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Climate OptiOns for the Long term (COOL)
Global Dialogue - Synthesis Report

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Abstract

This report synthesises the outcomes of an international dialogue between scientists, policy makers and stakeholders on long-term options for international climate policy making and their near-term implications. This dialogue was part of the Climate OptiOns for the Long-term (COOL) project. The COOL global dialogue project was designed as a series of four workshops using a back-casting methodology to explore options for long-term climate policy and their near-term implications. It took as its starting point a stabilisation of CO_2 concentrations at 450 ppmv (or 550 CO_2 equivalent) around 2100, translated into an emission reduction of 15-25% by 2050 compared to 1990 levels. It was found that such an emission reduction is technically feasible at limited economic costs provided that the world develops in an economically and politically favourable way (open world) and major social and institutional barriers can be overcome. It requires early involvement of developing countries in global emission control and the establishment of a global emission trading system to reduce emissions in a cost-effective way. This is turn seems to require the development of a comprehensive international climate regime since an ad hoc incremental evolution of the climate regime is unlikely to keep the option of stabilising CO_2 concentrations at 450 ppmv open. It is of crucial importance to account for the large inertia in both the natural and human systems. One needs to take a long-term perspective for near-term climate policy making, either by formulating provisional long-term climate targets, or by systematically reflecting on long-term implications of near-term decision making. The COOL project has also resulted in a number of desirable short-term actions.

Acknowledgements

This report is the product of an unique effort to which many have made an invaluable contribution. Most of all, we thank all policy makers and stakeholders who have participated in one or several of the COOL Global Dialogue workshops for their critical but stimulating comments on the scientific information presented and their contributions to the policy dialogue. We hope we have produced a proper and fruitful synthesis of their comments and ideas. Nevertheless, we would like to stress that the responsibility for the views presented in this report is ours and not that of the participants. Secondly, we thank all the scientists contributing to the science–policy dialogue, in particular, Bert de Vries for presenting his insights into the IPCC SRES scenarios and work on the IMAGE-TIMER model, Johannes Bollen and Ton Manders for their economic analyses with the WorldScan model, Rik Leemans for synthesising IPCCs latest insights into the possible impacts of climate change, Gerald Bush, Michael Sonntag for their work and presentations on sinks, Andre Faaij and Jose Roberto Moreira for their presentations on biomass, Rineke Oostenrijk for her contribution to the development of the FAIR model website; we are also indebted to Thomas Bruckner, Hartmut Grassl, and Carsten Helm for their presentations during the workshops. Moreover, we like to thank Joe Alcamo, Leen Hordijk and Ference Toth for their chairing of the workshop sessions and Andre de Moor for his comments on earlier versions of this report. We owe much thanks to those who have made an essential contribution to the organisation of the project: Ursula Fuentes, for her major contribution to the first part of the project and Albert Faber for helping us out when Ursula left, and Jolanda Volle and Carmen Ploeg for their excellent logistic skills in running the workshops, the basis of any successful event. We also thank Ruth de Wijs for her language-editing support.
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On behalf of the authors,

Marcel Berk

Contents

Samenvatting

Dit rapport vat de uitkomsten samen van een dialoog tussen wetenschappers, beleidsmakers en belanghebbenden (stakeholders) over lange termijn opties voor klimaatbeleid en hun implicaties voor de kortere termijn. Deze dialoog was onderdeel van het project Climate OptiOns for the Long-term (COOL). De Mondiale dialoog bestond uit een serie van workshops waarbij de methode van back casting werd gebruikt om de kortere termijn consequenties van lange termijn opties te verkennen. Als startpunt werd uitgegaan van een stabilisatie van de CO_2 concentratie op 450 ppmv (ongeveer 550 ppmv in CO_2 equivalente termen), wat is vertaald in een reductie van de mondiale CO_2 emissies met zo'n van 15-25% in 2050 ten opzichte van het niveau in 1990. Een bevinding van de dialoog was dat een dergelijke reductie technisch haalbaar is tegen beperkte economische kosten op voorwaarde dat de wereld zich economisch en politiek gunstig ontwikkelt (open wereld) en belangrijke sociale en institutionele barrières kunnen worden overwonnen. Het vergt voorts een vroege deelname van ontwikkelingslanden aan de mondiale emissiebeperking en de realisatie van een systeem van wereldwijde emissiehandel om te komen tot een kosteneffectieve aanpak. Het lijkt te vragen om een alomvattend internationaal klimaatregime aangezien een regime met incrementele uitbreiding van het aantal landen met emissiedoelstellingen op een ad hoc basis hoogstwaarschijnlijk leidt tot het onbereikbaar worden van stabilisatie op 450 ppmv. Het is cruciaal dat rekening wordt gehouden met de grote inertia in zowel natuurlijke als menselijke systemen. Beleidsvorming op korte termijn dient plaats te vinden vanuit een lange termijn perspectief. Daartoe kunnen ofwel voorlopige lange termijn klimaatdoelstellingen worden geformuleerd, dan wel kan een systematische verkenning van de lange termijn implicaties van korte termijn beslissingen plaatsvinden. Het project heeft voorts geresulteerd in een lijst van wenselijke korte termijn acties.

1. Introduction

The global climate is changing. Over the last 140 years, global average surface temperature has increased by 0.6 (± 0.2) ^{o}C. According to the latest report of the Intergovernmental Panel on Climate Change (IPCC, 2001a) this is mostly caused by human activities, resulting in emissions of greenhouse gasses (GHGs) to the atmosphere. Without any further action global average temperature may rise by another 1.4 - 5.8 °C over the next 100 years. Even today, we are witnessing clear impacts of climate change: land glaciers are retreating, ocean surface waters are warming and the extent and thickness of Arctic sea ice are decreasing. Further global warming is likely to result in increasing risks of negative impacts on both natural systems and human societies around the world. The least developed countries will be the most vulnerable for climatic changes due to their limited ability to adapt (IPCC, 2001b).

In 1992, the United Nations Framework Convention on Climate Change (UNFCCC) was established with the aim of stabilising the concentrations of GHGs in the atmosphere to avoid dangerous interference with the climate system. To fully stabilise atmospheric CO_2 concentrations, (net) global CO_2 emissions will ultimately have to drop to the level of persistent uptake by the biosphere and oceans, which is expected to be very small (<0.2 GtC/year compared to about 7.2 GtC in 1990) (IPCC, 2001a). The time frame in which this is accomplished will determine the level of stabilisation.

The question of controlling the risk of future climate change is thus, not if, but how, quickly global greenhouse gas emissions will have to be reduced. The risks of climate change are still uncertain, but we may find that lowering the risks to acceptable levels would imply drastic emission reductions within a relatively limited time period. How can we prepare ourselves for such a situation? Are such reductions feasible and what do they require? And what will the implications be for industrial and developing countries?

