TOWARDS A GLOBAL CLIMATE REGIME

PRIORITY AREAS FOR A COHERENT EU STRATEGY

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This report is based on discussions in the CEPS Task Force on "Towards a Coherent EU Climate Strategy beyond Kyoto: How the EU Can Provide International Leadership", which ran from September 2004 until April 2005. Participants in this CEPS Task Force included senior executives from a broad range of industry – including energy production and supply companies, energy-intensive industries and service companies – and representatives from business associations and environmental NGOs. A full list of members and invited guests and speakers appears in Annex 2.

The members of the Task Force engaged in extensive debates in the course of several meetings and submitted comments on earlier drafts of this report. Its contents contain the general tone and direction of the discussion, but its recommendations do not necessarily reflect a full common position agreed among all members of the Task Force, nor do they necessarily represent the views of the institutions to which the members belong.

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Preface by the Chairmen

Climate change is increasingly recognised as a serious threat to the future of our societies. Furthermore, it is seen as part of a broader pattern of global change, caused by human activity. Some scientists maintain that we are living in a new geological era, the Anthropocene. Given the impact of climate change policies on core sectors of our economies, in particular energy and transport, the challenges associated with climate change policy are particularly daunting. Important economic and social interests are at stake.

It is therefore not surprising that the road to a global response to climate change has been bumpy. The Framework Convention on Climate Change was concluded in 1992 and entered into force shortly thereafter; and the Kyoto Protocol, which specified precise quantitative commitments for industrialised countries, was agreed in 1997. When the United States decided not to ratify the Protocol in 2001, entry into force was uncertain for a long time. Finally, after a long-delayed Russian ratification, the Protocol became operative on 16 February 2005. The first Meeting of the Parties will be held in late November 2005 in Montreal.

The Kyoto Protocol will now be fully implemented, and all the contracting Parties need to make efforts to fulfil their commitments. At the same time, preparations are under way for the negotiations that will determine the post-2012 climate regime. This is a major international effort that will require patience, imagination and political will. The European Union has played a major role in the climate negotiations from the beginning. A prerequisite for continued success in this new phase will be a continued and effective leadership on the part of the EU, a heavy responsibility that the European Council has recognised and accepted.

Throughout this process, CEPS has supported these efforts through a careful analysis of climate change policies and presented its findings to a wide audience of policy-makers and negotiators. There has also been a strong commitment to providing a venue where different stakeholders can meet, exchange views and draw common conclusions.

The present report is part of that effort. It is based on thorough discussions among a broadly-based group of interested parties, including industry, environmental NGOs and researchers. Experts in different fields have made important contributions to the work of the Task Force.

We have considered in detail a number of key issues that need to be addressed over the coming years and decades. Our group represents many different interests; accordingly, all findings and recommendations are not supported by everyone. But on the fundamental points we all agree:

- Climate change is a real threat and it must be addressed now.
- The EU must continue to play a leading role in the global effort to reduce the risks and dangers for the future.
- We support strong efforts within the EU to reduce emissions in a fair, equitable and cost-effective way, recognising the need for a forward-looking climate policy.

As we submit this report, we wish to express our thanks to the CEPS team supporting our work, and in particular to the Rapporteurs Christian Egenhofer and Louise van Schaik, and to their colleagues Noriko Fujiwara and Kyriakos Gialoglou for their contributions, and to Isabelle Tenaerts for efficient administrative support.

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TOWARDS A GLOBAL CLIMATE REGIME
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REPORT OF A CEPS TASK FORCE
EXECUTIVE SUMMARY

For several years now, the EU has identified combating climate change as among its most important challenges, and has accordingly been engaged in a concerted effort to develop cost-effective policies for a coherent climate strategy. Most recently, the spring 2005 European Council endorsed the target of limiting the future global average temperature increase to 2°C above its pre-industrial level and indicated its willingness to explore with other countries the possibility of reducing greenhouse gas (GHG) emissions from industrialised countries by 15% to 30% from a 1990 level by the year 2020.

This report attempts to identify priority areas for coherent EU domestic policies in the short, medium and long term.[1] It gives a first indication of what meeting EU climate objectives would imply in concrete terms. Finally, it tentatively describes the potential EU contribution to international negotiations. Towards that end, the report attempts to frame the key elements of a rational and credible EU strategy to achieve emissions reductions as mandated by member state, EU and international obligations to facilitate an agreement to combat climate change at the global level.

This report focuses on policy coherence, cost-effective mitigation options in the short and medium-term and the interaction of such options with international negotiations in the 'post-2012 framework'. It is acknowledged that the overall climate change response must also take into consideration adaptation policies, even if the target of limiting the future global average temperature increase to 2°C above its pre-industrial level is met.

I. Key Messages

1. Tackling climate change poses one of the world's greatest challenges. The evidence is getting stronger that most of the temperature rise that has occurred over the last 50 years is attributable to human activity. As GHG concentrations continue to increase, the potential impact of greenhouse gas emissions on people and ecosystems may prove to be significant. Such damage could also lead to considerable costs. Achieving the necessary reductions, such as proposed by the March 2005 European Council, will be very challenging (see Table 2 and Box 2).
2. Meeting the global climate change challenge will need a long-term strategy engaging the EU and other Parties to the UN Framework Convention on Climate Change. Such a strategy should be built on a number of crucial elements, notably: i) inclusion of all major emissions sources, including CO_2 from fossil fuels, non-CO_2 gases, and CO_2 from land-use change and forestry; ii) concern for economic and trade effects; iii) the active engagement of industrialised countries and – at least the rapidly industrialising – developing countries; and iv) attention to several important issues related to adaptation. A potential agreement that does not meet these preconditions will neither be environmentally effective, since it is expected that developing countries' emissions will exceed those of industrialised countries by the year 2030, nor economically efficient, since restricted participation and coverage

[1] This report uses the term 'short term' to refer to a time perspective between now and 2012. 'Medium term' describes the period up to around 2020-35, while the 'long-term' means until 2050 and beyond.

increases overall compliance costs. And it would be inequitable, and therefore likely to become discredited.

3. Technology will play a central role in meeting the climate change challenge. Since technology takes considerable time to develop and to diffuse, increasing the efficiency of existing technologies in the short and medium term offers the greatest potential for reductions in GHG emissions, in combination with accelerated diffusion of technology, i.e. to encourage the use of the most efficient technologies currently available in a cost-effective manner. In the long term, 'breakthrough' technologies must be developed.
4. Incentives for abatement and innovation are inexorably linked. Governments have to both: i) provide proper incentives for environmental protection and innovation and ii) supplement private sector research with publicly-funded R&D that is not undertaken by private investors due to the likelihood of market failure. Regardless of how environmentally beneficial new technologies may be, they will have little influence on the rate at which firms retire older, more polluting plants in the absence of policies promoting technology or requiring reductions in emissions. It is also important to focus the debate on technology transfer, with a view to identifying which policies constitute an enabling regulatory framework and which constitute a barrier.
5. A strong commitment to climate change policy by the EU has helped to keep the issue on the international agenda. A continuation of this commitment is important. The impact of the EU's leadership can be increased by presenting a credible, multilateral climate change strategy that minimises costs and holds out the promise of leading to economic and social benefits. Hence, there is a need for cost-effective solutions, achieved through the appropriate use of market-based instruments and taking into account distributional effects.

II. Recommendations

1. It will be extremely difficult to meet the 2°C target. Therefore, the EU and its member states need to develop a coherent and comprehensive long-term strategy, taking into account the existing lead times related to capital stock turnover and to infrastructure development. Priority should be given to those strategies that provide co-benefits in terms of economic efficiency, security of supply, containment of local pollution or innovation and job creation.
2. The large potential for improvements in energy efficiency and conservation must be realised through immediate action, both by speeding up technology diffusion and introducing incremental changes in standard practices. This entails developing a comprehensive energy efficiency strategy based on the strengthening of existing and forthcoming EU legislation. Immediate priority should be given to existing buildings and housing as they constitute a great yet untapped potential for decreasing energy consumption.
3. Further work needs to be carried out in the highly promising area of substituting existing products with other products promising lower climate-change impact.
4. To facilitate the development of new technologies, the EU and its member states must develop a comprehensive technology policy that combines incentives both for reductions in GHG emissions and for R&D and innovation.
5. Research in climate-friendly technologies (e.g. in energy or transport) must become a priority in the EU and member state research policies and receive increased resources devoted to their development.[2] Research on climate science must also be explicitly fostered.

[2] For example, through the EU's 7th R&D Framework Programme.

6. The EU should play a leadership role in encouraging the use of new technologies and favouring technology investment and technology transfer. It must pursue integration of the UNFCCC activities on technology transfer, capacity-building and the project-based mechanisms, CDM and JI, to ensure the development of a coherent, global strategy that will facilitate the rapid diffusion and deployment of new and existing technology and know-how.
7. Member states must develop and implement sustainable energy strategies that are coherent and consistent, and that provide a long-term investment framework designed to progressively ensure cost-efficient and less-carbon-intensive energy and industrial production in Europe and must support similar developments abroad.[3]
8. Road transport strategies should be adopted that aim at accelerating improvements in vehicle emissions performance throughout the full life cycle as well as promoting shifts in preferred modes of transport.
9. The EU should bring into line its external policies – such as development cooperation, trade and the neighbourhood policy – with climate objectives. It must equally seek to align funding priorities of EU and international financial institutions (IFIs) with the objective of tackling climate change.
10. In order to meet its own climate targets in a cost-effective way, the EU must take the lead in promoting a comprehensive and differentiated framework that could facilitate full participation after 2012, based on a continuation of the key elements of the Kyoto Protocol.
11. Strategies to reduce greenhouse gas emissions post-2012, with a view to the stabilising and reducing atmospheric concentrations, must be guided by the latest scientific knowledge and the recognition that global participation will be necessary to achieve a meaningful and significant impact.

III. Full Summary

1. According to the Third Assessment Report of the Intergovernmental Panel on Climate Change of the United Nations, evidence is getting stronger that most of the temperature rise over the last 50 years is attributable to human activity. It warns that an increase in global temperature is likely to trigger serious consequences for humanity and other life forms alike.
2. The EU has set itself a target of limiting the temperature increase to a maximum of 2°C. It is uncertain, however, whether this target will actually avoid serious consequences. Since GHG emissions stay in the atmosphere for a long time, delaying action now risks making the challenge bigger in the future. Continued research in climate science will be needed.
3. Technology will play a central role in meeting the climate change challenge. While there are different opinions on whether medium-term goals can be reached with technically-proven technology, it is generally accepted that there is a need to develop new and technically unproven (i.e. breakthrough) technologies for the long-term.
4. There appears to be a positive correlation between productivity and levels of research and specialisation in high-tech activities. Spending 1.9% of its GDP on R&D – from both the private and public sectors– the EU is lagging behind Japan and the US, with expenditures of 2.9% and 2.6%, respectively.

[3] Governments can pursue one or a combination of four principal options: improving the efficiency of current technologies; renewables; carbon capture and storage; and nuclear.

5. R&D is a matter of both private sector and public spending. R&D can be left to the market when it comes to the *application* of new technologies, i.e. the area of commercial development or improved efficiency. In areas where the profitability is *uncertain*, however, due to for example the level of economic risk or a very long time horizon or both (e.g. fusion, hydrogen, CO_2 capture and storage), government support is needed.

6. Since most emissions growth will be outside the industrialised countries, the diffusion of efficient applicable technologies to developing countries is crucial. The success of *technology transfer* depends principally on sound and stable conditions for investment. To address the potential needs of developing countries, such as capacity-building or financial support, other additional instruments may be needed. The use of flexible mechanisms and rules and instruments of IFIs in ensuring diffusion would be particularly important components.

7. The capital stock, as reflected in investment in power plants, grids or refineries, has value for decades. Attempts to reduce emissions 'too quickly' may require premature retirement of invested capital, which in return increases abatement costs significantly. Delaying reductions, on the other hand, raises costs for future action because the investments that are undertaken now will last for decades and may therefore continue to pollute for a long time. The importance of this issue at the present time is underlined by the need for investments in the capital stock over the next 20 years.

Public infrastructure

8. A special case is public infrastructure, which through its long life span predetermines production and consumption patterns over a long period of time. Decisions taken by governments today will be decisive in terms of reducing emissions for decades to come. As for existing infrastructure, however, better management can produce important short-term results.

Policy coherence

9. Standard 'climate technologies' refer to energy efficiency, fuel switching or insulation. As a result, coherence means consistency of energy, transport and many other EU policies with the climate change policy objective of reducing GHG emissions. Further policy coherence could be achieved by a common EU energy policy. The EU's external policies, namely trade, development cooperation and the EU neighbourhood policy, would need to be aligned with climate objectives as well.

Synergies

10. Climate change policy has many co-benefits such as the reduction of local pollution caused by NOx or SO_2, innovation and technological leapfrogging. Thus, climate policy is likely to have significant, yet unforeseen benefits.

Sector-specific policies

11. *Energy efficiency* holds the greatest potential to reduce GHG emissions. More efficient use of energy in a wide range of applications, including vehicles, electrical appliances, lighting and industrial uses, could account for almost 60% of the potential short-term reduction in CO_2 emissions. Governments have yet to implement policies to achieve these goals.

12. *Transport* is a crucial sector (together with power) for climate change policy. Transport is a significant contributor to economic growth and enables people to participate in economic and social activity. At the same time, the fast-growing transport sector is responsible for somewhat more than 20% of total CO_2 emissions, and this figure does not include maritime

shipping and international aviation. While hydrogen and fuel cell vehicles offer great promise in the long-term for reducing GHG emissions, in the short and mid-term, there is major scope for technological cost-effective improvement of the existing conventional technologies, such as the internal combustion engine. Also on the fuel side there are major reduction potentials.

13. In the long-term, hydrogen (H_2) may become the principal preferred energy carrier for the road transport sector, as it is able to supply the necessary volumes and meet environmental standards. Hydrogen faces two basic challenges, however, the first being the development of effective infrastructure and the second being the development of vehicle technology. There is still controversy over which challenge will prove the more difficult to overcome when considering the potential for large-scale use of hydrogen.

