia and the Ukraine.

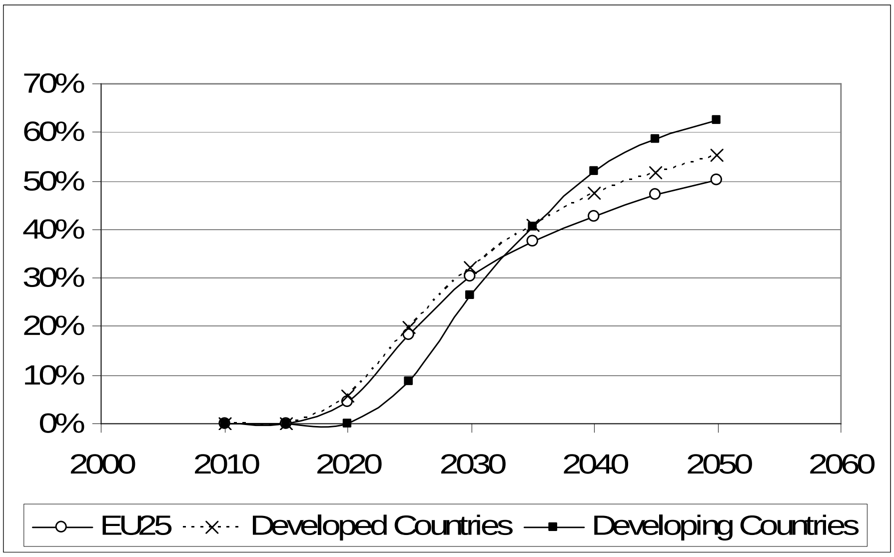


Figure 21: Share of Power Sector Emissions Captured (JRC-IPTS, POLES)

6. Despite the wide-spread deployment of CCS, coal consumption is projected to decrease. In 2030 and 2050, global coal consumption is projected to be 22% then 54%, respectively, below its 2005 levels. It is expected that conventional coal power plants will be replaced by advanced technologies such as supercritical and pressurized coal combustion and integrated coal gasification with combined cycle. Already by 2030, these could generate 44% of total coal-fired electricity generation due to their higher efficiencies and better suitability for carbon capture compared with conventional plants. This illustrates the importance of introducing CCS compatible power plant technologies relatively soon. By 2050, more than 90% of all coal-fired electricity generation is projected to take place in plants that are equipped with CCS.

7. Natural gas partly offsets the decrease in coal consumption globally, but only for a limited period. Over the past decades, gas has continuously increased its share in electricity generation in the OECD. This trend was particularly pronounced in the EU, where it was driven by relatively low gas prices and an extended gas infrastructure combined with the start of the liberalisation of the electricity markets. This trend is expected to continue globally for the next two decades with gas reaching a maximum share of 33 % in 2025. However, by 2050 this share will fall below that of 2005. While gas is competitive in the medium term, especially when replacing coal-fired power plants in a carbon constrained world, an increasing limit on CO2 emissions beyond 2025 gives it a disadvantage compared to carbon free fuel-based electricity generation options. More than one quarter of all gas-fired electricity will be produced in combined-cycle gas turbines with CCS already in 2030, rising to around 70 % in 2050.

8. Nuclear electricity is projected to increase its share in electricity generation to reach 23 % in 2030 (27 % in 2050). In absolute terms it remains close to the deployment in the baseline. The scenario assumes, however, that public acceptance and potential

problems with identifying a long-term safe way to dispose highly radioactive wastes or concerns about proliferation do not constrain the use of nuclear power.