These are the kinds of questions which the Climate OptiOns for the Long term (COOL) project was set up to answer. The COOL project was aimed at (i) exploring options for the long-term climate policy in the Netherlands in a European and global context, and (ii) making a contribution to the development of methods for participatory integrated assessment. The project thus consisted of a science-stakeholder dialogue at three policy levels - national, European and global - with an integration of results and experiences at the end of the project. In tune with the general aims of COOL, the COOL Global Dialogue project was more specifically to:

- explore possible long-term targets for stabilising GHG concentrations;
- explore the most promising options for long-term international climate policy and their implications for the medium term;
- enhance the understanding between countries with different positions and interests in the climate change;
- broaden the understanding of scientific aspects of the climate issue, and if possible,
- develop common frameworks for analysing and evaluating policy options.

The COOL Global Dialogue project was designed as a series of four workshops, taking place from July 1999 to February 2001. Participants to the workshops numbered about 25-30 people, consisting of policy makers from both developed and developing countries and stakeholders involved in international climate change policy negotiations, along with climate change scientists, mainly from Dutch research institutes.

Like the COOL National and European Dialogue projects, options for long-term climate policy and short-term implications were explored using a so-called back-casting methodology. This is the (backward) exploration of pathways, going from possible images of the future to the present with the aim of formulating important conditions, strategies and shorter term actions to make these futures attainable (see Text Box 1.1).

Box 1.1 Back casting

Back-casting analysis is a technique for exploring the implications of how a future state can be attained. It starts by defining the final state, followed by an exploration of preconditions that could lead to this state. The exploration includes the formulation of actions, conditions, barriers and opportunities that are crucial at various points in time to meeting the conditions. Back casting consists of three steps (Dreborg, 1996):

1.Constructing visions of the long-term future (e.g. low GHG future or climate targets)
2.Constructing pathways to establish the vision

- Future history writing (how do we arrive at a vision?)
- Milestones/accomplishments that have to be attained (challenges)
- Identifying barriers and opportunities

3.Designing strategies (e.g. for emission reduction)

- How to deal with barriers and make use of opportunities
- Formulating conditions
- Evaluating options and short-term actions

However, unlike the National and European Dialogue projects, where an 80% reduction of GHGs was taken as a starting point for back casting, the COOL global dialogue project started with an exercise to explore possible long-term climate targets related to avoiding unacceptable impacts of climate change. On the basis of this exercise, the participants were willing to adopt a stabilisation of CO_2 concentrations at 450 ppmv by 2100 as the starting point for back casting. It should be stressed, though, that this stabilisation level was neither considered to be ‘safe’ or ‘desirable’. In fact, some participants consider it not ‘safe’ enough, while others consider it too strict. The target was, nevertheless, accepted as a point of departure for an evaluation of technical, economic and policy implications of this stabilisation level.

For exploring possible image of the future, the long-term (2100) stabilisation target was translated by the COOL project team into a reduction of global CO_2 emissions of about 15-25% by 2050 compared to the 1990 levels. The range relates to the options for timing of emissions reductions to stabilise atmospheric CO_2 concentrations at 450 ppmv by 2100. In 1990 global anthropogenic CO_2 emissions amounted to about 7.2 GtC (including land-use emissions, for example, those resulting from deforestation). If global CO_2 emissions were to be limited to less than 9 GtC by 2010-2020, global emissions could be gradually reduced afterwards to about 6 GtC by 2050 before decreasing further to about 2.5-3.0 GtC by 2100. However, if emission reductions were to be delayed and global CO_2 emissions to increase to more than 10 GtC by 2020-2030, then emissions would have to drop more steeply afterwards to about 5.4 GtC CO_2 by 2050 and 2.0-2.5 GtC by 2100 (see Figure 1.1)

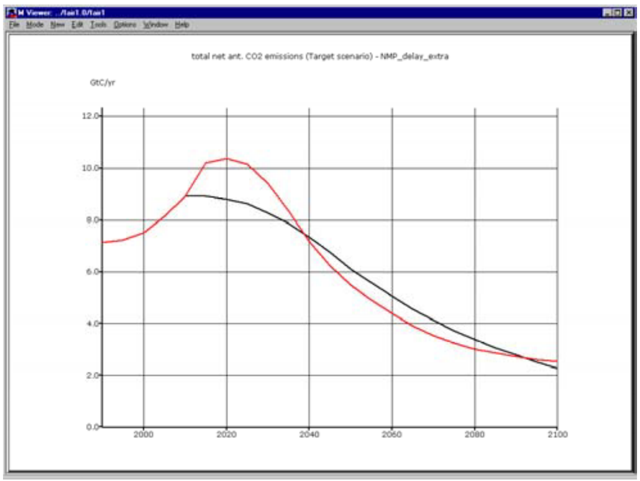


Figure 1.1: Alternative anthropogenic CO_2 emission profiles for stabilising CO_2 concentrations at 450 ppmv by 2100 (Source: FAIR model, Den Elzen et al., 2001; Berk and Den Elzen, 2001).

Such a reduction level may seem much less stringent than the 80% reduction adopted in the other parts of the COOL project. However, if future CO_2 emission allowances were distributed on a per capita basis, a global emission reduction of 15-25% would also imply reductions in developed country emission allowances of 70-80% by 2050 (see Figure 1.2).