14. An important factor will be the rate of renewal of the vehicle fleet, given that new vehicles must meet much stricter standards. In the case of private cars (the great majority of new vehicles), however, it is important to realise that a shift to larger, heavier cars does not offset the improvements in energy efficiency and environmental impact. Better infrastructure management could reduce emissions.

15. Further scope exists in modal shifts, such as from aviation to rail for short-hauls, to public transport or non-motorised trips for urban transport and some shift of freight transport to rail. Generally speaking, the passenger sector has more scope for modal shift as it tends to be more responsive to price changes. Conversely, much less scope exists for reducing the rate of growth in freight demand. There is also a role to be played by land-use planning to reduce the need for longer motorised journeys, for example in the location of shops.

16. *Generation of electricity* from fossil fuels, notably natural gas and coal, is another major growing contributor to CO_2 emissions. There are four possible options for reducing CO_2 emissions from power generation: i) increased efficiency in transmission/distribution, generation and fuel switching, mainly to gas; ii) expansion of renewable energy sources such as wind, solar, biomass and geothermal; iii) capture of CO_2 emissions at fossil-fuelled (especially coal) electric generation plants and permanent sequestering of the carbon; and iv) nuclear power.

    a. Energy efficiency in power generation and transmission/distribution depends on a combination of improved performance (due to technological progress) and market penetration of such new technologies. The latter is largely a function of when new technologies become economically viable.

    b. The uptake of new renewables will depend on their competitiveness with existing technologies. Policy can play an important role in bringing down costs, through R&D subsidies on the one hand and by support mechanisms, which ensure a certain level of market penetration, on the other. Increased market penetration historically has proven to reduce costs.

    c. Carbon capture and storage are seen by many as a key technology to combat climate change. It would enable the continuation of coal-fired power plants since many countries see no short- and medium-term alternative to coal owing to its advantages both in terms of economics and security of supply. The technical potential appears to be very high. Main issues remaining for further analysis include, for example, safety and leakage issues (i.e. permanence), economic viability and accurate assessment of storage capacities. Further research will be needed before large-scale application can occur.

    d. Nuclear power in principle is a potential source of GHG emissions reductions over the next 50 years. At present, however, nuclear power faces stagnation and decline according to most forecasts, for reasons of cost, safety, waste and proliferation. In order to reverse nuclear decline, changes in governmental policies are likely to be needed. There are also questions on the availability of sufficient uranium.

17. Buildings and houses constitute one of the biggest potential areas for GHG emissions reductions. They are responsible for about 40% of all CO_2 emissions in the EU if all electricity to end-use sectors and heat-related emissions are included. For example, an extension of the Directive on energy performance in buildings to all houses could save up to 70 Mt CO_2 p.a., which is equivalent to 2.4% of 1990 EU-15 emissions.

18. From both a practical and a strategic perspective, the EU ETS is the centrepiece of EU climate policy. Not only does it cover almost one-half of EU CO_2 emissions, it is also difficult to perceive absolute caps without the flexibility provided by emissions trading. At the same time, the potential of the EU ETS to achieve significant reductions at least to date remains uncertain and will depend on a future global agreement. It is unrealistic to assume that EU governments would impose a significant carbon constraint on 'their' companies unless major competitors would be willing to do the same. As of April 2005, the initial contribution of the EU ETS remains limited. It is estimated that the EU ETS' contribution under the first round of allocation would contribute to an annual savings of around 100 Mt CO_2 in the power sector. The 2006 EU ETS review, which will include allocation, sector coverage, new gases and distributional impacts, will be crucial for the future of the EU ETS.

19. Another means of reducing environmental and climate impact is product substitution, for which the construction, transport, car manufacturing and telecommunications sectors, in particular, offer significant opportunities. As changes rely on infrastructure (e.g. building codes, skills in the construction business, supply of raw materials), the potential for substitution should be seen in a longer-term perspective and is unlikely to play a significant role in a 2030 perspective.

The post-2012 international architecture

20. The principal challenge for the post-2012 architecture is to identify the nature and level of commitment that will provide sufficient incentives for all Parties, especially the largest emitters, to join a global agreement and achieve meaningful reductions in GHG emissions. A review of the literature suggests that there is no single framework, including the Kyoto Protocol, that would meet all possible evaluation criteria, such as the environmental outcome, economic efficiency, cost-effectiveness, distributional impacts, flexibility and simplicity and incentives to participate and comply.

21. Although there are different views worldwide as to whether a post-2012 framework should be built on the Kyoto Protocol, it is fair to say that the Kyoto Protocol has established or reinforced numerous areas where an international consensus has emerged or at least may be achievable. These include: i) differentiation, ii) a comprehensive approach to all emissions sources, iii) gradualism, iv) flexibility and v) flexible mechanisms.

22. It is realistic to expect that a comprehensive agreement on the post-2012 regime will need to ensure a fair amount of continuity with the Kyoto Protocol structure, while at the same time accommodating a number of additional components aimed at attracting universal participation in a global agreement. The following elements should be taken into consideration in any debate on a post-2012 regime:

    a. *Nature of commitments.* The Kyoto Protocol has set absolute targets for industrialised countries. The merit of this approach has been its relative simplicity and sensitivity to environmental integrity. The downside is their inherent inflexibility, notably as regards accommodating differences in population or economic growth. This has raised renewed interest, notably outside Europe, in alternative ways to formulate commitments such as, for example, intensity targets, sectoral policies, technology approaches or combinations thereof. In parallel, there is an interest in providing additional flexibility to absolute targets via flexible mechanisms, banking, the periodic of review of targets and possibly most importantly, a ceiling (i.e. price cap) on allowance prices.

b. *Flexible mechanisms, including emissions trading.* An absolute target approach must be seen in conjunction with emissions trading, both in the EU and internationally. As the EU continues to advocate absolute emissions limits (i.e. Kyoto Protocol-type caps), emissions trading almost becomes a prerequisite to achieve these caps in a least-cost fashion, provided potential distributional impacts can be addressed. Should absolute caps prevail, emissions trading is almost certainly to occupy a central place in the post-2012 regime.

c. *Adaptation.* Based on existing knowledge, adaptation measures both in the EU and other industrialised and developing countries are likely to become a crucial pillar upon which an eventual global agreement will rest. More work needs to be done in this area.

d. *Technology approaches.* In the medium to the long term, technology will play a decisive role, as ultimately stabilisation of GHG emissions, in line with the UNFCCC's objective, can only be met with new breakthrough technologies. There is a case to be made in favour of designing an enabling framework for technology diffusion via for example technology protocols.

e. *Domestic policies.* A focus on the potential of short- and medium-term domestic policies that accommodate individual and natural circumstances can help Parties to base negotiating positions on a firmer footing. This will implicitly provide an authoritative analysis of underlying costs and benefits.

f. *Institutional framework.* There is a possibility to make a distinction between the UN's role as the negotiations platform and as 'coordination' body for implementation. While informal negotiations can and in reality will take place in many different fora, including the UN but also the G8 among others, there is little alternative to the UNFCCC to oversee coordination of the management for example of the flexible mechanisms, the registry system, national communications or compliance rules. It may be possible, however, to delegate certain coordination tasks to executive agencies.

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REPORT OF A CEPS TASK FORCE

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Introduction

The entry into force of the Kyoto Protocol represents an important step towards reaching a global approach to climate change. More than 130 countries have ratified the agreement, encompassing most of the world's industrialised, transition and developing countries. Nevertheless, the Kyoto Protocol is only a first step. An effective and equitable agreement requires the full engagement of all countries, in particular the largest emitters from both the industrialised and the developing worlds. Without the participation of all principal emitters, the objectives of reducing GHG emissions and stabilising concentrations will most likely not be met. However, the principle of common but differentiated responsibilities, as enshrined in the United Nations Framework Convention on Climate Change (UNFCCC), requires ambitious actions from industrialised countries first.

Discussions on a 'post-2012' framework, i.e. for the period after the Kyoto Protocol's expiration in 2012, have started in earnest within the EU and internationally. Many proposals for a post-2012 architecture have been put forward. Whether based on the Kyoto Protocol or on other approaches, they will need to find solutions to further emissions reductions. Such solutions are more likely to be found if the EU, but also other Parties to the UNFCCC, are successful in developing a comprehensive long-term strategy or 'vision', including the different necessary ingredients of a successful approach to climate change: mitigation (including technology development), sinks and adaptation.

This report attempts to identify priority areas for coherent EU domestic policies in the short to the long run.[1] It gives some first indications on what meeting EU climate objectives would imply in concrete terms. It tentatively describes a rational and credible EU strategy to achieve an agreement to combat climate change at the global level.

The following analysis is primarily concerned with mitigation; hence, it focuses on the interface between government policy and technology development and diffusion. Neither policy nor technology on its own is sufficient to address the challenges of climate change. Both are necessary to reduce emissions in the magnitude needed. As we will show, incentives for abatement and for innovation are inexorably linked and both will be needed simultaneously to meet the climate challenge.

This report and its accompanying policy recommendations are meant as a contribution to the EU long-term strategy for combating climate change. On the one hand, these are aimed at internal EU discussions. On the other, the report seeks to contribute to discussions on climate change in international fora outside the EU, such as the G-8 or the UNFCCC.

This report places a strong emphasis of be on cost-effectiveness, i.e. achieving the necessary objectives at the least possible cost.

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[1] This report uses the term 'short term' to mean a time perspective until 2012. 'Medium term' describes the period up to around 2020-35, while 'long term' means until 2050 and beyond.

Following this brief introduction, the main report is structured in 7 sections. Section 1 introduces the challenges associated with climate change, while sections 2 and 3 present key climate-relevant data on sources of GHG emissions and data regarding growth and energy demand. Section 4 introduces preconditions for meeting climate objectives and argues for policy coherence. Section 5 develops an indicative proposal for a medium-term domestic EU climate change strategy (from approximately 2020 to 2025). Section 6 addresses the EU climate change strategy in the international context, and section 7 makes some concluding remarks.

The main findings of the report are contained in the Executive Summary, which includes Key Messages and Recommendations.

The report has two annexes, the first of which contains a glossary of technical terms and abbreviations, while the second contains a list of members of the Task Force and invited guests and speakers.

1. Climate change

According to the Intergovernmental Panel on Climate Change (IPCC) in its Third Assessment Report (IPCC, 2001), evidence is getting stronger that most of the temperature rise that has occurred over the last 50 years is attributable to human activity. This authoritative scientific body warns that an increase in global temperatures is likely to trigger serious consequences for humanity and other life forms, including a rise in sea levels, which will endanger coastal areas and small islands, and a greater frequency and severity of extreme weather events. On behalf of the EU, the European Environment Agency (EEA, 2004a) found similar indications.[2]

Box 1. Climate change: Some examples of expected impact on social, economic and natural systems

- Rise in sea level: Loss of coastal land/wetlands and increased costs of protection against floods
- Agricultural production: Adversely affected by droughts, desertification, changing rainfall patterns, extreme weather events, etc.
- Energy use: Changes in heating and cooling due to changing weather
- Human health: Higher incidence of the spread of diseases
- Eco-systems: Loss of productivity and biodiversity
- Water: Changes in resources, supply and quality
- Infrastructure: Damage through drought, flooding, extreme weather, etc.
- Migration: Through desertification or major events in the climate (e.g. collapse of the Gulf stream)

Sources: European Commission (2005b); IPCC (2001).

As early as 1996, the EU adopted a long-term target of limiting the temperature increase to a maximum of 2°C.[3] This was recently reiterated by the Environment Council in December 2004 with reference to the IPCC's Third Assessment Report and reaffirmed by the European Council

[2] Recent research on the scientific understanding and long-term implications of climate change as well as options to reach such goals were presented at the UK government-sponsored Conference on Avoiding Dangerous Climate Change, which was held in Exeter on 1-3 February 2005 (see http://www.stabilisation2005.com/index.html).

[3] See Conclusions of the Council of the European Union, meeting in Luxembourg in June 1996 (Council of the European Union, 1996).

in March 2005: "the overall global mean surface temperature increase should not exceed 2°C above pre-industrial levels".[4] It is uncertain whether this target will be sufficient to actually avoid 'serious consequences', as climate sensitivities are high and there is still much we do not know about climate change.

In the judgement of the Environment Council of December 2004, CO_2 concentrations may need to be stabilised below 550 ppmv CO_2 equivalent, which translates into around 450/475 ppmv CO_2 only in order to have a reasonable chance of limiting global warming to no more than the EU target of 2°C .[5] This level is significantly lower than the concentration levels previously mentioned by the EU in conjunction with this target. In comparison, pre-industrial CO_2 concentration levels stood at 280 ppm while they have increased to 370 ppm to date, leading to an increase in the average global temperature by almost 1°C. In the absence of measures, there will be no stabilisation below 700 or even 1,000 ppm. Such levels, according to the IPCC, are likely to lead to very damaging impacts, including structural alterations to weather patterns or even to changes of important ocean currents, such as the Gulf Stream. Furthermore, it is part of a broader pattern of global change caused by human activity.

It would be very difficult to achieve stabilisation at less than 550 ppmv CO_2 equivalent (450/475 CO_2 only), as that would require a peak of global emissions before 2020 (see Table 1), since GHG emissions stay in the atmosphere for a long time.[6] Tentative illustrations of the scale of the challenge in practical terms are provided in Table 2 and Box 2.

Table 1. Conditions for stabilising CO_2 concentrations

WRE CO_2 Stabilisation Profiles (ppmv)	Accumulated CO_2 emissions, 2001 to 2100 (GtC)	Year in which global emissions peak	Year in which global emissions fall below the 1990 level
450	365-735	2005-2015	<2000-2040
550	590-1135	2020-2030	2030-2100
650	735-1370	2030-2045	2055-2145
750	820-1500	2040-2060	2080-2180
1000	905-1620	2065-2090	2135-2270

Source: IPCC (2001).

Furthermore, the timing of policies required for drastic reduction of emissions concentration levels would not necessarily match investment cycles for capital investment in the principal emitting sectors of energy and transport (see section 4). Major transformations of infrastructure typically stretch over long periods of time, i.e. several decades. For example, most power plants last for almost half a century. Even short-lived gas turbines operate for at least a quarter of a century. And cars may be driven for up to 20 years. Early depreciation of the invested capital increases the cost to a considerable extent. For example, aiming at stabilisation at 650 ppmv CO_2 equivalent, which would be more in tune with investment cycles, could reduce the total abatement costs by about one-quarter compared to a goal of 550 ppmv (European Commission,

[4] Cited in the European Council Presidency Conclusions.