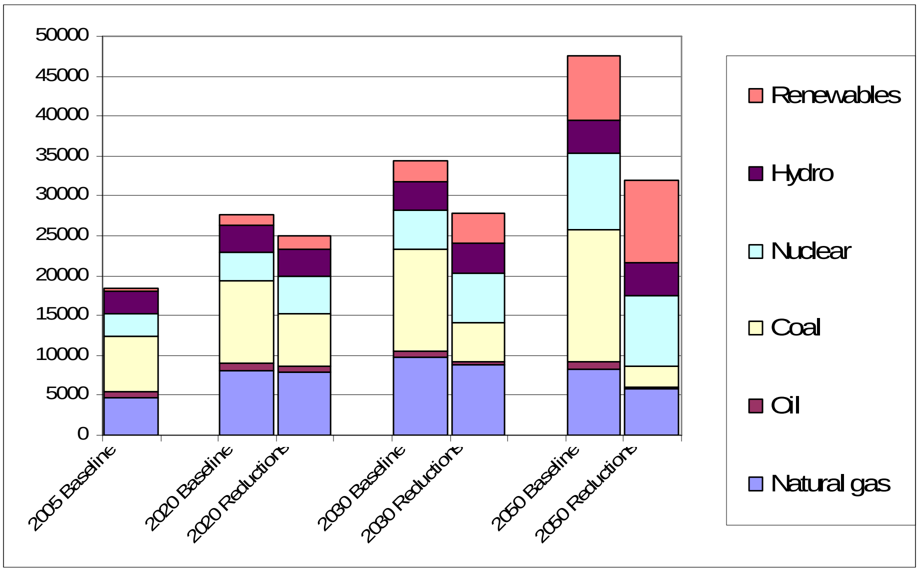


Figure 22: Development of the importance of different fuel types in the electricity generation mix (in TWh), POLES model results

6.2.4. Costs and emissions trading

The costs projected by the POLES model, as a result of investments in carbon low technologies, are estimated at an annualised cost of less than 0.5 % of global GDP by 2030. The emission projections derived under the Reduction Scenario in the previous section are the result of identifying total costs of the most cost-effective emission reductions without making any assumption as regards emission reduction targets for specific countries.

Assuming that developed countries would take on emission reduction targets within the range as proposed by the Council, i.e. up to 30 % and 50% in 2020 and 2030 respectively, this would trigger carbon trading across countries in order to achieve these cost-effective emission reductions on a global scale. Attaining the developed countries' emission reduction targets without trading would be much more costly; emissions trading reduces the global cost by three quarters.

Figure 23 represents the cumulative action undertaken in 5 year periods in developing and developed countries including the trade flows in emission credits between developed and developing countries. The diagrams illustrate domestic reductions and imports of emission rights with a positive sign and exports of emission credits with a negative sign. In this scenario, between 2010 and 2030 emissions trading would grow tenfold.

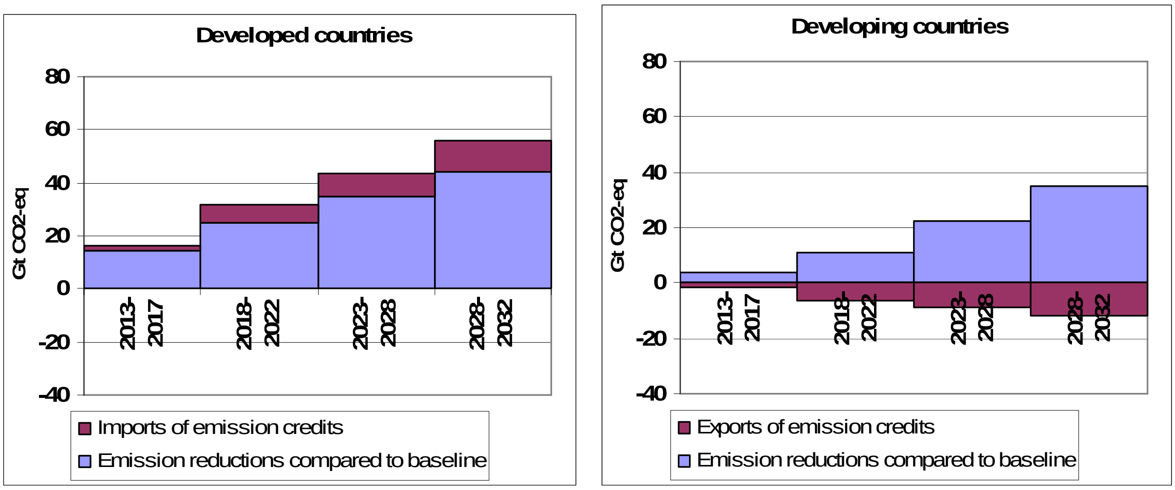


Figure 23: Cumulative reductions and emissions trading

6.2.5. Overall economic costs of the Reduction Scenario

Variant 1: Broad participation through an international agreement

The costs projected by the POLES model, as a result of investments in carbon low technologies, are not to be confused with the costs of reducing emissions to the economy. In order to assess the interactions and the impacts on the overall economy, the GEM E3 computable general equilibrium (CGE) model for the entire economy was utilised. This allows exploring the order of magnitude of the macroeconomic adjustment needed to meet the global greenhouse gas constraint, under a consistent framework that takes into account the interactions between all the sectors and agents in the economy as well as the trade-related knock on effects.