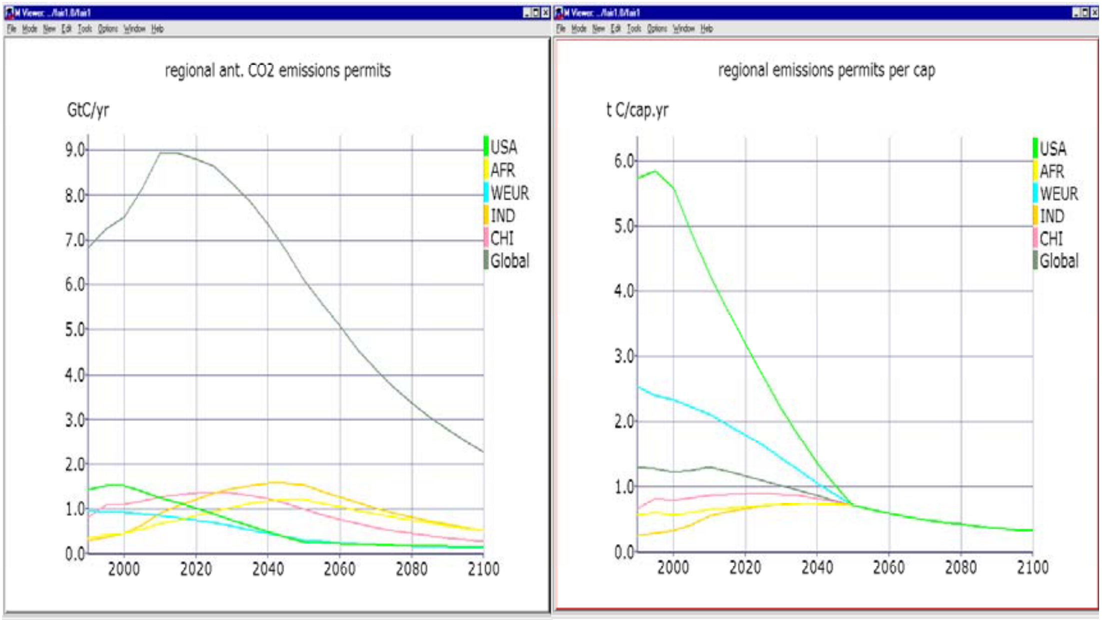


Figure 1.2: Regional emission allowances (absolute and per capita) with a linear convergence of per capita CO_2 emissions by 2050 under an emission profile for stabilising CO_2 concentrations at 450 ppmv (Source: FAIR model, Den Elzen et al., 2001).

This document contains the main results of the COOL global dialogue project. It is meant to be a strategic document that synthesises the results of the workshops, evaluating promising strategies for meeting stringent long-term climate targets and their implications for the short to medium term (e.g. second and third commitment period). The report was written by the RIVM research team, but reflects important shared insights as well as differences of opinion within the group of participants. In the next section the possible impacts of stabilising CO_2 concentrations at 450 ppmv (550 ppmv CO_2 equivalent) are assessed and related to what the

COOL participants defined as undesirable impacts. Section 3 focuses on the technical feasibility and economic implications of, and important barriers and opportunities for a 15-25% reduction of global CO_2 emissions by 2050. Section 4 addresses the issue of global co-operation and discusses options for future climate regimes for the differentiation of commitments. Section 5 presents short-term implications of a transition to a low-carbon intensive world and of promoting global co-operation. Finally, section 6 summarises the main findings of the COOL Global Dialogue.

2. Starting point: stabilising CO_2 concentrations at 450 ppmv - an assessment of the risks to natural systems and human society

2.1 What is the vulnerability of systems and societies to climate change?

Current and future changes in climate may lead to large-scale and possibly irreversible effects on human societies and natural systems. Some of these effects may be beneficial, while others will have a negative impact. A temperature increase of few degrees Celsius, for example, is expected to increase the crop yields in some regions, whereas glaciers and coral reefs are already negatively effected. The response of the systems to climate change depends on the vulnerability, and the magnitude and rate of climate change. The vulnerability is a function of the sensitivity of a system, its adaptation capacity and the risk of exposure (IPCC, 2001b). An increasing magnitude and rate of climate change is expected to lead to an increasing number of systems being negatively affected.

Recently, IPCC (2001b) listed 5 reasons of concern outlining why we should be aware of the vulnerability of natural systems and societies to climate change (as presented during the 2nd COOL dialogue workshop):

1. Risks to unique and threatened systems, (e.g. coral reefs)
2. Risk from extreme climate events (e.g. heat waves and storms)
3. Distribution of impacts (e.g. more negative impacts in developing countries)
4. Aggregated impacts (e.g. for economic sectors)
5. Risks of large-scale discontinuities (e.g. ocean circulation)

With increasing magnitude of climate change, more and more systems are expected to be dominantly negatively affected (Figure 2.1). Already limited temperature changes may, for example, threaten the existence and functioning of many unique systems. The risk to many other impact categories like large-scale discontinuities is low under limited temperature changes, but considerably increases if the temperature rises more than 2 - 3 °C compared to 1990 levels.

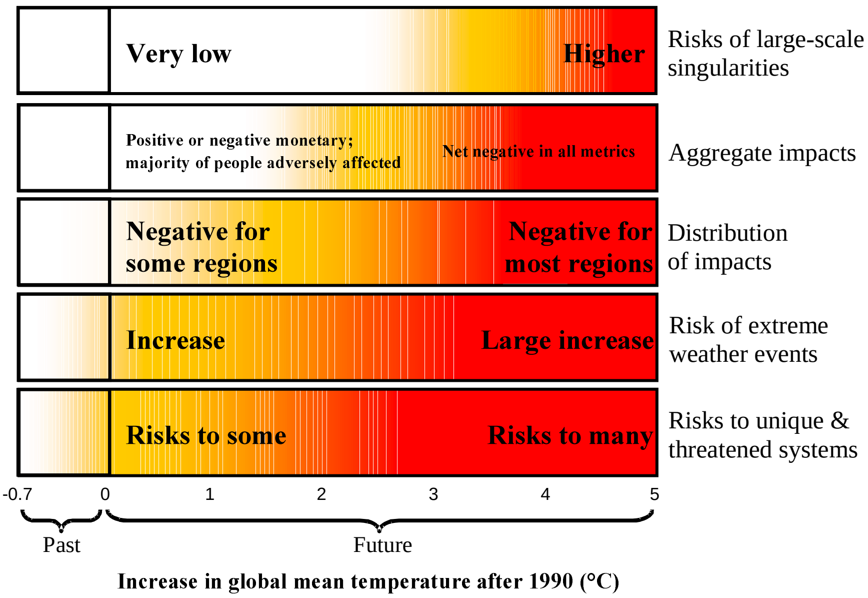


Figure 2.1: Risk of impacts from climate change according to reason of concern (IPCC, 2001b).

2.2 What are the risks of stabilising CO_2 at 450 ppmv?

What is the risk for various systems and societies of a long-term stabilisation of atmospheric CO_2 at a level of 450 ppmv (plus 100 ppmv equivalents for non-CO_2 GHGs)? The answer to this question depends partly the vulnerability of individual systems, which show significant differences. The answer also depends on the response of the climate system to enhanced GHG levels in the atmosphere. The so-called climate sensitivity is a measure to quantify the response. It is defined as the equilibrium global average temperature change under a doubling of the atmospheric CO_2 equivalent concentration (IPCC, 2001a). Recently, the IPCC reconfirmed that climate sensitivity ranges from 1.5 – 4.5 °C. Considering this IPCC climate sensitivity, the stabilisation level of 450 ppmv in the COOL project implies a change in the global average temperature in the very long-term of between 1 and 4 °C (based on analysis with the FAIR model, Den Elzen et al., 2001; see also IPCC, 2001a). This range of temperature change is relatively broad, illustrating the uncertainty around climate change impacts. At the low end of the range, the threat to many human and natural systems will be limited and few systems may even be affected beneficially. Negative effects are expected, especially on some unique systems around the world (e.g. coral reefs), and changes in the frequency of some extreme events may occur. A temperature increase at the high end of the climate sensitivity range (i.e. the temperature increases more under an enhanced GHG concentration) is expected to lead to significant negative impacts for nearly all reasons of concern. We might end up with significant impacts across the globe, sectors and categories.