[5] The indicator for potential climate change impacts is concentrations of GHG emissions as expressed for example in parts per million (ppm) or ppmv (ppm in volume) of CO_2 only or CO_2 equivalent. CO_2 equivalent means that the other greenhouse gases – CH_4, N_2O, SF_6, PFCs and HFCs – are translated into CO_2 on the basis of their global warming potential (GWP). Since not all greenhouse gases stay in the atmosphere for the same length of time, the relationship between CO_2 and CO_2 equivalent varies depending upon the time frame one takes into account.

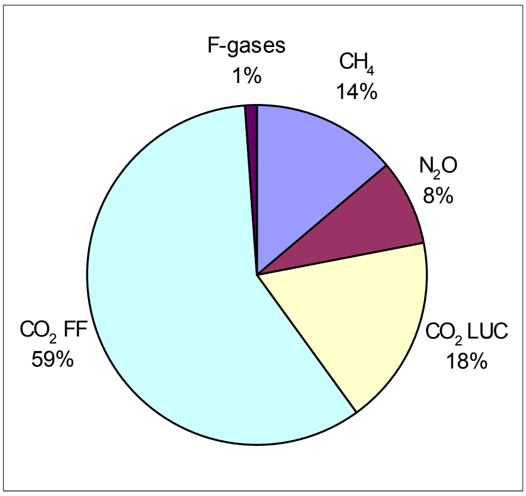
[6] For example, CO_2 stays in the atmosphere for about 100 years. What we emit today will cause damage for a long time in the future.

2005a, p. 15). However, in all likelihood, such a target would not be sufficient to succeed in limiting a global average temperature increase to 2°C above pre-industrial levels.

2. Greenhouse gases and their sources

The Kyoto Protocol covers six greenhouse gases: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulphur hexafluoride (SF_6), perfluorcarbons (PCFs) and hydrofluorocarbons (HFCs). Each has a different global warming potential (GWP), according to the expected impacts. In terms of volume, the most important one is CO_2, which is often used as a proxy for all GHGs. There are important differences between regions as to sources and impacts. As illustrated in Figure 1, CO_2 from fossil fuel combustion accounts for 59% of total global GHG emissions, CO_2 from land use change and forestry represent 18% and non-CO_2 gases, 23%. Among the non-CO_2 gases, the most significant are methane (14%) and nitrous oxide (8%). They are more important in the developing countries. The high GWP F-gases,[7] which represent only 1% of global GHG emissions, are emitted almost exclusively by highly industrialised countries (Baumert & Pershing, 2004).

Figure 1. Global greenhouse gas sources



CH_4	Methane
N_2O	Nitrous oxide
CO_2 LUC	Carbon dioxide from land-use change and forestry
CO_2 FF	Carbon dioxide from fossil fuels and cement (industrial processes
F-gases: HF_6 PFCs HFCs	 Hexafluoride Perfluorcarbons Hydrofluorcarbons

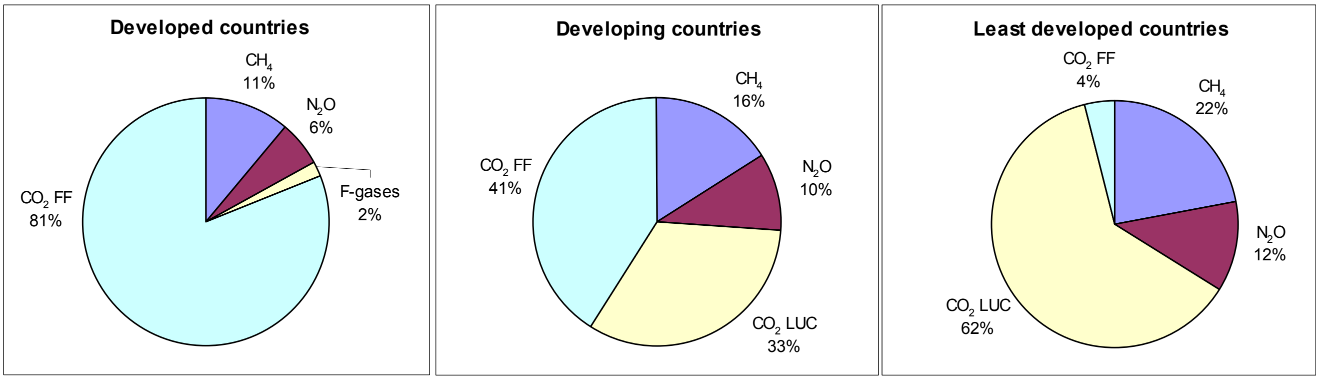
Source: Baumert & Pershing (2004, pp. 5-6).

Hence, CO_2 emissions (both from fossil fuels and from land-use change and forestry) are the most important GHG emissions, accounting for 77% of total global emissions and even 81% of overall emissions in industrialised countries (Baumert & Pershing, 2004).

Whereas land-use change in industrialised countries is believed to result in a net absorption of CO_2, in developing countries it generally represents 30% and in the least developing countries even more than 60% of greenhouse gas emissions (Baumert & Pershing, 2004). In some cases, CO_2 emissions related to land-use change and forestry are not included in emissions figures because of uncertainties associated with their calculation. Nevertheless, they matter in a global perspective since in countries such as Indonesia and Brazil, CO_2 emissions from land-use change and forestry are a principal emissions source.

[7] The three high global warming potential gases, or so-called 'F-gases', are sulphur hexafluoride (SF_6), perfluorcarbons PFCs) and hydrofluorcarbons (HFCs).

Figure 2. A comparison of greenhouse gas sources: developed, developing and least developed countries



CH_4	Methane
N_2O	Nitrous oxide
CO_2 LUC	Carbon dioxide from land-use change and forestry
CO_2 FF	Carbon dioxide from fossil fuels and cement (industrial processes
F-gases: HF_6 PFCs HFCs	 Hexafluoride Perfluorcarbons Hydrofluorcarbons

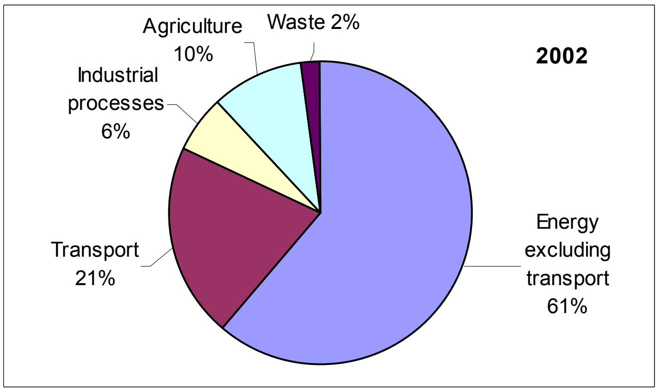
Source: Baumert & Pershing (2004, pp. 5-6).

Within the EU, the principal GHG emitting sources by sector are energy supply (excluding transport), industry, agriculture, waste management and transport. All sectors but transport have witnessed a reduction in the period 1990-2002 (EEA, 2004b). The energy and transport sectors are responsible for about four-fifth of total emissions in the EU.

It is expected that transport (together with power generation) will be the main contributors to emissions growth within the EU. According to the European Commission, transport-related emissions are projected to grow by around 50% between 1990 and 2010 (European Commission, 2001). The transport sector would become the primary source of CO_2 emissions in the EU-15 between 2005 and 2020, only to be overtaken by power generation thereafter. In the new EU member states in Central and Eastern Europe, transport-related CO_2 emissions may even grow up to 70% in 2030 against the 2000 baseline (see Zachariadis & Kouvaritakis, 2003).[8] When electricity-related emissions are allocated to end-users, the picture changes: industry then becomes the largest contributor followed directly by transport and households at equally high level (see Figure 4). The difference is that transport is fast-growing while households remain constant (Barbier et al., 2004). This illustrates the importance of industry, transport and households when considering options for reducing GHG emissions.

[8] By around 2030, one-half of the world's population may be living in developing countries – many of them with fast-growing economies. It is expected that such countries will account for most of the net increase of the motor vehicle fleet.

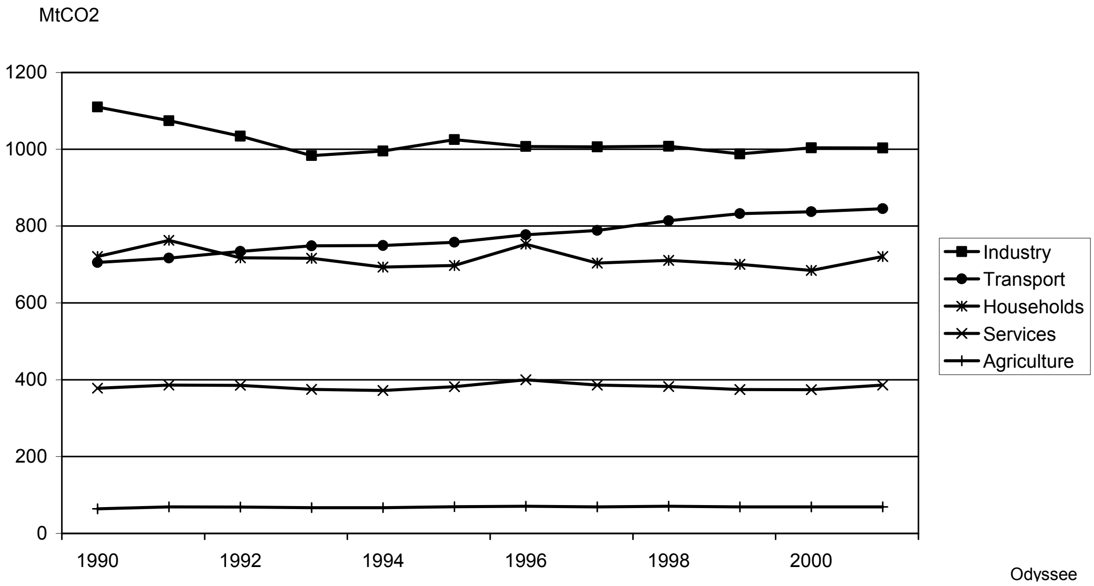
Figure 3. Sectoral emissions in the EU, 2002



Energy supply and use excluding transport	CO_2 from fossil-fuel combustion in electricity and heat production, refineries, manufacturing industries, households and services.
Transport	CO_2 from fossil-fuel combustion and N_2O from catalytic converters.
Industrial processes	CO_2 from cement production, N_2O from chemical industry, HFCs from replacing CFCs in cooling appliances and from production of thermal insulation foams.
Agriculture	CH_4 from enteric fermentation and manure management and N_2O from soils and manure management.
Waste management	CH_4 from waste disposal sites.

Source: EEA (2004b, p. 24).

Figure 4. Sectoral CO_2 emissions in the EU-15 with electricity-related emissions allocated to end-use sectors



Source: Barbier et al. (2004).

3. Growth, development, energy demand and climate objectives

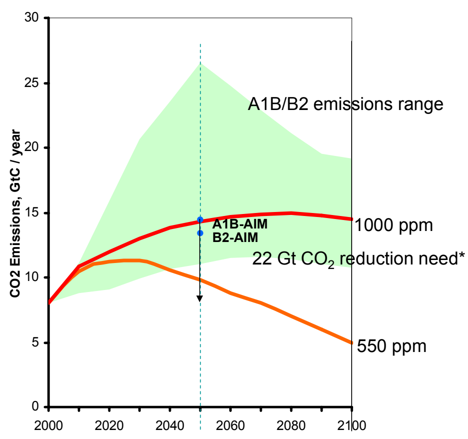
It is sobering to look at global energy demand projections against the background of climate change objectives. In 'business as usual' scenarios, world energy demand is projected to grow by around 60% or even more until 2030 (IEA, 2004a; European Commission, 2003; ExxonMobil, 2004), which means an average annual growth rate of more than 1.6%. Until 2050, global energy demand will double or possibly even triple (WBCSD, 2004a; see also Figure 5). The main drivers of increasing global energy demand are economic development, and projected population growth in developing countries. World economic growth is expected to average around 3% annually while the population will grow at an average of 1% per year according to most forecasts. Hence population could increase to 9 billion by 2050 (see UN, 2004).

It is realistic to assume that the EU and the world at large will continue to rely on fossil fuels as the principal fuels for the time being. The IEA (2004a) assumes that fossil fuels will continue to dominate global energy use in 2030, accounting for some 85% of the *increase* in world energy demand. Total global CO_2 emissions are expected to grow to over 50 billion tonnes.

By 2030, two-thirds of the increase in global energy demand will come from developing countries. Around 2025 to 2030, developing countries are projected to overtake industrialised countries in absolute terms of GHG emissions. This means that even considerable reductions in GHG emissions in the industrialised world will not suffice to achieve stabilisation.

In order to achieve stabilisation of GHG concentrations at a level of 550 ppm CO_2, based on work by the IPCC (2001), there is a need to reduce global CO_2 emissions by 22 billion tonnes of CO_2 per year by 2050 as compared to a 'business as usual' scenario, which is slightly less than current total global emissions[9] (see Figure 5 and WBCSD, 2004a). This corresponds to a 40% reduction compared to 'business as usual'.

Figure 5. Achieving an acceptable CO_2 stabilisation



* 22 Gt CO_2 is equal to 6-7 Gt of carbon.

Source: WBCSD (2004a), based on scenarios from the IPCC's Third Assessment Report (IPCC, 2001).

[9] 22Gt CO_2 equals 6-7 Gt of carbon.

Table 2 illustrates the scale of the task by citing several massive activities whose implementation could achieve reductions of 3.3 billion tonnes of CO_2 emissions (or 1 gigatonne of carbon). For example, one could install 150 times the current wind power capacity, bring into operation 1 billion hydrogen cars to replace conventional 30 (US) miles per gallon (7.84 litres per 100 kms) cars or install five times the current nuclear capacity. Alternatively, one could use half of the US agricultural area for biomass production.