In order to reach the emissions profile compatible with the 2 degrees Celsius objective, the world average carbon price increases over the period 2020 to 2030 as the global greenhouse gas emissions constraint becomes more stringent. In 2020, the world average carbon price is €31 per tonne of CO_2 equivalent[42]. In 2025, the world carbon price rises to €39, corresponding to a peak in global emissions at +18 % compared to 1990. In 2030, carbon price reaches €65 per tonne CO_2 equivalent, with global emissions going back to a level +8 % higher than 1990 emissions.

Table 3 illustrates emission targets for 2020 and 2030 expressed in relative terms compared to 1990 that would limit global emissions to a level compatible with the EU's 2°C objective. For developed countries these are emission reduction targets, while most of the developing countries would limit their emission growth. The relatively large reduction target for the Former Soviet Union reflects largely the potential for emission reductions. Developing countries benefit from their emission reduction possibilities through project based mechanisms.

42 It is the average of the emission trading sector and the domestic price for the other sectors for all regions with reduction targets. It is stated in US$2001 at an exchange rate of € 1 = US$ 1.27

Table 3: Relative emission reduction and growth targets and domestic emission reductions, compared with 1990 emission levels, GEM-E3 results

	2020		2030	
	Emission targets	Of which: Domestic emission reductions	Emission targets	Of which: Domestic emission reductions
USA	-23 %	-4 %	-39 %	-21 %
EU27	-31 %	-21 %	-46 %	-35 %
FSU	-42 %	-39 %	-54 %	-51 %
Japan	-26 %	-24 %	-41 %	-37 %
Brazil	31 %	32 %	34 %	31 %
India	165 %	165 %	218 %	179 %
China	140 %	85 %	150 %	103 %
World	**13 %**		**8 %**	

With respect to the development of the GDP, Figure 24 shows that climate change policies and economic growth are compatible with each other. The world will continue to grow and global GDP is expected to almost double in the coming 25 years with stringent climate change policies. In 2030, the world's macroeconomic adjustment is around -0.19% compared to baseline GDP in annual terms in 2030.

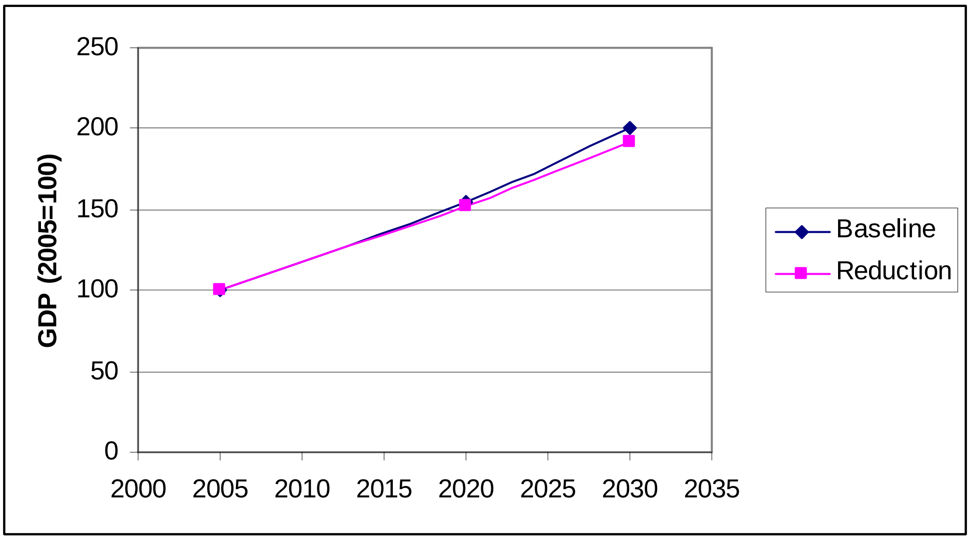


Figure 24: The impact on international climate change policy on global Gross Domestic Product, 2005-2030, GEM-E3 model results