2.3 What are the undesirable effects?

The participants to the COOL global dialogue project defined particular climate change impacts that should be avoided, if possible (Table 2.1). The participants were anxious about the impacts on human societies because of the direct threat to human welfare, for example, through the effect on food and water security. The listed impacts on natural systems were identified as undesirable for reasons such as (i) the large-scale and the often irreversible character; (ii) the uneven spatial distribution of negative impacts, mainly in developed countries; (iii) the threat to certain ‘valuable’ systems (i.e. because they are unique or have an important regulating function for the water supply). The prioritisation of the undesirable effects varied among the participants of the workshops. All participants, however, identified large-scale non-linear effects (e.g. changes in ocean circulation) as an effect that is highly undesirable and should be avoided.

Table 2.1 Undesirable climate change effects according the participants to the COOL global dialogue process (Berk, Van Minnen and Metz, 2001)

Human society	Nature
1. Impacts on indigenous groups of people around the world	1. Large-scale melt of glaciers and arctic ice fields
2. Instability of global water and food supply	2. Shifts in occurrence of extreme events
3. Threat of human health	3. Threat to biodiversity
4. Human displacement due to sea level rise and severe flooding	4. Source-sink shift of the terrestrial biosphere
	5. Changes in ocean circulation

2.4 To what extent are the undesirable impacts avoided with stabilisation at 450 ppmv?

The risk of climate change on these undesirable effects can be determined by linking them to the above-mentioned reasons for concern. However, for some of the undesirable impacts this is difficult, for example, in the case for the risk for indigenous groups of people. The relationships between causes and effects are complex and non-climate related factors often more dominant.

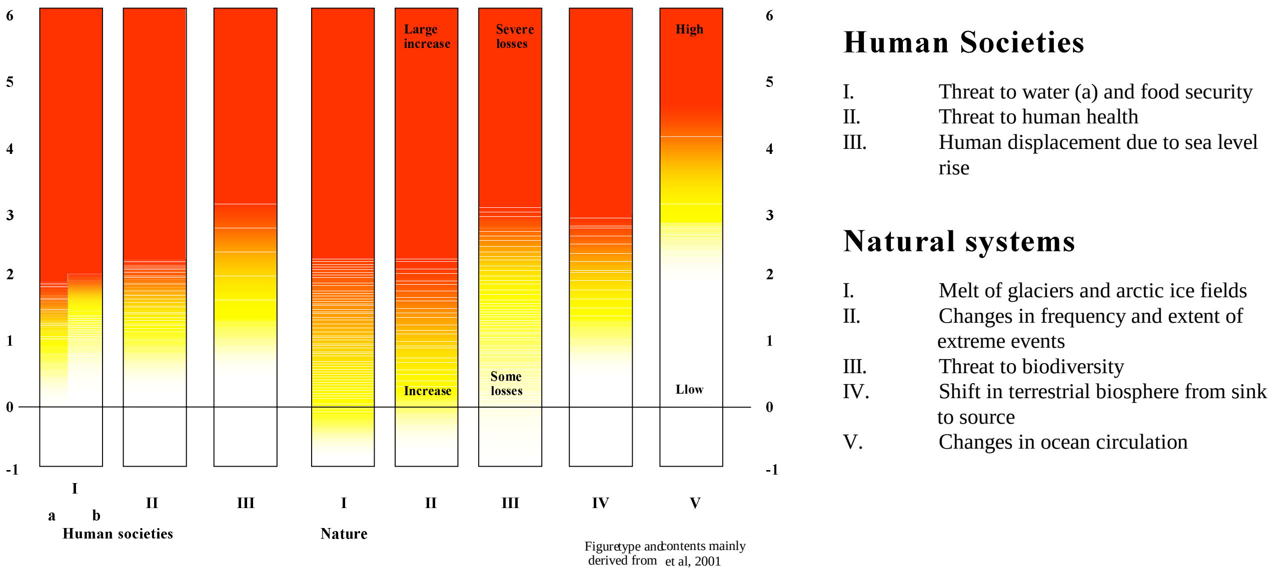


Figure 2.2: Risk of adverse climate change effects on a number of human and natural systems that are defined by the participants as highly relevant.

For other impact categories a link to the reasons for concern is possible (Figure 2.2). As previously mentioned, a stabilisation of CO_2 at 450 ppmv + 100 ppmv for other GHGs implies a global temperature change of around 1 – 4 °C. At the high end of the temperature range the risk for most undesirable effects is high. Even changes in ocean circulation or a (slow) melting of the Greenland ice sheet (see text box) cannot be excluded then, whereas all participants identified such impacts as highly undesirable. If the resulting temperature increase is less severe , the risks for the undesirable effects become obviously lower. If the temperature change stays below the range of 1.5 –2 °C compared to the present (thus 2.1 – 2.6 °C compared to pre-industrial levels), most of the undesirable effects are likely not to occur. At the same time, changes in extreme events and loss of unique systems like glaciers and coral reefs are hard to avoid. Already observed changes in climate have triggered effects on these systems.

To summarise, a stabilisation of the atmospheric CO_2 concentration at 450 ppmv in combination with additional 100 ppmv equivalents for non-CO_2 greenhouse gasses still implies a substantial risk for various impact categories, defined by the COOL participants as being important. In addition, other impact categories, as defined by IPCC (e.g. rare ecosystems systems like coral reefs), become threatened. If the climate sensitivity is low (i.e. accompanied changes in temperature that are small), overall negative effects may be limited to unique (eco)systems, the melting of glaciers and ice sheets and changes in the frequency of some extreme events. A temperature increase at the high end of the climate sensitivity range is expected to lead to overall negative impacts for nearly all reasons of concern. Even the risk for changes in ocean circulation or a (slow) melting of the Greenland ice sheet will then exist.

Box 2.1 Stabilisation levels, the Greenland ice sheet and sea level rise

After greenhouse gas concentrations have been stabilised, temperature will continue to rise for several decades to centuries, although at a much slower rate. Obviously, the lower the level at which GHG concentrations are stabilised, the less temperature increase will be induced. For a stabilisation of CO_2 at 450 ppmv, temperature increase in 2100 is between 1.2-2.3 °C, whereas its theoretical equilibrium increase (requiring centuries) is estimated at 1.5-4 °C. (IPCC, 2001a).