Table 2. The challenge: 3.3 billion tonnes of CO_2 emissions reduction per year requires… Reductions to achieve 550 ppm stabilisation (-22 Gt CO_2 by 2100)

Technology	Required for 3.3 Gt CO_2/yr
Coal-fired power plant with CO_2 capture/ storage	700 x 1 GW plants
Nuclear power plants replace average plant	1500 x 1 GW (5 x current)
Wind power replaces average plant	150 x current
Solar PV displace average plant	5 x 106 ha (2000x current)
Hydrogen fuel	1 billion H_2 cars (CO_2-free H_2) displacing 1 billion conventional 30 mpg (7.84 litres per 100 kms) cars
Geological storage of CO_2	Inject 100 mb/d fluid at reservoir conditions
Biomass fuels from plantations	100 x 106 ha (half of US agricultural area)

Source: Presentation by ExxonMobil to the Task Force at its meeting on 22 October 2004 (http://www.ceps.be/files/TF/1).

The objective of a 15-30% reduction in CO_2 emissions by 2020, as has been proposed in the Presidency Conclusions of the European Council of 22 and 23 March 2005, is a similar challenge. Possible options for achieving a 20% reduction in CO_2 emissions under a mid-range growth scenario are summarised in Box 2.

Box 2. Possible combination of options to achieve 20% CO_2 reductions by 2025 in the EU

- *Coal*. Consumption of coal remains constant, but nearly a third of coal-fired generation must use sequestration. This means that zero emissions from coal-fired generation must become a fully commercial 'off-the-shelf' process in the near future.
- *Mobility*. Vehicle kms increase by 20%, but oil consumption falls by 30% as vehicle efficiency improves by over 50% (for the on-road fleet) and bio-fuels make up 8% of the vehicle fuel mix.
- *Natural gas consumption* would need to increase by 50%, mainly for power generation. As the total emissions budget shrinks but energy demand rises, it is unavoidable that coal and oil emissions would be reduced to make way for gas.
- A marked shift to *electricity* (nearly double) to minimise end-user emissions.
  - 10-fold increase in wind-power (80,000 units of 5 MW turbines in place)
  - No decline in nuclear, but growth of 10% (over the whole period, not per annum)
  - Distributed solar power provides 5% of electricity needs

Note: These figures are based on the assumption that there is a 6% growth in energy demand in the EU – over the 20 year period covered – as a combined result of energy efficiency in highly developed countries and improvements in standards of living in accession and cohesion countries.

Source: Shell (this set of options should not be considered as an actual scenario for the EU, but merely as an illustration of what set of measures taken in combination might result in an emissions reduction of 20% by 2025).

It becomes clear that in order to meet the climate change challenge, there is a need to change the energy use/development relationship in the direction towards a fundamentally lower energy intensity trajectory (i.e. GDP/energy consumption). This will require both behavioural changes and better utilisation of energy through improved technologies. Finally, this implies a global effort while taking into account the special needs of developing countries. At the same time, it will be crucial to keep the costs of climate change policies as low as possible (see Box 3).

Box 3. Reducing the costs of mitigation and adaptation

Historically the fear of (excessive) costs has been a major impediment to full participation in the Kyoto Protocol both by industrialised and developing countries. Hence, the cost issue has been at the centre of the post-2012 debate (see e.g. Aldy et al., 2003). Some considerations in attempting to lower costs include:

- *Emissions trading*. By theoretically ensuring that the market price of carbon is equal to the lowest marginal abatement cost among all controlled sources, emissions trading helps to meet environmental goals at least cost. The gains can be considerable: a majority of studies find that full emissions trading would halve the compliance costs (see e.g. IPCC, 2001). The EU ETS is expected to reduce total compliance costs incurred by the covered sector by one-third. Emissions trading has distributional impacts, however, which in some cases can lead to economic rents that undermine efficiency.
- *Projects mechanisms.* Even if credits from the project mechanisms are not fully fungible (e.g. in EU ETS), they still offer possibilities for low-cost options.
- *Sector coverage.* Costs for the economy as a whole will decrease to the extent that all sources (or sectors) are covered by climate policies and ideally make a comparable effort. This ensures that the highest possible number of low-cost reduction opportunities is achieved. Distributional impacts, however, might lead to the fact that costs and benefits will be unevenly distributed.
- *Multi-gas strategy.* The literature generally agrees that a multi-gas strategy reduces compliance costs significantly (see Hyman et al., 2002; Kets, 2002; Reilly et al., 2004. Capros et al. (2000) find that a '6-gas strategy' approach for the EU ETS could decrease costs by more than a third.
- *Co-benefits*. Some mitigation actions may yield extensive benefits in areas outside climate change, which are called co-benefits or ancillary benefits, such as reduced local pollution caused by NOx or SO_2, less congestion or noise from transport, and savings on fossil fuel subsidies (EEA, 2004b). According to the OECD (2002), ancillary benefits have been estimated at anywhere from 30% to over 100% of abatement costs.
- *The timing of policies*. It is particularly important to create synergies with business investment cycles. This is even more important for the energy infrastructure, which often lasts for several decades and sometimes even more.
- *Participation*. The broad participation of many countries reduces the costs of GHG abatement policies. According to European Commission models, the costs for the EU could triple in the event that no other country participates. But even full participation is no guarantee against distributional impacts.
- *Technology*. The extent to which existing technologies are successfully deployed and disseminated around the globe and the extent to which new 'breakthrough' technologies are developed lowers costs. While emerging and future technologies will need to be competitive with existing technologies, take-up of new value-propositions can lead to market-driven change that leads to cost reduction.

Costs for mitigation and adaptation cannot be seen in isolation from the damage inflicted by GHG emissions. Avoided damages as a result of climate policy constitute negative costs (i.e. benefits).

4. Preconditions for meeting climate objectives

Meeting climate change objectives will require major changes in the way we produce and consume energy such as achieving higher energy efficiency, switching fuels or installing insulation (see section 5). Since climate change objectives will necessitate significant (re)-building of the infrastructure (see section 4.4) and capital stock turnover (see 4.3), strategies must be designed for the long term. Successful climate policy will need to be integrated into many key EU and member state policies. In particular, this calls for coherence and integration of environmental protection including climate policy into all other EU policies, as is mandated by Art. 6 of the EC Treaty. On the other hand, some mitigation options for action are expected to yield benefits in areas other than climate change (i.e. co- or ancillary benefits).

4.1 Research and technology

Technology will play a central role in meeting the climate change challenge. While there are different opinions on whether stabilisation of GHG emissions in line with the UNFCCC's objective can be reached with technically proven technology,[10] it is uncontroversial that there is a need to develop new and technically unproven (i.e. breakthrough) technologies in the long term.

Given that technology takes time to develop, especially as long as the global carbon constraint remains limited, reductions in the short-term are likely to be achieved by increasing the efficiency of existing technology solutions (see 5.1) and by accelerating technology diffusion, i.e. to encourage the use of the most efficient technologies[11] in a cost-effective manner (see 4.2). Outside of climate change policy, there are constant pressures to improve technology as part of the drive to achieve greater competitiveness.

The European Commission's Competitiveness Report (European Commission, 2004) identified a positive correlation between productivity and levels of research and specialisation in high-tech activities. This in return appears to foster an entrepreneurial culture. However, R&D spending in the EU – public and private – at 1.9% of GDP lags behind Japan and the US, with 2.9% and 2.6% respectively.[12] As a result, the EU set itself a target at the Lisbon European Council in 2000 to increase RTD (research and technological development) spending to 3% of GDP by 2010.

R&D and innovation fall within the domain of both private and public spending. R&D in many cases can be left to the market. New technologies are likely to be developed in particular if they promise economic rent. Companies want to distinguish themselves from their competitors through technological innovation. This is mainly the case for the *application* of new technologies, i.e. the area of commercial development or efficiency. Fostering this kind of

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[10] Pacala & Socolow (2004) and IPPC (2001) argue that the climate problem for the next 50 years could be solved with current technologies, whereas Hoffert et al. (2002) hold that new and revolutionary technologies would be needed.

[11] For example, those based on a life-cycle analysis.

[12] There has been a clear trend to reduce public funding. Nine OECD countries currently perform more than 95% of the world's public-sector energy R&D (the US, Japan, Germany, the Netherlands, the UK, France, Italy, Canada and Switzerland). Between 1985 and 1995, these nine countries each reduced their budgets for energy R&D on average by more than 20% in real terms. Data from the International Energy Agency (IEA) show that the trend has not been countered yet; government budgets for energy R&D are still falling, although not as fast as in the 1985-95 period (see the "Beyond 20/20" dataserver of the IEA for a database on RD&D spending in the IEA member countries (http://www.iea.org/rdd/eng/ReportFolders/Rfview/Explorerp.asp).

research is not so much a matter of public funding as of creating appropriate incentives for companies, i.e. making research more profitable by addressing market failures. This includes for example increased financial resources provided by banks, guarantees for the protection of innovation (e.g. patent laws), support for cooperation and research joint ventures, broader diffusion of information on a national and international scale, improvements in basic learning and innovation (e.g. increased interaction between universities and applied research) and technology diffusion via firm-level cooperation agreements (see Galeotti & Carraro, 2003). An important observation is that companies with healthy profits and a solid cash flow tend to invest more in R&D than those facing economic constraints. A major determinant therefore is the economic and business environment in which companies operate.

In areas where the economic rent is *uncertain* due to, for example, the level of economic risk or a very long time horizon or both (e.g. fusion, hydrogen, CO_2 sequestration), R&D cannot be left to the market. Market failure is usually associated with basic research or the pre-commercial *development* of new technologies. In these fields governments support is needed.

In conclusion, governments have to i) provide proper incentives for environmental protection and innovation and ii) supplement private sector research that is done for short- and long-term strategic economic reasons with socially useful R&D, which due to market failures is not undertaken by private investors (Fischer, 2003). Policy measures aimed at advancing technological innovation should take into account the following considerations:

- Investors must be confident that they can reap the fruits of R&D via for example, efficient patent protection systems.
- To aid diffusion, governments can take measures to lower information costs and to remove other barriers to technology diffusion.
- Producers and consumers should pay the full costs, including those from carbon emissions.
- But even with an efficient patent and technology diffusion system, firms do not invest in the 'right' kind of R&D; governments need to finance basic research.
- As governments have proven to be bad at picking winning technologies, governments should provide broad rather than specific R&D subsidies.

The principal message is that incentives for abatement and innovation are inexorably linked. A climate change policy that is independent from technology policy is likely to prove more costly and possibly even ineffective. Similarly, technology policy is not a substitute for climate policy. If there are no incentives to reduce emissions, too little abatement is performed, in turn lessening the incentives for R&D. Equally, if innovation incentives are lacking, climate policies are likely to become more costly, which may lead to lower abatement than needed.

The EU has responded by improving coordination and re-orienting research policy while focusing on climate-related research, such as sustainable energy and transport systems as well as global change and ecosystems, which altogether saw a budget volume of more than €2 billion under the 6^{th} Research Framework Programme of the European Commission.[13] The climate change focus in the 7^{th} Framework Programme is likely to continue and be expanded.

An additional area warranting more research is the set of complicated processes that lead to climate change, and their relationship to other elements of human-induced global change. It is the natural sciences that have an essential role to play, but since efficient action to mitigate climate change will have profound consequences for society, social sciences such as economics, political science and sociology will increasingly be involved. This will require increased EU and member state funding.

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[13] Although not all of this expenditure was relevant for climate change.

4.2 Technology diffusion and transfer

Once the technology is developed, it will need to be diffused on a global scale. Broader diffusion of existing and more efficient new technologies, such as renewables, clean coal, and combined heat and power is a prerequisite for industrialised and developing countries alike to move to a lower-carbon trajectory while allowing for economic growth. Increasing the uptake of new technologies has the additional benefit of reducing costs further. This is encapsulated in the learning curve concept, or sometimes referred to as 'learning by doing' (see especially section 5.3.3).

Within the industrialised world, technology diffusion primarily depends on incentives for investment, which inter alia are a function of the long-term stability and the appropriateness of the incentives provided by the regulatory environment. Technology diffusion mainly takes place through commercial investment decisions of private companies as part of companies' commercial strategies, including foreign direct investment. Governments can influence these decisions mainly by shaping an enabling environment to stimulate low or zero carbon technologies by addressing for example regulatory, legal, technical, personnel and intellectual property issues (see Fischer, 2003). Additional benefits in terms of security of supply or development of sunrise technologies, for example, may justify a pro-active policy.

By and large, the same holds true for technology transfer between industrialised and developing countries. Technology transfer is principally undertaken by private companies on a commercial basis. To address and compensate for developing countries' needs, e.g. as capacity-building and resources, different funding instruments are available. These include in particular special funds,[14] the financial flows of EU and international financial institutions such as the EIB, EBRD or the World Bank. Their objective is to leverage private investment, including FDI, many times the size of the funds or to provide investment incentives to companies. There is a debate over whether the Kyoto Protocol's project mechanisms, i.e. CDM and JI, should focus more on technology transfer. Their original objective had been to assist developing countries to reduce emissions and facilitate sustainable development. The CDM in its current shape is not expected to lead to very significant technology transfer. Within the context of the UNFCCC, the issue of technology transfer seems not have progressed much beyond 'technology needs assessment'.

4.3 Aligning climate policy with capital cycles

The principal source of GHG emissions in the EU is the burning of fossil fuels in the energy and transport sectors. Both sectors however are characterised by very high capital investment. The capital stock, in the form of power plants, grids and transport infrastructure once built, lasts for decades, during which time the investment will need to be paid back. Attempts to reduce emissions "too quickly" require early retirement of capital, which in return increases abatement costs significantly. Delaying reductions, on the other hand, raises costs for future action because the investments that are undertaken now will last for decades and may therefore continue to pollute for a long time (see sections 5.1-5.3).

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[14] For example, the Global Environmental Facility (GEF) by 2002 spent about $1 billion on climate change projects and leveraged about $5 billion on combined loans with other international financial institutions (IEA, 2002). Another fund with a focus on technology transfer is the Special Climate Change Fund decided upon at COP6 bis in Bonn in 2001. In the EU, the Commission proposed to establish an Energy Facility (€250 million) to support in developing countries "increased use of renewable energy; and enhanced energy efficiency, including cleaner and more efficient use of fossil fuel technologies, efficient appliances and more efficient use of traditional biomass". See COM(2004)711 final, 26 October 2004. See also http://www.euei.org/.