Depending on the allocation of emission reduction commitments the impact on national GDP will vary from country to country. Table 4 illustrates the changes in GDP compared to the baseline in 2020 and 2030 of major emitters in the world. They are also specified in annualised terms. The GDP change for the EU27 region is in the range of -0.19% to -0.24% in annual terms, with lower impacts for the USA and Japan, while for the Former Soviet Union the annualised adjustment in GDP is around twice that of the EU27. The large developing countries, though without commitments in 2020, also observe a reduction in their GDP compared to their baseline. This is the knock-on effect of lower growth in economic activity in the developed countries with commitments. However, their GDP changes are small, ranging from -0.06 % in Brazil and China to -0.1 % in India in annual terms.

Table 4: Changes in Gross Domestic Product, GEM-E3 results

	Impact on GDP					
	2020			2030		
	Baseline GDP, 2005=100	relative to baseline	Annualised from 2005	Baseline GDP, 2005=100	relative to baseline	Annualised from 2005
USA	156	-2.2 %	-0.15 %	195	-4.8 %	-0.20 %
EU27	135	-2.8 %	-0.19 %	158	-5.8 %	-0.24 %
FSU	214	-5.2 %	-0.37 %	299	-11.2 %	-0.47 %
Japan	130	-1.1 %	-0.08 %	163	-2.6 %	-0.11 %
Brazil	165	-0.6 %	-0.04%	245	-2.3 %	-0.09 %
India	205	-1.4 %	-0.10%	332	-2.6 %	-0.11 %
China	213	-0.7 %	-0.05%	317	-2.8 %	-0.11 %
World	**155**	**-2.0 %**	**-0.14%**	**201**	**-4.6 %**	**-0.19 %**

Given the stringency of the carbon constraint, the overall cost of the policy remains rather limited. In conclusion, reducing global emissions to a level that accomplishes the 2°C objective is both technically and economically feasible. The assessment however also shows that it will require an effort by all countries. It foresees that:

– All countries, including developing countries, take reasonable measures to improve their energy efficiency and implement additional measures to reduce emissions in the transport, residential and tertiary sectors.

– Energy intensive sectors, in particular the power sector, gradually integrate into a global carbon market ensuring cost efficient emission reductions on a global scale.

– Developed countries take on individual reduction targets around 30 % in 2020 compared to 1990 and have full access to the global carbon market. Such target would result on average in domestic emissions reductions in developed countries 2020 of 20 % compared to 1990 levels. Developing country emissions start to level out.

– By 2030, developed countries need to take on individual emission reduction targets of between 40 and 55 % compared to 1990. By then all countries, except low income developing countries, have fully integrated their energy intensive sectors in the global carbon market. Developing countries' emissions are decreasing.

Variant 2: Domestic EU emissions reductions

Reaching a global agreement that drives these required reductions will be a top priority for the EU. However, this does not mean that in the absence of an international agreement on an inclusive climate change regime, the EU should stop to undertake emissions reductions and keep the EU emissions trading scheme linked to the global carbon market, in particular the Kyoto Protocol's Joint Implementation (JI) and Clean Development Mechanism (CDM). Taking on such a reduction target in particular if fully coherent with the EU energy policy and its strategy for jobs and growth would send important political messages. This would strengthen the confidence of the private sector in the global carbon market and show leadership in the negotiations on an international framework for climate change policies after 2012.

The European Commission's previous assessments underlying the "Winning the Battle against Global Climate Change" Communication showed that reductions in the EU's greenhouse gas emissions alone are not sufficient to halt climate change. However, the analysis presented here shows that reducing emissions in the EU would be beneficial for energy security and air pollution in the EU. It would stimulate development and deployment of new technologies for the future and increase long-term competitiveness for EU industry.

The environmental and the economic impact of domestic reductions of 21 % and 31% by 2020, compared to 1990 levels, were assessed with the GEM-E3 model which is summarised in the Table below.

The environmental impact on global emissions of such a unilateral move would in any case be very limited. In variant 1 with broad participation , the reduction target of the EU-27 would be 31% and domestic emissions would actually be reduced by 21%.

The impact of autonomous EU action on its GDP is limited, particularly if full access to project-based mechanisms would be granted.

Without access to CDM, carbon prices will be 8–11 times higher. This underlines the need to continue access to CDM after 2012 period, even without broad participation.