The responses of ice sheets and sea levels show an even much longer time lag. They will continue to react to climate warming for many centuries, even if the temperature increase has been stopped. The reasons for this is that it takes a very long time before seas and ice sheets are again in 'equilibrium' with the elevated atmospheric temperature. As a result sea level continues to rise due to thermal expansion (in the range of 0.5-5 m) and ice sheets continue to melt even after atmospheric temperatures have more or less stabilised. The contribution of ice sheet melting to sea level rise may be limited to centimetres during this century, but can be in the order of meters in the very long term.
The Greenland ice sheet is the most vulnerable to global warming. For moderate warming, the ice sheet can be retained. However, only if the temperature returns back to lower levels. For high temperature increases, the ice sheet can not survive, especially if sustained for centuries to millennia. This may contribute about 1-10 m of sea level rise over a thousand years. A complete melting of the Greenland ice sheet (except for some glaciers in high altitudes) is already possible if local average temperature increases more than 2.7 ^{o}C and is sustained for millennia (IPCC, 2001a). Translating the local Greenland temperature increase into global average values indicates that an exceedance of the 2.7 ^{o}C is possible for nearly all combinations of IPCC-SRES scenarios and climate sensitivity values. Only for low stabilisation profiles (e.g. leading to 450 ppmv CO_2 stabilisation) and low climate sensitivity values, can the temperature increase in Greenland stay below this critical value. Stabilising at 450 ppmv thus does not exclude the risk of a gradual melting of the Greenland ice sheet and an eventual sea level rise of a few meters.

3. De-carbonising the Global Economy

3.1 What is the challenge?

Climate Change is particularly related to the global energy system, which by 1995 was responsible for about 80% of global CO_2 emissions and 65% of all greenhouse gases released primarily by the wealthiest 1 billion people on earth. At the same time, about 2 billion people worldwide lack access to modern fuels and electricity, which are important for increasing their opportunities for economic development (UNDP, 2000). Moreover, major energy shortages and power-system breakdowns hinder many developing countries' economic development. So, from a global sustainability perspective, increasing the access to modern energy is one of the necessities for development.

The problem is the nature of present energy use: (1) the low efficiency in providing energy services (such as light, heat or transport) and, in particular, (2) the pollution and waste resulting from its generation. From the climate change perspective the release of greenhouse gases, carbon in particular, is the key problem, but there are many local and regional environmental problems related to the extensive use of fossil fuels as well. The challenge is to provide billions of more people with adequate energy services, while reducing the carbon-intensity of the world economy: economic development with fewer carbon emissions.

Box 3.1 What do we mean by de-carbonisation of the world economy?

The term de-carbonisation often refers to the carbon intensity of energy use, that is the amount of carbon emitted per unit of energy consumed. De-carbonisation of the economy is a broader concept that relates to the idea of de-linking CO_2 emissions from economic growth. It is a function of both the carbon intensity of energy use (C/E) and the energy intensity of the economy (amount of energy use per unit of economic value) (E/GDP). The carbon intensity of the economy (C / GDP) can thus be expressed as:

$$C / GDP = E / GDP * C / E$$

This implies that if we want to de-link CO_2 emissions from economic growth we can try to reduce both energy intensity and carbon intensity.

3.2 Where will present trends lead us?

In its World Energy Outlook 2000 (IEA, 2000), the International Energy Agency explored the world's energy future for the next two decades. The study indicates that world energy use and CO_2 emissions are expected to grow steadily in the next two decades, with 2/3 of the growth in developing countries. Energy intensity is projected to decrease at about same rate as in 1971-1997 period (about 1%), but world carbon intensity is expected to increase, reversing the long-term de-carbonisation trend (of about 0.5% / year).

Other assessments (e.g. World Energy Assessment of UNDP (2000); IPCC-Third Assessment Report (IPCC, 2001c)) indicate that also in a longer time frame scarcity of fossil fuels is not expected to be a major driver of change in energy systems. The fossil resource base is at least 600 times current fossil fuel use (UNDP, 2000). Although the use of proven conventional oil and gas reserves would not yet result in a CO_2 concentrations exceeding 450 ppmv by 2100, total conventional reserves, including coal, could exceed 1000 ppmv. Unconventional fossil reserves will be abundantly available for many centuries and could lead to cumulative carbon emissions many times more than those of even the highest IPCC baseline scenarios (Figure 3.1).

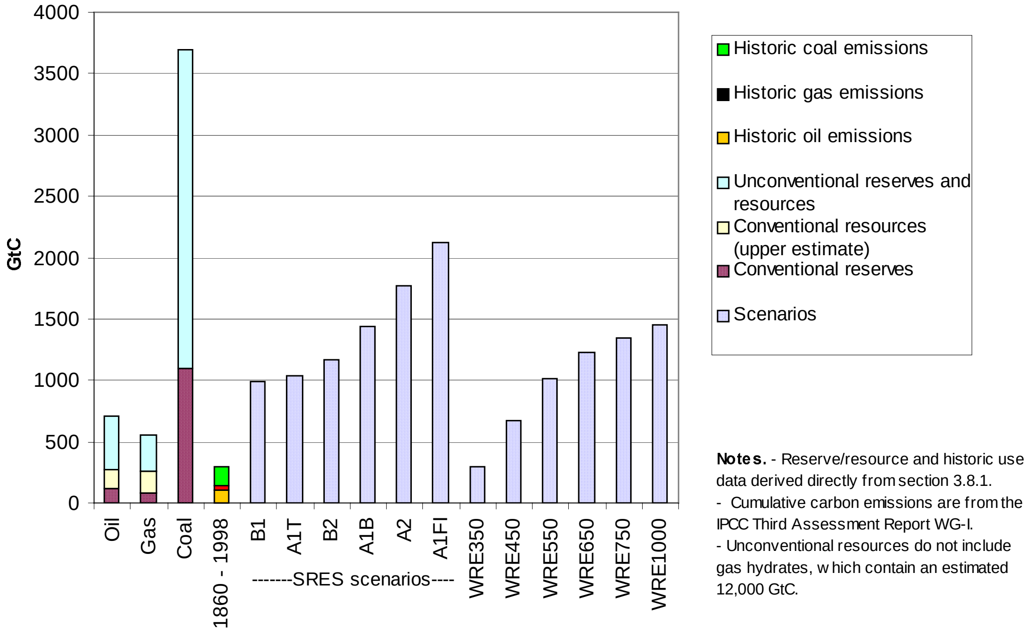


Figure 3.1: Carbon in oil, gas and coal reserves and resources compared with historic fossil-fuel carbon emissions 1860-1998, with cumulative carbon emissions from a range of SRES scenarios and TAR stabilisation scenarios up until 2100. (IPCC, 2001c).