Thus, today's capital investment decisions will have implications for decades. According to the IEA (2004a, p. 72), the global energy sector will require new investment in the magnitude of $16 trillion until 2030 under a 'business as usual' scenario. This constitutes a major opportunity for moving to lower-carbon infrastructure. As shown in a PEW Center study on capital cycles (Lempert et al., 2002), investment depends on many different factors, of which external market conditions such as expected environmental regulation or oil prices appear to have the most significant influence on a firm's decision to invest or to decommission large parts of the capital stock. The study finds that the physical lifetime of capital investment tends to be extended through regular maintenance rather than being retired. New investment is mainly driven by attempts to capture new markets. The current need in the EU for additional power generation capacity of 600 GWe until 2020 offers a major opportunity to create low-carbon capital stock.

Another key finding of the study is that "however beneficial new technology may be, it will likely have little influence on the rate at which firms retire older, more polluting plants in the absence of policies promoting technology or requiring statutory emissions reduction" (Lempert et al., 2002, p. iv). The exception is performance improvements of large magnitudes. This should however not obscure the fact that in the rare event a firm makes major new capital investment, carbon prices – even if low – or government incentives make firms focus on cost-effective abatement opportunities.

In sum, there are two principal drivers for changes in the capital stock. Major new investment tends to be undertaken to capture new markets. Hence, in times of high economic growth, the GHG efficiency of the capital stock is expected to go up. In other times, there appears to be less scope for significant improvements, unless there are major technological breakthroughs, which either can lead to a self-sustaining period of technological change or a significant scale of retrofitting of existing capital stock.

4.4 Public infrastructure

A special case is public infrastructure, which is particularly important as it has a long life span and predetermines people's choices of where to live and work, what to consume, what sort of economic activities to carry out, and of other people to communicate with. As infrastructure investment shares the same feature as capital investment, infrastructure development will be a critical factor for both costs and overall effectiveness of climate policies. Moreover, history matters. Past infrastructure investment determines the present, although economists disagree on how widespread the path-dependency is. The role of governments in infrastructures is however more direct than in other capital investment. Infrastructure investments – even if privately financed – are under direct government control. It is up to governments whether to invest into roads, railways, ports, airports or public transport systems. Nevertheless, the fact that infrastructures increasingly are seen as a tool to achieve comparative advantages by countries or regions means that infrastructure investment has to follow basic economic rationale. Irrespective of new infrastructure investment, better management can however produce important short-term results in reducing emissions. A prime example is European air traffic management. A joint study by EUROCONTROL and FAA (2000) found that the planned improvement of the air traffic management system would result in savings of 5% fuel and associated CO_2 (See 5.2).

4.5 Synergies

Climate change policy can have important benefits beyond achieving climate policy objectives. These are so-called 'co-benefits'. Typical co-benefits of climate change measures include the reduction of local pollution caused by NOx or SO_2, less congestion or noise from transport, double-dividend opportunities (e.g. reduced labour taxes and employment creation), innovation and technological leapfrogging and employment (OECD, 2002 and 2003). According to the OECD (2002), ancillary benefits have been estimated at anywhere from 30% to over 100% of abatement costs. In fact, most studies on reducing GHG emissions assume that the external costs of *local* pollution are higher than the external costs of global GHG reductions. Thus, climate policy is likely to have significant, but as yet unforeseen benefits.

Similarly, increasing the penetration of hydrogen in the transport sector could have a positive effect on reducing oil-import dependence, notably on countries from the Middle East where most if not all of the increased supply is expected to come from. Given the limited domestic options to reduce the upward drift in the price inelasticity of domestic oil consumption, more radical measures of opening up new energy vectors, especially hydrogen, to supply the transport sector may be needed (see Fisk, 2004). This converging interest between the climate change and the transport fuel agendas may show the cost/benefit ratio for hydrogen in a most positive light, thus creating additional incentives to provide support for hydrogen.

Nevertheless, there can be real trade-offs between reductions in GHG emissions and other environmental policy objectives. There are some conspicuous examples for such trade-offs, such as between reducing NOx/SO_2 on the one hand and CO_2 on the other in air transport or between SO_2 and CO_2 in petrol production. Another example is the end of life vehicle Directive, which requires a high level of recycling of cars. To achieve this, cars would have to be constructed so that they were more easily disassembled, which subsequently means that they would become heavier, thereby increasing fuel consumption. Similarly, the packaging waste Directive requires high recycling targets by countries for specific materials, leading to increased transportation costs in some countries.[15] There is evidence that strict implementation of the water framework Directive by some member states (e.g. Italy and Austria) has reduced the hydro generation capacity by a significant margin.

4.6 Policy coherence

Climate change policy objectives can only be achieved if principal EU policies – notably energy and transport – are brought into line with the EU's climate objectives. For example, subsidies to fossil fuels prolong their burning and hinder the development and market penetration of lower-carbon or carbon-free fuels. The EEA (2004c) found that fossil fuel subsidies within the EU still amount to about €25 billion p.a. Other principal EU policies worth mentioning are the major expenditure programmes such as the Common Agricultural Policy (CAP) or the Structural Funds, which together account for about three-quarters of EU spending. In addition, the EU's external policies, namely trade, development cooperation and the EU neighbourhood policies, should be consistent with EU climate policy objectives. Art. 6 of the EC Treaty calls for integration of environmental protection including climate change, into other policy areas. In addition, the impact assessment tool that is applied in European Commission policy formulation should lead to greater consistency.

At the international level, coherence can be improved by aligning EU and international financial institutions such as the EBRD, EIB or export credit agencies (ECAs). National ECAs worldwide provide loans, loan guarantees and risk insurance to promote exports of their countries of origin. According to Sussman & Helme (2004), ECA participation in energy-intensive projects amounted to about $20 billion p.a., of which they supported about $8.5 billion p.a. in loans, guarantees and insurance. Hence, Export Credit Agencies not only participate in a large number

[15] For example, the entire country of Sweden has only one glass smeltering plant in the southwest to which all used glass containers have to be transported for smelting. On a bigger scale, only a handful of PET (polyethylene terephthalate) recycling facilities exist in the EU, thereby also leading to increased transport.

of projects, but they also provide significant leveraging of funds. In so doing, they offer a major tool to apply this instrument in a way that changes the technology trajectory.

5. Concrete reduction options

This section focuses on sector-specific EU strategies in the short and medium term (2005-20), i.e. from now until the period when a more consistent global carbon constraint can be expected to emerge. Since short- and medium-term strategies cannot be seen in isolation from longer-term targets, the analysis will be undertaken against the background of longer-term commitments. Finally, although the options we discuss have a strong EU focus, they may have relevance beyond the EU, including possibly even in those developing countries that are rapidly industrialising.

5.1 Energy efficiency

Energy efficiency holds the biggest potential to reduce GHG emissions. In the World Alternative Policy Scenario formulated by the IEA in its 2004 World Energy Outlook, more efficient use of energy in a wide range of applications, including vehicles, electric appliances, lighting and industrial uses, accounts for almost 60% of the reduction in CO_2 emissions. A shift in the fuel mix for power generation in favour of renewables and nuclear energy power accounts for most of the rest. For the potential reductions identified by the IEA, see Table 3.

Table 3. Reduction in energy-related CO_2 emissions in the IEA's alternative scenario compared to the reference scenario by contributing factor in the period 2002-30

	World	OECD	Transition economies	Developing countries
End-use efficiency gains	58%	49%	63%	67%
Fuel switching in end-uses	7%	10%	1%	7%
Changes in the fossil fuel mix in power generation	5%	8%	0%	4%
Increased nuclear in power generation	10%	12%	21%	5%
Increased renewables in power generation	20%	21%	15%	17%

Source: IEA (2004a, p. 379).

Improved energy efficiency would need to replicate and even reinforce the trends towards higher efficiency that has been achieved throughout the 1970s and 1980s. According to the IEA (2004b), the greatest reductions of CO_2 emissions/GDP took place in the 1970s and 1980s, mainly as a result of energy efficiency, which was responsible for about 60% of the total.[16] The high energy prices brought on by the oil crises of the 1970s stimulated energy efficiency and the search for new energy sources. Similarly the declining energy savings rate in the 1990s can be explained by lower relative energy prices from 1986 onwards. For example, the energy share of total production costs for industry has fallen by 50%. Similarly, the share of income spent on energy has fallen by 20-50%. And compared to overall disposable income, fuel costs for cars have fallen by 20-60%.

Recently, however, energy prices have risen again, drawing increased attention to security of supply and notably energy efficiency as a means to ensure the former, whilst at the same time

[16] The remaining 40% was attributable to the introduction and extension of nuclear energy, fuel switching and renewable energy.

reducing CO_2 emissions. For the European Commission, energy efficiency has become a key priority to be addressed in a special green paper that is due for late spring 2005. According to Andris Piebalgs, European Commissioner for energy, Europe should set a target "to save, by 2010, the equivalent of 70 million tonnes of oil per annum", representing "a savings of €15 billion per annum" and "a very significant reduction of CO_2".[17] A Directive on energy efficiency[18] that was proposed in December 2003 and that aims at a 1% improvement in energy efficiency per year is still under discussion in the Council of Ministers. Energy savings have also received increased attention in the energy policies of several EU member states.

5.2 Transport

Transport is a significant contributor to economic growth and enables people to participate in economic and social activity. Transport contributes in several ways to the GDP. This includes the manufacturing of transport vehicles, the production of the fuels, private and public expenditure related to the provision of transport infrastructure and the value of transport services that are sold by providers of such services. Arguably, the role of transport is even more fundamental. The very basic function of transport is to connect people and move goods. Long-term trends, such as the lowering of global trade barriers or EU enlargement, increase volumes of traded goods and therefore transport activity.

On the other hand, transport is also responsible for negative environmental effects. The fast-growing transport sector is responsible for more than 20% of total CO_2 emissions. About half of the emissions growth from 1990 to 2010 is expected to come from this source. Within the transport sector, the growth rates of freight transport and aviation are the highest. Efforts to reduce specific vehicle emissions have largely been offset by higher demand in the past. This does not yet count maritime shipping and international aviation, which still remains outside the UNFCCC framework (and the scope of this report).

Potential of vehicle technologies and transport fuels

Hydrogen and fuel cell vehicles offer great promise for addressing GHG emissions in the long-term. In the short and mid-term, however, there is scope for technological improvement in existing conventional technologies, such as the internal combustion engine, in a cost-effective way. Forecasts give a potential for specific fuel consumption reduction for vehicles with direct drive until 2030 of around 20%, compared to current diesel vehicles. Internal combustion engines typically convert 15% of the energy content of fuels into useful mechanical work. Even small improvements in engine efficiency from 15% to 20% can therefore make a large impact on energy demand (see WBCSD, 2004a). The use of hybrid technology can also contribute to substantial reductions in CO_2 emissions. Combined with advanced aerodynamics, lightweight materials, the reduction of rolling resistance (including low rolling resistance tires) and high efficiency engines, there is further scope for increased efficiency.

It is possible that hydrogen (H_2) will be the preferred energy carrier for the road transport sector in the long-term, capable of meeting necessary volumes and environmental standards. However, fossil fuels will be the main source for hydrogen in the next decades – given the fact that the costs for producing hydrogen via electrolysis of water will not be competitive for example with natural gas reforming. Therefore, until we master carbon capture and storage, hydrogen has little

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[17] "Towards Zero Emission Power Plants", speech by Andris Piebalgs, European Commisisoner for Energy, SPEECH/05/221, Brussels, 13 April 2005.

[18] Proposal for Directive of the European Parliament and the Council on energy end-use efficiency and energy services, COM (2003) 739 final.

value for reducing GHG emissions. And even after technological breakthroughs are achieved, hydrogen faces two basic challenges. The first concerns the development of infrastructure; the second is the vehicle technology. There is still controversy over which of these two challenges is the more difficult to overcome when considering the potential for large-scale use of hydrogen.

Bio-fuels also offer significant potential to reduce CO_2 emissions. Alcohol fuels such as ethanol generated from biomass or other renewable sources can be used in gasoline engines. For diesel engines, bio-diesel containing biomass-derived fatty acid methyl ester (FAME) is an option. Other fuels that cannot be used as blend components, such as compressed natural gas (CNG), liquefied petroleum gas (LPG), di-methyl ether (DME) as well as hydrogen, require a significant level of investment in delivery infrastructure.

An important factor will be the rate of renewal of the vehicle fleet, given that new vehicles must meet much stricter standards. Investment in new vehicles, which replace existing stock – as distinct from a net increase in the fleet – will thus aid environmental and sustainability objectives. However, in the case of private cars (the great majority of new vehicles), it is important that a shift to larger, heavier cars does not offset the improvements in energy efficiency and environmental impact. In many countries within Europe there are also tax differentials by car size that may offset this effect. Increasing the proportion of car taxation that is variable (for example, on fuel rather than annual vehicle duty) would further encourage such perceptions (Pelkmans & White, 2000).

Influence on growth rate

An earlier CEPS Task Force (Pelkmans & White, 2000) identified the scope of reducing the potential growth rate in the passenger sector. Since most growth in the passenger sector is expected to stem from greater travel per person resulting from increases in trip length and in trip purposes, such as leisure, the passenger sector is likely to be more responsive to price changes. Much less scope exists for reducing the rate of growth in freight demand. While the tonnage of goods being produced may grow less rapidly than GDP, increasing specialisation of production leads to a greater volume of tonne-km being generated. Due to savings in production and inventory costs, it is unlikely that this process will be reversed or significantly altered in the short term, even if transport costs were to rise rapidly.