With full access to the CDM, the bulk of the emission reductions would be realised abroad because of the low marginal abatement costs. In this case, however, there would be no positive co-benefits, neither on air quality nor on energy security within the EU. In the case of an autonomous 21% reduction, EU-27 greenhouse gas emissions would even go up compared to 1990 emissions. In order to avoid this, complementary mandatory policies within the EU would have to be introduced or the access to CDM would have to be restricted, raising concerns about competitiveness. Policies under the Strategic EU Energy Review, such as energy efficiency measures, renewables targets and mandatory CCS requirements could ensure in such a scenario a higher EU domestic effort leading also to additional improvements in energy security, local air quality and long term competitiveness.

Table 5: Impact of autonomous EU-27 emission reductions and access to project based mechanisms on domestic emission reductions, GDP and the carbon price by 2020, GEM-E3 results

	Broad global participation	**Autonomous domestic emissions reductions (EU-27)**			
EU-27 emissions target	**- 31 %**	**- 21 %**		**- 31 %**	
	With CDM	**No CDM**	**With CDM**	**No CDM**	**With CDM**
Domestic emissions	- 21 %	- 21 %	+ 4 %	- 31 %	- 7 %
GDP baseline [2005=100]	135				
GDP impact in 2020	- 2.8 %	- 1.4 %	- 0.3 %	- 2.3 %	- 0.9 %

Annualised GDP impact	- 0.19 %	-0.09 %	-0.02 %	- 0.16 %	- 0.06 %
Carbon price [€]	31	44.2	4.2	77.6	9.4
Global emission reduction (compared to baseline)	- 24 %	- 3.5 %		- 4.6 %	

In conclusion, the results of this analysis largely confirm the earlier findings of a similar analysis of the European Commission in 2005[43]. If the EU wanted to pursue primarily domestic policy objectives, strong policies would have to be put in place, i.e. measures in the energy package would have to be ambitious and mandatory. If these would not be mandatory, one would have to limit demand for CDM in other ways. Placing a low ceiling on the use of the CDM, however, would increase carbon prices drastically and, therefore, push up economic costs significantly. The CDM should act as a safety valve which would keep overall costs of policies manageable.

6.3. Reversing deforestation

Reducing emissions by 25 % in 2050 in the sectors covered by the POLES scenarios will not be sufficient to reach the 2°C objective. As stated in Section 5, the role of emissions from land use change and, to a lesser extent, agriculture will also be key in achieving the 2°C objective. The Food and Agriculture Organisation (FAO) in its global forest resources assessment 2005 estimated that about 13 million hectares of forests are lost per year, an area of a size roughly equal to the size of Greece, resulting in large net emissions from changes in land use that are not compensated by afforestation. This forest loss also has a negative impact on biodiversity.

Projections for baseline emissions for land use change tend to be highly divergent and depend for instance on forestry policy, population growth and agricultural productivity. Some projections assume that deforestation will be halted and land use change would become a net sink even in baseline projections, without specific climate change policies. For instance the IPCC's Special Report on Emissions Scenarios projects for the land use sector by 2050 a range going from a net sink of -1.5 $GtCO_2$ in the sustainable development policy scenario (B1) towards net emissions as large as 3.4 $GtCO_2$ in the business as usual scenario (A2).

The Integrated Sink Enhancement Assessment (INSEA) project funded under the 6th Framework Research Programme aims to identify land use activities that could help manage greenhouse gas emissions. Preliminary results from the Dynamic Integrated Model of Forestry and Alternative Land Use (DIMA) used in this project estimate that a further 200 million hectares or around 5 % of today's forest area will be lost between 2006 and 2025, resulting in a total release of additional 64 $GtCO_2$ or an annual average of 3.2 $GtCO_2$. It estimates that in the next 100 year the loss of today's forest cover will be 500 million hectares, which is 1/8 of the current forest cover (Kindermann et al., 2006).

43 See Russ et al. (2005) and also the summary in SEC(2005)180, page 26.

The DIMA model estimates the drivers for deforestation and afforestation through relative incomes from different types of land-use (e.g. forest versus agriculture, built up areas etc.) and simulates land use changes in terms of net emissions and the uptake of carbon dioxide in the forest biomass. The DIMA model thus provides projections on what the impact could be when a carbon value would be attached to forests. For this impact assessment, a financial incentive per tonne of carbon dioxide was introduced in the DIMA model that is similar to the price projected in the POLES model at regional level in the emission reduction scenario, i.e. more than € 60 per tonne of CO_2 in 2030.