3.3 What will be the emission reduction effort needed for stabilising at 450 ppmv?

The emission reduction effort[1] needed will depend on the way the world may develop in the future. Recently, IPCC developed a new set of non-intervention or baseline scenarios as part of its Special Report on Emissions Scenarios (SRES) (Nakicenovic et al., 2000). These provide alternative emissions trajectories for the main direct and indirect greenhouse gasses up to 2100. In contrast to previous IPCC scenarios these scenarios are based on explicit story-lines about how the world could develop demographically, socio-economically and technically. Combining two dimensions - the level of globalisation and a materialistic versus a sustainability value orientation - four different ‘families’ of possible futures emerge (Figure 3.2).

[1] That is the difference between baseline projections and required emissions trajectory to achieve stabilisation at 450 ppmv. This is different from reduction levels compared to 1990 levels.

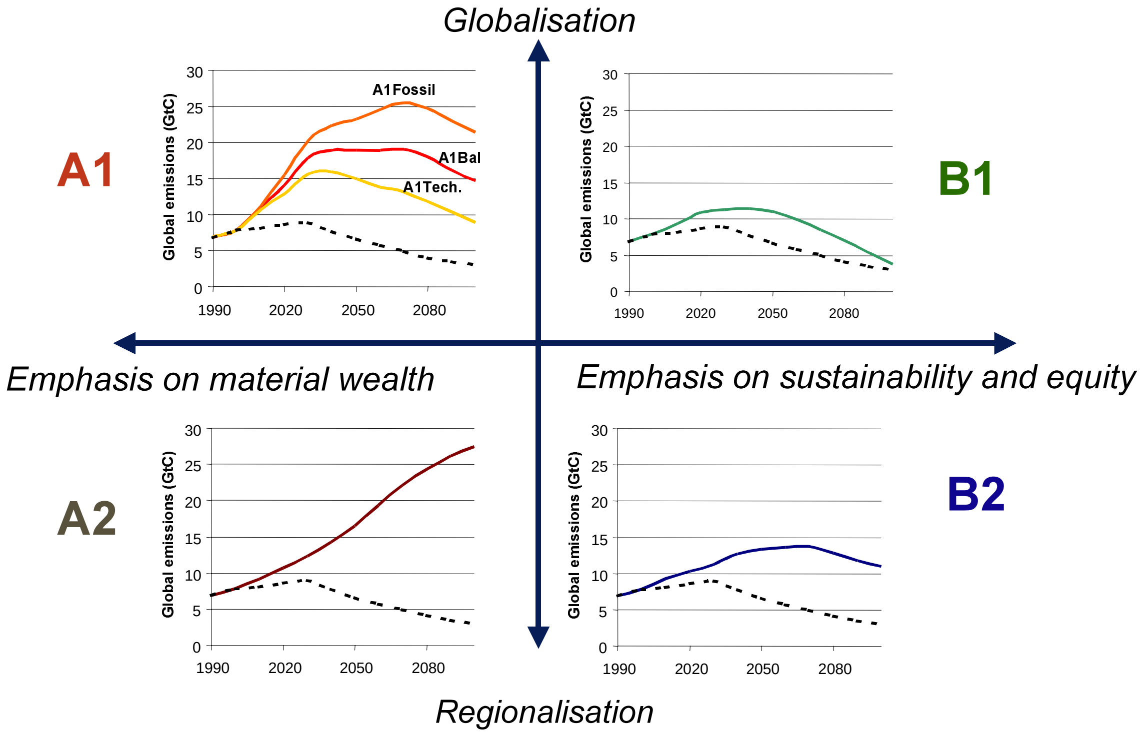


Figure 3.2: Global CO_2 emission trajectories for the different IPCC-SRES scenarios marker scenarios compared to a 450 stabilisation emission profile (dotted line; based on the FAIR model (Den Elzen et al., 2001).

From the set of SRES emission scenarios we can draw a number of conclusions about their implications for strategies to limit future CO_2 concentrations to 450 ppmv:

- First, the level of emission reduction effort needed to attain an emission profile for stabilising CO_2 concentrations at 450 ppmv is highly dependent on the way the world will develop. By 2050 it can range between 40% for a B1 world to over 60% for a A2 world, and even 75% in an A1-fossil fuel oriented world (allowed global emissions compared to baselines).
- Second, the economic, social and political conditions in the various worlds have important consequences for both the willingness and capacity for mitigating global CO_2 emissions: a less affluent and/or divided world is less likely to be able to strongly reduce CO_2 emissions than a rich and globalised world.
- Third, the type of world has also consequences for the acceptability of possible mitigation strategies and preferred policy instruments. In the B-type of worlds the concerns for environmental and social consequences of climate policy options are likely to be stronger, while the A-type of worlds may have a stronger preference for least-cost, market-oriented solutions than B worlds. The B type of worlds may be willing to pay more for renewables to avoid the need for nuclear, large-scale biomass or CO_2 removal.
- Finally, the A1 and B1 type of worlds offer better perspectives for the development of effective global climate regimes than an A2 type of world. In a B2 world greenhouse gas mitigation may be less dependent on global arrangements and could also result from regional efforts and/or other policies supporting sustainable development.

Thus not only will the overall emission reduction effort be influenced, but also the conditions and likely menu of options for emission reduction strategies by the way the world develops. This also has implications for the feasibility a 15-25% reduction in global CO_2 emissions by 2050: it will be much larger in a B1 or A1b world than in A2 or A1 fossil intensive world. For policy making this implies that preventing the world to develop into the latter type of worlds will contribute much to the prospects for stabilising CO_2 at 450 ppmv. Vice versa, striving for a world oriented towards sustainable development will also make it much easier to meet stringent climate goals.

3.4 Is a 15-25% reduction of global CO_2 emissions by 2050 feasible?

In the COOL project we focused our assessment of the feasibility of such an emission reduction on two different worlds: A1 and B1. This choice was made because these worlds offer contrasting, but favourable, conditions for the development of effective policies to meet such a stringent climate target. For this assessment, the participants performed a back-casting exercise, supplemented with insights from the IMAGE TIMER energy model, and other information, such as the IPCC-Third Assessment Report (IPCC, 2001c).

Our assessment indicates that a 15-25% CO_2 reduction can be considered technically feasible in both types of worlds. However, it will be more difficult to realise in an A1 than a B1 type of world due to both higher baseline emissions and the drive for a least-cost energy supply in a market-orientated world. To reduce global CO_2 emissions it will be necessary to make use of almost all options (energy saving, efficiency improvement, fuel switch, biofuels, renewables, etc); no single option will be able to generate sufficient emission reductions.
In an A1 world with high emissions it is expected that there will be more a need for and acceptance of large-scale contributions from both biological and physical carbon sequestration and/or nuclear energy. By contrast, in a B1 world, with relatively low baseline emissions, the need for and acceptance of such options are likely to be low. Energy saving and supply shifts are expected to be more easy to implement in a B1 world due to the environmental concern.