Nevertheless, there is scope for greater efficiency within the road freight sector, which in some cases could result in GHG emissions reductions. The same report has also identified some scope for modal diversion, especially where public transport (or, for very short trips, non-motorised modes) can provide an attractive alternative. Similarly, some short-haul flights could be replaced by high-speed rail transport as there is scope through developing complementarity between transport modes.[19] The growth of 'park & ride' systems provides a means by which car users can switch to public transport for the greater part of their journey into congested city centres. Conversely, modal diversion of freight transport has much less scope, since short-distance movement is already handled by road. However, for longer-distance trips, some diversion to rail or shipping is feasible. Railways are disadvantaged in gaining a larger market share, however, due to their limited marketing and organisational presence outside their national borders. There is also a role to be played by land-use planning to reduce the need for longer motorised journeys, for example in the location of shops.

[19] See the European Commission's Rail Air Intermodality Facilitation Forum (RAIFF), an initiative to stimulate a debate on the ways to develop combined use of rail, in particular high-speed rail services, and air.

5.3 Power sector

Generation of electricity from fossil fuels, notably natural gas and coal, is the other major growing contributor to CO_2 emissions. Within the time frame covered in this report and even up to a 2050 perspective, there are *four* possible options for reducing CO_2 emissions from the power sector:

- Increased efficiency in transmission/distribution, generation and fuel switching, mainly to gas or CHP;
- Expansion of renewable energy sources such as wind, solar, biomass and geothermal;
- Capture of CO_2 emissions at fossil-fuelled (especially coal) electricity generation plants and permanently sequestering the carbon; and
- Nuclear power.

Demand-side measures, which provide additional important instruments, are discussed elsewhere in this report.

5.3.1 Increased thermal and carbon efficiency in the power sector

Energy efficiency in the power sector, i.e. generation and transmission/distribution, depends on a combination of improved performance (due to technological progress) and market penetration of such new technologies. The latter depends significantly on when new technologies become economical.

In terms of generation technologies for gas, it is principally gas turbine combined cycle (CCGT) and gas turbine combined cycle for combined heat and power (CHP) that hold the greatest promise. And for coal, high hopes are pinned to supercritical coal power, integrated coal gasification combined cycle power (IGCC) and direct coal-fired combined cycle plants (European Commission, 2003). There are major technological improvements in transmission and distribution as well.

Natural gas

CCGTs are already the most successful power generation technologies, with an expected share of 22% in 2030. Further improvements in thermal efficiency from a current 53% to 59% or even 63% are feasible. Gas turbine cycle for combined heat and power also has potential to achieve further improvements of both electric and steam conversion of up to 2%.

Coal

All of the above-mentioned advanced coal generation technologies (i.e. supercritical coal power, IGCC and direct coal-fired combined cycle plants) can achieve conversion efficiencies of 50% or more as opposed to current efficiencies, which are around 40%.

Whether these technologies will be able to penetrate the market will depend inter alia on fuel costs, including the climate constraint, but also on the development of capital costs. Within the EU, between now and 2020, around 600GWe[20] (i.e. the current installed capacity) will have to be built. The EU faces a major crossroad as to the long-term carbon intensity of the power generation sector: with the average lifetime of a gas turbine being 25 years or more and a nuclear station between 30-60 years, what is built in the next decade or so will remain in operation until around 2050.

[20] This equals 23 CCGTs per annum from now to 2020.

5.3.2 Renewables

According to the IEA (2004a) Reference Scenario, renewables used for power generation[21] are estimated to reach around 18.3% of the EU's electricity mix by 2010, below the stated target of 22% in the renewables Directive (2001/77/EC). A precondition is the continuation of strong support measures such as direct payments, fiscal and investment assistance or priority access to the network. Additional sources of growth are expected to lie in technological progress and greater willingness on the part of the public to purchase 'green' electricity.

Wind power is the main explanation for the increased share of renewable electricity in Europe. It is expected to cover 10% of the continent's electricity needs by 2030 (compared to 1% in 2004). Under the World Alternative Policy Scenario of the IEA (2004a),[22] renewables as a share of total energy demand will reach 16% by 2030. The IEA expects that by 2030 over 40% of wind power will be generated in offshore wind farms at a price range of €35-€42 per MWh, excluding costs for reserve capacity maintenance, balancing and grids.[23] Biomass offers another promising source, which is considered to be economical in industrial applications in the price range of €30 per tonne of CO_2 (Egenhofer et al., 2005).

The uptake of emerging and future technologies (e.g. new renewables) depends on their competitiveness with existing technologies. Policy can play an important role, however, in bringing down costs, through R&D subsidies on the one hand and by support mechanisms, which ensure a certain level of market penetration, on the other. Increased market penetration has historically contributed to reducing costs (i.e. the learning curve concept). According to the IEA, renewables are no different from other technologies. A doubling of the capacity reduces costs by half. A critical requirement in this context is the structuring of incentives in such a way that they exert a downward cost pressure on renewables technologies, thereby avoiding long-term economic rents based on ill-designed regulation.

5.3.3 Carbon capture and storage

One might expect that coal burning will continue to generate high levels of emissions, because major industrialised and developing countries are expected to continue to rely for reasons of security of supply on fossil fuels (mainly coal) to generate power. However, fossil fuels can be used with minimal atmospheric emissions of carbon dioxide only if the CO_2 is captured and stored in geological structures (IEA, 2004c). This fact has sparked interest in the different existing techniques, post-, pre- and oxy-fuel combustion.[24] Carbon capture and storage is seen by many as a key technology to combat climate change. This has also been fully acknowledged by the European Commission, which has identified carbon capture as one of its priority areas in its research programmes. It is generally acknowledged that further research and development is needed to allow large-scale application (see IEA, 2003a).

Although estimates vary considerably, the technical potential appears to be very high – ranging from a minimum of 100 billion to more than 10,000 billion tonnes of CO_2 (De Coninck, 2005).

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[21] Increases in renewables will almost exclusively have to come from new or non-hydro renewables, as hydro capacity cannot be further expanded.

[22] The Alternative Scenario is based on a more efficient and environmentally-friendly estimation of the energy future vis-à-vis the Reference Scenario. It demonstrates that policies on energy security and the environment already considered by countries, together with increased R&D, will lead to reduced energy demand and CO_2 emissions.

[23] According to the Dena study (2005), the aggregate costs for grid integration of wind energy are estimated at €4-€12 per MWh.

[24] For details, see IEA (2003b).

The IEA (2003a) estimated that the technical potential to store energy-related CO_2 emissions would be in the range of several decades of current global CO_2 emissions at a minimum. Higher estimates assume the capacity for capture and storage to be in excess of three centuries' worth of average current emissions (IEA, 2003a; p. 5).

To date, a number of demonstration projects exist, notably the Sleipner, Weyburn, In-Salah or K-12B projects, but there is no large-scale application. Main issues remaining for further analysis include, for example, a more accurate assessment of actual storage capacities, safety and leakage (i.e. permanence) and also economic viability (IEA, 2004c).

There are still large discrepancies in cost estimates ranging from below €50 to above €100/tonne. Existing technical solutions do not encourage widespread market uptake (IEA, 2003b, p. 12). The technique of carbon capture and storage has another disadvantage compared to abatement: it needs energy. For example, a coal-fired power plant would take an efficiency loss when fitted with a system to capture the CO_2 from flue gases. This so-called 'energy penalty' has been estimated in the range of 14-20% using existing technology and still 7-17% in 2012, assuming improved technologies. Numbers depend largely on the reference technology for electricity production (see e.g. Ha-Duong & Keith, 2003). Nevertheless, a number of recent studies suggest carbon capture and storage could become an economically viable option, although only for new power plants as required retrofitting would raise costs.

5.3.4 Nuclear

Nuclear power in principle is a potential source of GHG emissions reductions over the next 50 years. At present, however, nuclear power faces stagnation and according to most forecasts, decline. With a market share of 32% for EU-25, nuclear power displaces between 700 (Foratom, 2004) – in case nuclear's share is replaced by the current energy mix[25] – and 300 million tonnes of CO_2 (European Commission, 2005b), if nuclear were to be replaced by gas. This would translate into 16.5% or 7% of (expected) 2010 EU CO_2 emissions. However, nuclear's market share is expected to decline to around 25% in 2030 (European Commission, 2003). The situation on a global scale is similar. The main reasons for stagnation and decline are costs, safety, waste and proliferation (MIT, 2003).

- *Costs*. Within the EU internal energy market, nuclear power is likely not to be cost-competitive with coal and natural gas. Experience has shown that the power generation sector favours the solution with the lowest capital investment and the shortest returns. However, reductions by industry in capital costs, improvements in operation and maintenance, quicker planning and permit-granting processes to speed up construction, as well as the EU emissions trading scheme, could reduce the gap (as recent studies suggest[26] that costs of nuclear generation in US and EU are getting closer). Prevailing negative public opinion increases the economic (as well as political and market) risks[27] and is likely to increase the cost gap.
- *Safety*. This requires paying continuous attention to the safety of the overall nuclear plants, including their vulnerability to terrorist attacks.

[25] 2004 EU-25 energy mix in power generation is: nuclear (32%), coal (30%), gas (18%), hydro (11%), oil (6%) and renewables (3%).

[26] IEA (2005), University of Chicago (2004); see also http://www.uic.com.au/nip08.htm.

[27] The economic risk arises from delays and measures to accommodate opposition that change the economics of the project. The political risk is that the government may retreat from its original decision, which is particularly high after a change in government. The market risk could involve the damage of a well-established brand name in the face of sustained public opposition.

- *Waste*. Geological disposal is technically feasible but is not yet applied on a large scale.
- *Proliferation*. The reprocessing system in Europe, Japan and Russia, which involves separation and recycling of plutonium, presents major proliferation risks, which cannot be controlled.

The MIT study concludes that in order to reverse the decline in the use of nuclear power, changes in government policies are needed. These policies include reducing costs through modifications in the permit and planning process, support for new safety-enhancing reactor design, federal or state portfolio standards, long-term waste R&D programmes and a shift to the open, once-through fuel cycle (MIT, 2003). To become a serious option to reduce GHG emissions, EU governments would most likely need to undertake a deliberate 'pro-nuclear' policy, which they do not seem ready to do. As to technology, the WETO (European Commission, 2003) study has developed a scenario where the standard large Light Water Reactor as of 2010 is gradually replaced by a new evolutionary nuclear design, which could reduce construction costs by 30% by 2030. According to this scenario, the nuclear power share worldwide would increase from 9% to over 15.5% (and from 16% to 37% in the OECD).

It is questionable whether sufficient fuel, i.e. uranium 235, would be available. At a capacity of 10 TW globally (today's installed capacity is roughly 0.26 TW), which would equal an enhanced nuclear scenario, uranium based on current estimates might last not much longer than between 6 to 30 years (Hoffert et al., 2002, p. 985).

5.4 Buildings and houses

Buildings and houses offer tremendous potential for reducing GHG emissions, for they are responsible for about 40% of all CO_2 emissions in the EU if electricity and heat-related emissions related to end-use sectors are included (Barbier et al., 2004). The principal savings potential lies with space heating (through thermal insulation and higher-efficiency heating system) and appliances. Nevertheless, the 40% figure needs to be qualified with the statement that the two principal areas – space heating and appliances/lighting, which are responsible for 95% of demand[28] – will need to be addressed with different policy instruments. During 1990-2000, energy efficiency in the residential sector increased by around 5%, but this improvement was more than offset by two conflicting trends: increases in the dwelling size per capita and increases in electricity consumption. As a result, over the same period total energy demand in the residential sector grew by 7% in EU-15 (Barbier et al., 2004). According to the statistics, however, CO_2 emissions decreased as a result of fuel switching to natural gas for space heating, thermal insulation, but also because emissions from increased electricity use are normally recorded in the power sector.

Thermal insulation

According to EURIMA, the European Insulation Manufacturers' Association, old houses pre-dating the first oil shock, which make up around 60% of the total housing stock, have energy savings reduction potentials of more than 30%. Newer houses built from 1974-94 (accounting for about 20%) and more recently (accounting for the remaining 20%) still offer a potential of over 15%, although the pay-back period increases from 3 years for old houses to 5 and more for newer houses. The principal savings potential lies in insulation of existing building stocks. Newly-built houses generally already comply with higher performance standards and therefore offer only incremental – and possibly higher cost – savings potential.

[28] This figure corresponds to the residential sector alone and represents the EU average. There are variations across member states, mainly due to climate.

The Directive (2002/91/3C) on energy performance of buildings (EPB) tries to address this potential, mandating in essence energy-efficiency improvements of newly built and retrofitting of existing buildings larger than 1,000 m^2 if they undergo significant renovation. Extending the EPB Directive to all houses could save up to 70 Mt CO_2 p.a. of an overall technical potential of almost 400 Mt CO_2 p.a. (Ecofys, 2004),[29] which would equal 2.4% of 1990 EU-15 emissions. The potential in the new member states is even higher.

Table 4. Actual and technical potential of the EPB Directive (in Mt CO_2)

	Actual potential in 2010	Technical potential**
Current EPB Directive (> 1,000 m^2)	34	82
Extended to 200 m^2	42	151
Extended to all houses*	70	398

* The reason for the big increase in both columns from 200m^2 to all houses is that it is single-family dwellings (smaller than 200 m^2) that dominate the existing building stock and that have a particularly high specific heating energy demand, partly due to the fact that their external surface per capita is bigger than for multi-family dwellings.

** See footnote 29 below.

Source: Ecofys (2004).

5.5 Developing the EU ETS further

The EU emissions trading scheme (ETS) is critical for the post-2012 strategy in several respects. It is the most important single instrument, targeting almost half of total 2010 EU CO_2 emissions by covering two critical sectors, i.e. power/heat and industry. Furthermore, the EU ETS has proven to be industry's instrument of choice, as several previous CEPS Task Force reports have documented. As the EU continues to advocate absolute emissions limits (i.e. Kyoto Protocol-type caps), emissions trading almost becomes a prerequisite to achieve these caps at the least cost. Both from a practical and strategic perspective, therefore, the EU ETS is the centrepiece of EU climate policy, including the post-2012 architecture. Nevertheless, there are a number of potentially controversial issues, the distributional impact being among the most important.

The potential of the EU ETS to achieve significant reductions remains uncertain. Most likely, it will depend on the existence of a global agreement and consequently, the nature and scale of commitments. It is unrealistic to assume that EU governments would impose a significant carbon constraint on 'their' companies unless major competitors would do the same. As of April 2005, the initial contribution of the EU ETS remains limited. Eurelectric, the European electricity industry association, estimates that the EU ETS contribution under the first round of allocation would contribute to savings of around 100Mt CO_2 annually.