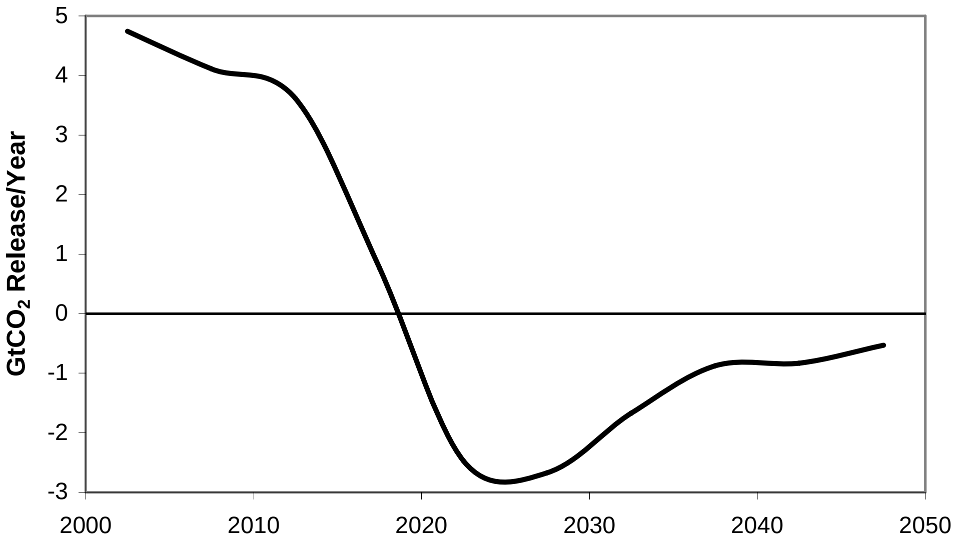


Figure 25: Climate change mitigation scenario in the Land Use Change sector induced by a carbon price

The projected impact on land use change is large, showing a sharp reduction in emissions from land use change. By 2020, greenhouse gas removals from the atmosphere resulting from planted forests would exceed by far yearly emissions from deforestation, with a surplus that with the maturation of the planted forests tapers off in the period after 2025. The results of the model indicate that substantial reductions in the land use chance sector could be achieved, however, illustrating the necessity for ambitious additional policies to reverse the emissions from deforestation.

Reversing trends in land use change will be challenging, but not inconceivable. Most developed countries have gone through periods of deforestation, but managed to reverse the trend by introducing forest policies, developing sustainable forest management systems and encouraging afforestation. China has recently managed to turn its net deforestation into a massive increase in forest areas through concerted action on forest protection and afforestation. However, at the same time China’s demand for timber in the international market has increased rapidly.

The issue of forests has been a priority on the international policy and political agendas for the past 15 years. Several processes and organisations are currently working to promote sustainable forest management and reduce deforestation, of which the United Nations Forum on Forests (UNFF), the International Tropical Timber Organisation (ITTO), the FAO, the Convention on Biological Diversity (CBD), the Forest Law Enforcement and Governance process (FLEG) and the EU Forest Law Enforcement, Governance and Trade Action Plan (EU FLEGT Action plan) are the most relevant ones.

At its sixth meeting in February 2006, the United Nations Forum on Forests (UNFF), agreed on a resolution containing four global objectives of which objective 1, *"reverse the loss of forest cover world wide through sustainable forest management, including protection, restoration, afforestation and reforestation, and increase efforts to prevent forest degradation*" is of particular relevance for the climate change process. The objectives are non-binding for the individual country, but countries agree to work globally and nationally to achieve progress towards their achievement by 2015.

However, reversing emissions from deforestation will require strengthening the EU profile in international forest related processes and considerably step up ongoing work for combating deforestation, as foreseen in the recently approved EU Forest Action Plan.

The introduction of a financial incentive to reverse deforestation at the international level will however require further careful analysis. The financial incentive introduced in the DIMA model could become astronomical if it were introduced for all the standing stocks of forest to avoid its deforestation. However, such a financial incentive would need to be seen in a broader context than the carbon value of a forest alone, and address the entire range of ecosystems services delivered by forests (e.g. genetic diversity, biological diversity, functions within the local and global water cycle and weather system). These and other services provided by forests are as vital, regionally and globally.