While improvement in energy intensity (i.e. resulting from energy saving, energy efficiency improvements, Combined Heat and Power) will remain important, particularly during the first decades, eventually the reduction in the carbon-intensity of the energy system (i.e. by the use of alternative energy sources) will become a more important factor.

3.5 What are robust options in different worlds?

Since we do not know (nor assume to be really able to control) the way the world will develop we need to look for strategies that are likely to be attractive and effective for mitigating greenhouse gas emissions irrespective of the way the world develops. In other words, to look for robust strategies or policy options. From the TIMER analyses (Van Vuuren and De Vries, 2000, 2001), the back-casting exercise and other studies (IPCC, 2001c; Riahi and Roehrl, 2000; UNDP, 2000) a number of rather robust energy technology strategies emerge:

- energy saving and efficiency improvement (both in energy supply and demand, including combined heat and power (CHP));
- a fossil fuel shift to natural gas use (power sector);
- development of fuel cell use (in both the transport, power and residential sectors);

- development of biomass energy use (in particular biofuels in the transport sector);
- renewables, notably wind and solar energy (power and residential sectors).

Most of these options even seem to be robust in the case of less stringent stabilisation levels, like 550 ppmv (Riahi and Roehrl, 2000).

In the *power generation sector*, gas combined cycle technology will, in the short to medium term, in particular, be very attractive (where natural gas infrastructure is available) to replace coal-based power stations. Gas-combined cycle technology may also bridge the gap to a hydrogen-based energy infrastructure when combined with more advanced fossil options (like coal gasification combined with CO_2 removal), biomass and other renewables (wind /solar) and electricity production based on fuel cells. Fuel-cell technology seems a robust energy technology because of its high efficiency and its flexibility in scale (both decentralised and centralised applications) and input (natural gas, hydrogen from renewables, synthetic fuels from biomass). Biofuel use may play a substantial role in regional power generation, but this seems less robust than its role in the transport sector. An increased access to natural gas and the development of gasification and fuel-cell technology will also result in better opportunities for highly efficiently distributed co-generation of heat and electricity.

In the *transport sector*, fuel-cell powered vehicles are likely to become ultimately dominant in the transport sector, combined with energy carriers such as synthetic liquids from bio-mass (ethanol) or from fossil fuels (methanol) and eventually hydrogen. This transition could be smoothened by the introduction of the hybrid car, because this will enhance the development of electric traction technologies and reduce the need for a rapid adjustment of energy supply infrastructure.

Renewables. In addition to biomass, other renewables will also be needed to provide both electricity and heat. Wind energy is already competitive and its growth has been the highest of any energy sources over the past five years - more than 30 % per year. Market penetration in some regions is now between 10 and 20% of total electricity provided. In the shorter term, solar photovoltaics (PV) will be still too expensive for providing grid supply, but it has particular potential to provide a major proportion of distributed electric power for buildings in industrial countries, and village power in rural settings in developing countries. Solar thermal systems for hot water have a great potential to substantially reduce the use of fossil fuels and electricity for this purpose, particularly in the residential sectors. Space heating and cooling of buildings can be substantially reduced. not only by improved structural design but also by making use of passive solar features and proper orientation. With respect to the long term, analyses suggest that renewable technologies are all robust technologically, and that on the basis of experienced costs reductions in the past, their costs are likely to drop to a level that makes them increasingly competitive in climate policies. This may result in a substantial share of renewables in the overall energy supply by 2050.

Organisational options. In addition to these technical options, there are also socially or organisationally robust options that reduce the need for mobility and promote a shift from car use to public transport and non-motorised ways of transportation. These relate to issues such as urban planning, improvement of logistics, the use of information and communication technologies and measures to discourage car use.

3.6 What are the economic impacts of reducing global CO_2 emissions for stabilising CO_2 at 450 ppmv?

The economic impacts of mitigation of CO_2 are an important concern for policy makers. But the mitigation costs are only part of the overall economic picture. Ideally, to judge the economic soundness of GHG mitigation, the avoided damages and co-benefits of GHG mitigation should also be taken into account. During the COOL global project their relevance was acknowledged but avoided damage was not quantitatively assessed. Some attention was paid to the issues of timing and co-benefits of GHG mitigation.

Main determinants of the overall economic impacts (in terms of loss of welfare) of stabilising GHG concentrations are the stringency of the stabilisation target, the reference scenario, discount rates used, the distribution of emission reductions over time, and policies and measures implemented. IPCC indicates that the welfare effects of stabilising CO_2 concentrations at 450 ppmv are generally twice to three times as high as stabilising at 550 ppmv, depending on the baselines used. Nevertheless, except for very high baselines (like the IPCC A2 scenario), global welfare effects of stabilisation of 450 ppmv seem to be limited; in particular, given the huge increases in welfare projected in most baseline scenarios.

According to analyses with the WorldScan model (CPB, 1999), the global loss of GDP by 2050 for the A1 and B1 scenarios would be in the order of 1.4 and 0.6%, respectively (Table 3.1). These figures carry substantial uncertainties stemming from model assumptions (for example, on resource, production factor and trade elasticities). Nonetheless, there is an upward bias to CO_2 mitigation cost estimates, because the model does not account for the option of carbon sequestration, nor for technological learning, which particularly affects implementation costs on the long term.

On the other hand, most models used for assessing the costs and economic impacts of GHG mitigation, including IMAGE/TIMER and WorldScan, too easily assume a major fuel shift away from coal in response to climate policies for coal-dependent countries like China and India. While economically sound, it would have major social implications that may pose great political obstacles, as we still see in many developed countries. If this fuel-shift option cannot be (fully) implemented, the economic impacts of GHG mitigation for such countries will be much larger than projected.

At the same time it is clear that full emission trading and / or early participation of developing countries are important to keeping the overall costs low. Analyses of stabilisation at 450 ppmv on the basis of the A2 baseline show that large welfare impacts will be much larger (up to 4% by 2050). This confirms that stabilisation at 450 ppmv will be very hard to reach in a A2 type of world for both economic and political reasons (even with full emission trading).