The Directive foresees a comprehensive review in 2006 to adapt the EU ETS in the light of initial experiences. Inter alia, the review will recommend its possible extension to: i) more gases (i.e. non-CO_2 greenhouse gases), ii) more sectors (e.g. more industrial sectors, transport) and iii) more countries (e.g. via linking), in addition to addressing a number of implementation issues such as allocation. Finally, the 2006 review will examine the relationship of the EU ETS to international emissions trading (IET) under the Kyoto Protocol.[30]

[29] The technical potential is far higher but it cannot be achieved taking into account the time lag for retrofitting the existing building stock but also the effects of demolition and new construction.

[30] The EU ETS is the subject of a separate CEPS Task Force. Some of the related issues have been analysed in an Issues Paper (see http://www.ceps.be/Article.php?article_id=409).

5.6 Product substitution

Another means of reducing environmental and climate impact is to substitute products with others with a lower impact. Construction and telecommunications, which are discussed below, offer some possibilities. Naturally-grown materials to serve as product sinks provide other examples as does higher material efficiency including recycling.

A study conducted in the US (Lippke et al., 2004)[31] undertook a life-cycle assessment of different construction products and techniques, considering such issues as how materials were grown or mined, processed, produced, used and ultimately disposed of. The authors found that wood as a construction material can have major climate change and other environmental advantages. Other studies (Glass, 2001) have shown that concrete buildings, if appropriately designed, may equally hold a climate change advantage as their propensity to store and release energy reduces energy consumption for cooling and heating during the entire service life of the building. Similar potentials are offered by lightweight steel structures in car manufacturing. However, all studies on life-cycle analysis still need to undergo rigorous peer review.

There is scope for greater use of telecommunications, which could offset some of the need to travel, i.e. a substitution effect has yet to materialise between physical mobility and service provision at a distance in the form of extensive use of teleworking, telebanking, teleshopping, teleconferences or distance education. Since transport services are generally demand-driven, policies affecting land-use, vehicle ownership, taxation and industrial structure should be coherent and addressed increasingly, although not exclusively, through the prism of climate change policy.

Since changes rely on infrastructure (e.g. building codes, skills in the construction business, supply of raw materials, availability of telecoms infrastructure), the potential for substitution should be seen in a longer-term perspective and is likely not to play a significant role in a 2030 perspective.

6. Implications for international climate change negotiations

The entry into force of the Kyoto Protocol is seen as an important first step towards reaching a global climate change agreement. However, it does not yet amount to a credible long-term comprehensive approach towards meeting the UNFCCC goal of stabilisation. Issues have been raised regarding environmental effectiveness, economic efficiency and equity (i.e. distributional impacts). That the Kyoto Protocol has been rejected by some major industrialised countries and that it exempts fast-growing developing countries from any hard carbon constraints make a straightforward extension of the treaty (i.e. Kyoto II) environmentally ineffective. In addition, capping only one-third of global emissions – as the Kyoto Protocol did in practice– is likely to increase total compliance costs as a result of foregone low-cost options in the other two-thirds.

Since the EU is expected to account for no more than 8% of total 2050 GHG emissions (currently, around 12%), reductions in the EU as well as all other industrialised countries would not suffice to combat climate change. On the other hand, given that per capita emissions in the EU are about three times[32] the emissions of developing countries such as China or India (Baumert & Pershing, 2004), it is the responsibility of the EU and other industrialised countries to start making reductions. This has been acknowledged both under the UNFCCC and the Kyoto

[31] The Consortium for Research on Renewable Industrial Materials (CORRIM), Seattle, Washington, (www.corrim.org).

[32] EU per capita emissions are about 2.5 times the emissions of China and 5.6 times the emissions of India (Baumert & Pershing, 2004).

Protocol with reference to the concept of 'common but differentiated' responsibilities. Nevertheless, the fact that major competitors of the Kyoto Protocol countries have either rejected the Treaty or are not subject to legally-binding targets[33] has raised concerns that the burdens are unequally distributed. Given the complexity of a global climate change agreement, climate negotiators agreed already in 1997 in Kyoto to develop a follow-up treaty when the Kyoto Protocol expires in 2012.

Box 4. Principal requirements of a global climate change agreement: A stylised overview

Based on the state of the negotiations and legal frameworks, we can identify a number of preconditions for a global treaty to work in terms of environmental effectiveness, economic efficiency and distributional impact.

Effectiveness

- An effective global agreement will need to include all sources of emissions, including CO_2 from fossil-fuel burning (59%), non-CO_2 gases (23%) and CO_2 from land-use change and forestry (18%).
- The principle of common and differentiated responsibilities, as included in the UNFCCC, requires as a precondition the participation of and ambitious action by all industrialised countries.
- By 2030 at the latest, emissions from developing countries are projected to overtake those from industrialised countries, which implies that participation and reductions as compared to 'business as usual' scenarios will also be required from at least the economically fast-growing developing countries.
- There is an urgency in undertaking reductions now, as greenhouse gases stay in the atmosphere over a long period of time.
- Although it is controversial whether or not the projected targets until 2050 can be met with existing technologies, there is no doubt that in order to meet the long-term stabilisation target, new breakthrough technologies will be needed. Hence, research and development as well as technology diffusion will become central to meeting climate change objectives.
- Despite a high level of uncertainty on what stabilisation means in terms of emissions reductions and a cap on the rise in temperature, there is increasing evidence that adaptation to climate change both in developing and industrialised countries, including Europe, will be needed.

Efficiency

- Climate change policy at the international level is likely to fail if it is perceived as undermining economic development. This is true for industrialised and developing countries alike. Hence there is a need for cost-effective (i.e. least-cost) solutions, which points to both the use of market-based instruments and the search for synergies between climate and other public policy objectives, such as reducing other environmental pollution, security of energy supplies, innovation and job creation.
- In the event that emissions trading is adopted, overall compliance costs theoretically decrease to the extent that the size of the market (i.e. countries, sectors, gases) increases, provided that the emissions market is efficient.

Distributional effect (equity)

- The key criterion for an agreement to be achieved is its distributional effect. Unless there is a sense of equitable sharing of costs and benefits, it will remain politically difficult to agree on a comprehensive global agreement.

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[33] The Berlin mandate explicitly decided to exempt developing countries from quantified emissions reductions.

6.1 The post-2012 architecture and the Kyoto Protocol

Although there are different views throughout the world as to whether a post-2012 framework should be built upon the Kyoto Protocol, it is fair to say that the Kyoto Protocol has established or reinforced numerous areas where international consensus has emerged or at least might be achievable. These include: i) differentiation, ii) a comprehensive approach to all emission sources, iii) gradualism, iv) flexibility and v) flexible mechanisms.

While differentiation ('common but differentiated responsibilities') has been part of the international climate change *acquis* since the entry into force of the UNFCCC, the Kyoto Protocol has reinforced it and attempted to make it operational. At the same time, the Kyoto Protocol addresses the problem of climate change in a comprehensive way by including six gases and 'carbon sinks' such as forests and farm land, which are capable of absorbing GHGs. The Kyoto Protocol has acknowledged the need for a gradual approach, i.e. modest initial commitments, although the definition is open to interpretation. Gradualism is coupled with flexibility to accommodate the complexity of climate change policy arising from a combination of the global nature of the problem and hence the solution, the long-term character of greenhouse gas abatement and the strong policy interactions. Flexibility can take the form of multiple-year commitment periods, banking or sinks. Finally, the Kyoto Protocol has firmly established the importance of the use of flexible mechanisms, such as emissions trading and the project mechanisms. It seems that these five elements of the Kyoto Protocol will also need to figure in any post-2012 architecture.

The EU has shown a strong commitment both to start reducing GHG emissions and to play a major role in multilateral negotiations. Its self-declared policy of leadership has been documented extensively in the literature (e.g. Gupta & Grubb, 2001; Kanie, 2003) and has been much in evidence in practice. It was the EU that initially led the international effort to ensure entry into force of the Kyoto Protocol. At the Göteborg European Council in June 2001, the then-15 EU member states made a collective political statement to implement the Kyoto Protocol, unilaterally if necessary. And indeed, a systematic review of other multilateral environmental agreements reveals that leadership (usually by the US) has been one of the most decisive elements in achieving an agreement (see Miles et al., 2002). To some extent, EU leadership has been successful in convincing other Parties to join the Kyoto Protocol. In the end, most industrialised countries, with the notable exception of the US and Australia – although the latter has indicated that it will meet its Kyoto Protocol obligations – have ratified the Kyoto Protocol. This should however not obscure the fact that many Parties, including the EU itself, have difficulties in meeting the Kyoto Protocol commitments. This, together with the fact that emissions reductions of all industrialised countries, economies in transition and at least the fast-growing developing countries will be needed for environmental, economic and equity reasons alike, indicates that modifications to the current Kyoto Protocol framework will be needed.

6.2 Edging towards a post-2012 architecture

The major challenge in devising the global architecture is to identify the nature and level of commitment that will be necessary to provide sufficient incentives for Parties to participate in a global agreement.

Efforts were made in both the UNFCCC and the Kyoto Protocol to address the participation issue in several different ways. Most importantly, differentiation between emitters according to historical emissions, state of development and capacity has been enshrined into the present architecture and will continue to remain a central pillar. Other elements include financial transfers via emissions trading, including the project mechanisms and specific funds such as the adaptation fund.

There have been numerous alternative proposals to *enhance participation*, incorporating many of the ideas from the existing theoretical and empirical literature. Consideration has been given, for example, to allowing different time frames for entering into commitments (i.e. a graduation concept), to a country's or region's response to impacts (i.e. adaptation), to implementation (i.e. how to ensure compliance) and to the framework for negotiation (i.e. institutions). Perhaps the biggest and most prominent part of the literature in industrialised countries has focused on the *nature of the commitments* (i.e. type of targets) such as absolute caps, efficiency targets, technology development or objectives, coordinated carbon taxes, coordinated sector-specific domestic policies or a mixture thereof. For an overview of the numerous proposals put forward, see Box 5.

Box 5. Different approaches for post-2012

- An international agreement with **absolute – Kyoto-style – targets**, but with modifications such as a safety valve, i.e. a maximum price on allowances (Jacoby & Ellerman, 2002; Kopp et al., 1999; Hourcade & Ghersi, 2001; McKibbin & Wilcoxen, 2002).
- **Energy** or carbon**-intensity targets** to improve energy efficiency. Ultimate targets can be an equal per capita emissions target (Meyer, 2003; Müller et al., 2001).
- **Linkages**, i.e. linking participation to R&D cooperation or financial transfers (Buchner et al., 2003; Buchner & Carraro, 2003; Carraro & Galeotti, 2003).
- **Environmental conditionality** that links emissions trading to environmental 'progress', e.g. the Green Investment Scheme, trade and back approaches (Tangen et al., 2001; Blyth, 2003; Viguier, 2003).
- **Sector-specific targets,** i.e. a coordinated approach for domestic policies (e.g. IEA, 2002, p. 82).
- Coordinated **global carbon taxes** (Cooper, 2001).
- Technology development and international cooperation on R&D activities, often referred to as '**technology protocol'** (Humphreys, 2001; Barrett, 2003; Edmonds, 2003).
- A **combination** of different instruments, such as a combination of the intensity targets, sector-specific domestic measures and technology development in the so-called 'triptych approach' (Phylipsen et al., 1998; Den Elzen, 2002).
- **Orchestra of treaties** focusing on different co-existing commitments under different legal frameworks (Sugiyama et al., 2003).

For a comprehensive survey of post-2012 approaches, see also Bodansky (2004).

Source: Egenhofer et al. (2004).

When assessing different sets of commitments against criteria – such as environmental outcome, economic efficiency, cost-effectiveness, distributional impacts, flexibility and simplicity – and incentives to participate and comply, there is no single framework including the Kyoto Protocol that would meet all the evaluation criteria (see for example Aldy et al., 2003b; Bodansky, 2004; Torvanger et al., 2004; Kameyama, 2004).

6.3 Six elements of a post-2012 architecture

A comprehensive agreement on the post-2012 regime will need to ensure a fair amount of continuity with the Kyoto Protocol structure, while at the same time accommodating a number of additional components aimed at attracting near-universal participation in a global agreement.

6.3.1 Nature of commitments

The Kyoto Protocol has set absolute targets for industrialised countries. Despite their merits of relative simplicity as a negotiation tool and of sensitivity to environmental integrity, such an approach is inherently inflexible. In particular, it could not accommodate differences in economic or population growth. Targets that are negotiated and agreed at international levels but do not lead to a perception of an equitable outcome risk not being respected. The more stringent the targets, the higher such a risk will be. To accommodate the risk of non-compliance arising from an inequitable outcome of the negotiations, the Kyoto Protocol foresaw relative short-term targets, subject to periodic revision. Short-term targets, however, can cause behavioural changes, but they are unable to trigger the required structural changes on account of their on-going renegotiation. The time frame of policy cycles concerning climate change may not coincide with that of business in which an investment decision is made on a mid- to long-term basis (see Aldy et al., 2003b; Reinstein, 2004; Lempert et al., 2002 and IEA, 2002, for an overview).

Success in phasing out ozone-depleting substances in a multilateral framework, i.e. the Montreal Protocol, is generally credited to the absolute cap approach. However, the Montreal Protocol had special features such as readily-available technologies, and perhaps most importantly, it was recognised that the *only* solution to avoid ozone depletion was to phase out the responsible substances. It is also often forgotten that the Montreal Protocol foresaw reviewable exemptions for 'essential uses' (Victor, 2005). To induce compliance with the Kyoto Protocol, several approaches were proposed and some were introduced to reduce the rigidity of absolute targets, including the flexible mechanisms, banking provisions, periodic revision of relative short-term targets, transfers and possibly most important price caps on allowance prices, the so-called 'safety valves' (Kopp et al., 1999; McKibbin & Wilcoxin, 2002; Hourcade & Ghersi 2002; Jacoby & Ellerman, 2002). It is interesting to note in this context that if the value of an internationally agreed safety valve is low enough, it will in effect function as a globally harmonised carbon tax, doing away with multilaterally negotiated quantitative emissions targets (Jacoby & Ellerman, 2002).