Changes in land-based carbon are reversible in nature and can quickly turn an ecosystem from an active sink into a net source (for instance fires and storms). This must be taken into account when considering appropriate policy approaches. Many other issues make the introduction of an incentive scheme a complex matter. Forests are degraded for different reasons at different locations (logging, agriculture, ranching, firewood, etc.). Governance and tenure of forests is diverse and often unclear in areas with high deforestation rates. Data on the use of forest is often imprecise and the institutional capacity to monitor them it is not adequate in many countries. Furthermore, not only do forests represent a carbon value in a global carbon constrained world, they also have a value due to their other local and global environmental services such as for instance biodiversity. A recent tropical forest report by the World Bank, *'At Loggerheads'*, proposes carbon financing as a tool to limit further degradation of global forest cover. But it also points out to the need of many other measures to manage our forests in a sustainable manner such as financing for biodiversity preservation, better monitoring and evaluation including local capacity building, better legislation concerning property rights and their enforcement and better planning procedures such as the expansion of the road network.

There have been various proposals for approaches to reverse global deforestation trends and for monitoring those trends. Several propose an international funding mechanism that would give incentives to developing countries to curb deforestation. Countries could select themselves the policies and measures to attain the needed reductions. Introducing a carbon price at the level of those persons that utilise the forest resources directly is challenging. It could be done through a direct incentive payment but would require micro management. Costa Rica already introduced such a scheme.

There is an urgent need for a better understanding on how economic incentive measures or other policy approaches at the scale required could be made to work properly. Experience exists with various incentive schemes and other policy approaches, but it is very difficult to apply these experiences at the international level to achieve the desired goals. One of the next steps should be to gather practical experience through pilot schemes at national or regional level.

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ANNEX 2: Preliminary Results PESETA

The objective of the PESETA project (Projection of Economic impacts of climate change in Sectors of the European Union based on bottom-up Analysis) is to make an assessment of the impacts, including monetary estimates, of climate change in Europe (EU25, Rumania, Bulgaria and Turkey) in the 2011-2040 and 2071-2100 time horizon, based on bottom-up physical methodologies.

The project largely benefits from DG Research projects that have developed impact modelling capabilities (e.g. the DIVA model) and high resolution climate scenarios for Europe (the PRUDENCE project). It is coordinated by JRC/IPTS and involves several research institutes[44].

The PESETA project focuses on the following sectoral impacts: Coastal systems, Energy demand, Human health, Agriculture, Tourism, and Floods. Each of these sectoral categories comprehends a sectoral study in the corresponding field carried out by the partners of the project, considering cross-sectoral issues. It does so for two global scenarios from the IPCC's Special Report on Emissions Scenarios (SRES), belonging to the A2 and B2 scenario storyline.

The Heterogeneous World Scenarios (SRES A2)

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

Assumptions for PESETA study:

– CO_2 concentrations in the atmosphere: approximately triple by the end of this century compared to the pre-industrial concentration.

– Global mean temperature increase of 3°C in 2071-2100 relative to 1961-1990

– Agriculture: Lower levels of wealth and regional disparities.

– Natural ecosystems: Stress and damage at the local and global levels.

– Coping capacity: Mixed but decreased in areas with lower economic growth.

– Vulnerability: Increased

The Local Sustainability Scenarios (SRES B2)

[44] JRC/IES, ICIS-Maastricht University, AEA Technology, FEDEA, University of Southampton, FEEM, and Polithecnical University of Madrid). The project also benefits from the collaboration of the Rossby Center that has provided climate data. Moreover, a multidisciplinary Advisory Board has been established in order to advise IPTS on the coordination of the project and to review the various project deliverables.

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

Assumptions for PESETA study:

– CO_2 concentrations in the atmosphere: approximately double by the end of this century compared to the pre-industrial concentration.

– Global mean temperature increase of 2.2°C in 2071-2100 relative to 1961-1990

– Agriculture: Lower levels of wealth and regional disparities.

– Natural ecosystems: Environmental protection is a priority, although strategies to address global problems are less successful than in other scenarios. Ecosystems will be under less stress than in the rapid growth scenarios.

– Coping capacity: Improved local

– Vulnerability: global environmental stress but local resiliency