The developing countries will continue to refuse to accept absolute quantitative targets. At the same time it is clear that somewhere along the line, the largest emitters among the developing countries will have to accept to limit their emissions in an internationally agreed way. Different approaches of the kind envisaged in section 6.2 above will probably be tested in the negotiations. Other central questions will relate to the timing of commitments, possible graduation and issues related to the base year. It will be necessary for all Parties to show flexibility and imagination in creating the basis for a long-term stable climate regime.

6.3.2 Flexible mechanisms

An absolute target approach must be seen in conjunction with emissions trading, both in the EU and internationally. As the EU continues to advocate absolute emissions limits (i.e. Kyoto Protocol-type caps), emissions trading almost becomes a prerequisite to achieve these caps in a least-cost fashion. Should absolute caps prevail, emissions trading is almost certainly to occupy a centrepiece of the post-2012 regime.

There seems to be broad agreement at least in principle on the importance of flexible mechanisms. Especially since the CDM faces design and implementation problems, there is a need for reform to make the CDM a major tool for both developing and industrialised countries to combat climate change. It is critical for the EU to make the EU ETS work in order to prove the suitability of emissions trading in practice as a tool towards this end.

6.3.3 Adaptation

For many developing countries, a satisfactory inclusion of an agreement on adaptation measures will most likely be a precondition for participation. As the European Commission Communication (European Commission, 2005a) points out, even meeting the EU's 2°C target will most likely lead to a negative climate change impact. Thus, to increase resilience, adaptation measures are almost certainly to be needed. This has prompted the European Commission to identify adaptation as one of the four principal climate change challenges. Although this report has primarily dealt with mitigation and technology, it is important to reiterate that adaptation both in the EU and other industrialised and developing countries is likely to become a crucial pillar upon which an eventual global agreement will rest.

6.3.4 Technology approaches

In the long run, technology will play a decisive role, as ultimately stabilisation of GHG emissions at politically acceptable levels can only be met with new breakthrough technologies. A number of technology approaches have stressed the crucial role of technology in stabilising concentrations of GHG emissions at low costs, the need for a portfolio of R&D investments across a broad spectrum of technology classes, and integration of energy technology development as part of a larger comprehensive strategy (e.g. Humphreys, 2001, Edmonds, 2003; Barrett, 2003). The focus is on fostering international cooperation of both public and private sectors. The major shortcoming of such a 'technology-only' approach is that it provides little incentive to apply advanced technologies, which by definition would have high costs but no real economic benefit for a company, unless research support is seen as a mere subsidy or state aid. The approach does not necessarily guarantee real emissions reductions – at least in the short to mid term – and risks missing the potential of current technologies. Hence, the long-term technology focus needs to be complemented with incentives to apply technologies, for example with further protocols for the short-term options such as 'targets and timetables' or other commitments or domestic measures.

6.3.5 Domestic measures

One of the issues of Kyoto Protocol-type 'top-down' approaches ('what needs to be done') has been that negotiations tended to be disconnected from the reduction potentials that Parties actually possess in reducing emissions. Therefore, focusing on the potential of short- and medium-term policies across sectors to translate potential absolute emissions targets into specific commitments (i.e. 'what can be done'), can help Parties to base negotiating positions on a firmer footing, thereby reducing the risk of non-compliance. Credible domestic long-term comprehensive climate policies can be expected to induce countries to accept long-term commitments. They will most likely provide authoritative analysis on underlying costs of policies, benefits in terms of avoided damage, co-benefits such as other environmental benefits, technological innovation and improved economic efficiency (see for example Browne, 2004). Credible national and EU policies addressing climate change are crucial both for international credibility and for understanding of what is economically and politically feasible.

6.3.6 Institutional framework

Legally speaking, the negotiating framework is the (global) UN system, but in reality the delicate balance between conflicting interests has dictated the discussions. This is even more the case after the United States defected. In fact, the negotiations to date have been characterised by attempts to find a balance between the EU, the US, Japan, Russia, other Parties and developing countries (see Den Elzen & de Moor, 2001; Egenhofer & Cornillie, 2001; Grubb & Yamin, 2001; Ott, 2001). This raises the question of which framework would be the most appropriate for climate negotiations (cf. Victor, 2001; Bodansky, 2002). Does the focus on the UN system still reflect the reality or have we *de facto* moved to a system where groupings of key countries form an informal ‘directorate’ including the EU, the US, Japan, Russia plus key developing countries such as China, India, Brazil, and others? An approach based on a ‘directorate’, ‘like-minded countries’ or ‘major emitters’ may possibly be more effective as asserted, for example, by Bodansky (2002). Reducing the number of actors to a few increases the likelihood of finding an agreement.

Irrespective of whether such a major-emitters’ approach could constitute a feasible way forward, there is a distinction to be made between the UNFCCC’s role as a negotiation platform and as a ‘coordination’ body for implementation. While informal negotiations can and in reality will take place in many different fora including the UN but also the G8, or in bilateral ones (e.g. EU-US, EU-China), there is no alternative to the UNFCCC for managing the formal negotiations and overseeing coordination of the management of the flexible mechanisms, the registry system, national communications, compliance rules, etc. It may be possible, however, to delegate certain coordination tasks to executive agencies.

7. Concluding remarks

It has been acknowledged that climate change is one of the world’s greatest challenges with potentially far-reaching negative effects, but yet at the same time it is very hard to reach a global agreement. The climate change challenge is associated with a number of well-known features (see Carraro & Galeotti, 2003). The problem is global. Climate change is a global public good, inclining states to free-ride. In addition, the problem is long term. Uncertainty is pervasive. There are no magic technological solutions available. Policy interactions are strong as climate change policy affects many of the key national, EU and international policies, including notably development. At the same time, the consequences of climate change will most likely be irreversible. There is no international institutional framework that is able to deal with the many complexities associated with climate change. While it is true that other environmental issues possess some of the same features, the climate change challenge has higher intensity and stronger interaction.

The UNFCCC and the Kyoto Protocol were first steps to address the climate change challenge. Further steps will be needed at national, regional and global level. This CEPS Task Force hopes that it has made a useful contribution to the international climate change debate.

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Annex 1

Glossary of Terms and Abbreviations

AAU	Assigned Amount Unit, a part of the overall absolute target of GHG emissions assigned to Annex B Parties to the Kyoto Protocol
Absolute target	A cap on emissions expressed in absolute terms (e.g. X tonnes of CO2); see also sector-specific targets and intensity targets)
Annex 1	Annex 1 of the UNFCCC refers to industrialised countries (including many economies in transition)
A1B	IPCC scenario
B2	IPCC scenario
CAP	Common Agricultural Policy (of the EC)
CCAP	Center for Clean Air Policy (see: http://www.ccap.org)
CCS	Carbon Capture and Storage. Technologies to capture and store CO_2 in geological structures
CCGT	Combined Cycle Gas Turbine
CDM	Clean Development Mechanism: Art. 12 of the Kyoto Protocol establishes that Annex I Parties (and firms in these countries) can transfer certified emissions reductions (CERs) from projects in developing countries
CHP	Combined Heat and Power (co-generation), which has a conversion efficiency of 70% or more
COP	Conference of the Parties, consisting comprising representatives of governments that are Party to the UNFCCC. The COP is the supreme decision-making body in the UNFCCC negotiations
CO_2	Carbon dioxide, the main greenhouse gas (GHG) covered in the Kyoto Protocol
CH_4	Methane, one of the six GHGs covered in the Kyoto Protocol
CNG	Compressed Natural Gas, a transport fuel with relatively low carbon intensity
DME	Di-Methyl Ether, a relatively low carbon fuel that could be used for transport
EBRD	European Bank for Reconstruction and Development
EC	European Communities, referring to the economic competencies of the European Union
ECA	Export Credit Agency
ECCP	European Climate Change Programme, the European Commission’s programme to consult with stakeholders on climate change
EEA	European Environment Agency
EIB	European Investment Bank
EPB Directive	Directive (2002/91/3C) on energy performance of buildings
ET	Emissions Trading: generic term for trade of emissions rights (see also EU ETS, IET, International Emissions Trading)

EU	European Union (see also EC)
EU ETS	EU Emissions Trading Scheme, covering CO_2 emissions from industry and the power sector
EU neighbourhood policy	EU policy framework for relations with neighbouring countries, that have no immediate prospect of membership or are outside the geographical boundaries of the EU
European Council	Regular meetings of the heads of all EU governments to discuss and set out the strategic direction of the EU
EU R&D Framework Programme	The EU's financial instrument to support R&D
FAME	Fatty Acid Methyl Ester; a biofuel that could be used in diesel engines
FDI	Foreign Direct Investment
F-gases	Three GHG gases with a High Global Warming Potential: Hexafluoride (HF6), Perfluorcarbons (PFCs) and Hydrofluorcarbons (HFCs)
Flexible Mechanisms	Those market-based mechanisms established by the Kyoto Protocol that allow the transfer or exchange of emissions reductions obligations between Parties. Sometimes also referred to as the Kyoto Mechanisms or Mechanisms (see also CDM, JI, ET)
GDP	Gross Domestic Product
GHG	Greenhouse gas, usually referring to one of the six gases covered by the Kyoto Protocol: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6).
GW or GWe	Gigawatt electric; measure for installed capacity in power sector. One GW is 1.000 MW
GWP	Global Warming Potential. The index used to translate the level of emissions of various gases into a common measure (usually CO_2)
Greenhouse effect	The earth has a natural temperature control system. Certain atmospheric gases are critical to this system and are known as greenhouse gases. On average, about one third of the solar radiation that hits the earth is reflected back to space. Of the remainder, some is absorbed by the atmosphere but most is absorbed by the land and oceans. The earth's surface becomes warm and as a result emits infrared radiation. The greenhouse gases trap the infrared radiation, thus warming the atmosphere. Naturally occurring greenhouse gases include water vapour, carbon dioxide, ozone, methane and nitrous oxide, and together create a natural greenhouse effect. Human activities are causing greenhouse gas levels in the atmosphere to increase and this has occurred to such a level as to bring about climate change.
G-8	Regular summit of the heads of the eight most important economies
GtC	Gigatonne of carbon (1 Gt = 1,000 Mt)
$GtCO_2$	Gigatonne of carbon dioxide
hectare	10,000 m^2
Hydrogen (H_2)	Energy carrier that if produced by carbon-free fuels such as renewables or nuclear is theoretically carbon free.
IEA	International Energy Agency

IET	International Emissions Trading, as established under Article 17 of the Kyoto Protocol, allowing Annex B Parties to trade Assigned Amount Units (the GHG emission units of the Kyoto Protocol)
IGCC	Integrated Coal Gasification Combined Cycle
IPCC	Intergovernmental Panel for Climate Change, a scientific body created by the UN, generally assumed to be the most authoritative source on climate change science, which operates on the basis of peer review
Intensity target	The level of GHG emissions per unit of economic output (e.g. GDP)
JI	Joint Implementation: Art. 6 of the Kyoto Protocol establishes that Annex I Parties (and firms in these countries) can transfer Emission Reduction Units from individual projects
Kyoto Protocol	1997 Protocol under the UNFCCC to reduce GHG emissions globally. It entered into force on 16 February 2005 and will cover the period from 2008-2012; After 2012, a new framework or protocol will be needed. See "post-2012 framework"
LPG	Liquefied petroleum gas; transport fuel with a relatively low carbon-intensity
Mb/d	Thousands of barrels per day
MIT	Massachusetts Institute of Technology
mpg	Miles per gallon (US)
Mt	Million of tonnes. One Mt of CO_2 in the atmosphere is equivalent to 0.3 Mt carbon
$MtCO_2e$	Millions of tonnes of carbon dioxide equivalent, the most commonly used way to express quantities of GHGs
MW	Megawatt electric; measure for installed capacity in power sector. One MW is 0.001 GW
NGO	Non-Governmental Organisation
NOx	Nitrogen oxide, a precursor of acid rain
N_2O	Nitrous oxide, one of the six GHGs covered by the Kyoto Protocol
Parties	Countries that are party to the UNFCCC. The European Community is also a Party
Post-2012 framework	Describes the – yet to be established – global framework beyond 2012 to reduce GHG emissions, when the Kyoto Protocol expires
ppm/ ppmv	Parts per million/parts per million volume, the most commonly used way to express quantifies of GHG concentrations in the atmosphere. Usually expressed in CO_2-equivalent whose value is established on the basis of the Global Warming Potential (GWP) for each GHG
PV	Photovoltaic; technology to generate solar energy
Radiative forcing	The change in the balance between radiation coming into the atmosphere and radiation going out. A positive radiative forcing tends on average to warm the Earth's surface and a negative forcing tends on average to cool the surface
R&D	Research and development, sometimes also called RTD, research and technological development or RD &D, research, development and deployment

Sequestration	The capture of CO_2 in sinks
Sinks	The ability of land to absorb CO_2. Land-use changes that lead to sinks (such as afforestation, reforestation) or remove sinks (e.g. deforestation), are counted against a country's emissions
SO_2	Sulphur dioxide, a precursor of acid rain
Sector-specific target	A GHG emissions reduction target for specific sectors (e.g. energy intensive industry)
UNFCCC	United Nations Framework Convention on Climate Change, agreed at the UN Conference on Environment and Development (Rio de Janeiro, 1992). The ultimate objective of the UNFCCC is to stabilise GHG emissions at a level that would prevent dangerous anthropogenic interference with the climate system. The most important climate agreement negotiated in the UNFCCC so far is the Kyoto Protocol
WBCSD	World Business Council for Sustainable Development
WETO	World energy, technology and climate policy outlook, produced by the European Commission
WRE profiles	A widely-used set of CO_2 concentration stabilisation pathways (or 'profiles) devised by Wigley, Richels and Edmonds. The WRE profiles were designed to take account of the economic costs of reducing CO_2 emissions below a no-policy baseline ('mitigation') by assuming that the departure from the no-policy case is initially very slow (negligible in the idealised WRE cases)

Annex 2

List of Task Force Members and Invited Guests and Speakers

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