Table 3.1: Economic impacts of per capita convergence by 2030 for stabilising CO_2 concentrations at 450 ppmv for two baseline scenarios (IPCC-SRES A1 and B1)

Percentage change in Gross National Product for 12 world regions (a)

	A1		B1	
	2030	2050	2030	2050
OESO	**-0.7**	**-1.5**	**-0.3**	**-0.4**
Japan	-0.2	-0.7	-0.1	-0.2
Pacific OESO	-1.1	-2.4	-0.6	-0.9
United States	-1.1	-2.2	-0.5	-0.6
European Union	-0.4	-0.9	-0.2	-0.3
FSU and Eastern Europe	**-1.2**	**-2.3**	**-0.6**	**-1.3**
Eastern Europe	-0.8	-1.1	-0.3	-0.6
Former Soviet Union	-1.3	-2.9	-0.7	-1.
Asia	**0.3**	**-0.9**	**0.5**	**-0.5**
China	0.0	-2.1	0.2	-1.3
Dynamic Asian economies	-0.7	-2.3	-0.6	-1.1
India	1.9	1.3	2.2	0.7
Rest of the World	**-0.2**	**-1.5**	**0.1**	**-0.7**
Latin America	-0.6	-1.3	-0.3	-0.7
Middle-East & North Africa	-1.1	-4.3	-0.4	-1.5
Sub Sahara Africa	2.6	1.9	2.0	0.4
Annex B	**-0.7**	**-1.7**	**-0.3**	**-0.5**
Non Annex B	**0.1**	**-1.2**	**0.3**	**-0.6**
Global	**-0.3**	**-1.4**	**-0.1**	**-0.6**

[a] **Percentage difference to baseline scenario**

Source: WorldScan model, Bollen, 2001

3.7 What will the regional economic impacts be?

The regional economic impacts will depend on the burden differentiation, the level of emission trading and the position of regions as an energy importer or exporter. They can be much larger than world average levels and result in (relative) losers and winners, which could even change over time. This is illustrated by the WorldScan analyses of stabilising CO_2 concentrations at 450 ppmv under a regime of convergence of per capita emission allowances by 2030 with full trade (Table 3.1). Even in such a case, can the economic impacts for some developing countries be larger in the long run than for most developed countries.

3.8 How should we deal with fossil-fuel dependent countries?

Global CO_2 mitigation is likely to particularly negatively affect fossil-fuel dependent countries, such as coal- and oil exporting countries and countries that rely heavily on (domestic) coal. During the COOL project it was debated if this would imply the need for compensation measures, as demanded by OPEC. While it was acknowledged that particularly low-income oil exporting developing countries may be significantly affected, compensation was not considered the proper strategy. First, the level of economic impacts will differ greatly between individual countries, depending on the relative importance of fossil-fuel exports to the economy and options for exporting gas. Moreover, the losses projected in the short term are often within the range of historical price fluctuations. During the 21st century, the depletion of conventional oil will make a shift to other energy resources and/or economic activities inevitable for most oil-exporting countries, even without climate policies (see Figure 3.1). Climate policies are likely to delay the depletion of conventional oil and extend revenues over a longer time period (Van Vuuren and De Vries, 2000, 2001). The matter was therefore considered as mainly an issue of economic adaptation to a new market reality. This does not exclude support low-income developing countries for adaptation policies. Moreover, use of the Kyoto Mechanisms, taxation on carbon rather than energy, the removal of coal subsidies, and use of bio-sinks will help to reduce the impact on oil producers and lower the overall costs of GHG reductions as well.

As noted, a (relatively) rapid shift away from coal to other energy resources may be particularly difficult in coal-intensive countries for social and political reasons. Physical carbon sequestration could then be an important option to limiting carbon mitigation costs and reducing their resistance to global GHG emission control. It therefore was considered important by many participants to further explore this option together with fossil-fuel dependent countries.

3.9 What is the importance of the timing of emission reductions?

It is often argued that the least-cost pathway for stabilising GHG concentrations is a gradual departure from baseline emission trends with more rapid reductions later on. This is explained by the fact that a gradual near-term transition from the world's present energy system minimises premature retirement of existing capital stock and provides time for technology development. While this seems generally true for stabilisation levels of CO_2 at 550 ppmv or higher, it does not seem to hold in the case of stabilisation at 450 ppmv.
The options for delaying action to achieve stabilisation of 450 ppmv have become more limited than a decade ago and will be further limited after the Kyoto Protocol.

A delayed response pathway for meeting 450 ppmv results in much higher levels of carbon intensity reduction than early action. According to IPCC (2001c), in the case of high emissions baseline scenarios (like A1F and A2) and for stabilising at 450 ppmv, early GHG mitigation is essential to avoid serious pressure on social development and technological progress in the second half of the 21st century. Calculated differences in costs between early action and delayed response are mainly dependent on the baseline and the applied discounting rates. In the case of stabilising at 450 ppmv and when using low discount rates (like 3%) early actions seems economically attractive, even in the case of low baseline scenarios, like B1, due to the advantages of technological learning (Van Vuuren and De Vries, 2000, 2001). Up to now, most macro-economic analyses using models (including WorldScan) do not take the advantages of technological learning into account. There is another reason why early action is to be preferred. It will result in a quicker reduction in the rate of climate change, which is much higher than ecosystems have been exposed to for the last 100,000 years, and is generally considered too high for many ecosystems to adapt to (IPCC, 2001b).

3.10 What are the co-benefits of GHG mitigation?

Policies and measures that reduce CO_2 emissions result in substantial co-benefits related to the impacts of simultaneous reductions of other pollutants, like particle matter, sulphur and nitrogen oxides. Measures to reduce carbon dioxide emissions go along with comparable reductions in nitrogen oxide and sulphur dioxide emissions (Figure 3.3), which are major contributors to transboundary air pollution, resulting in acidification and local air pollution with significant health effects.

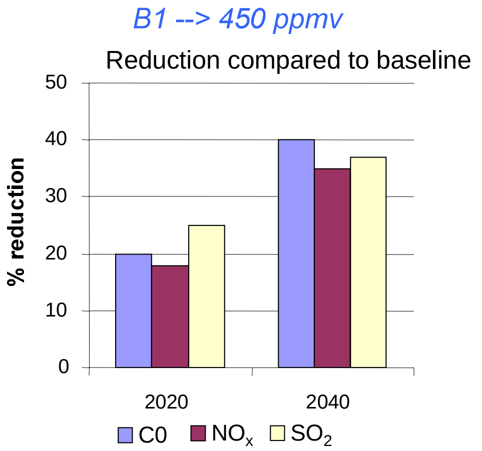


Figure 3.3: Co-benefits: reductions in global sulphur and nitrogen oxide emissions resulting from CO_2 mitigation in a 450 stabilisation scenario based on B1-based analyses with the IMAGE/TIMER model (Van Vuuren and De Vries, 2000).

Non-climate benefits are often excluded in evaluating optimal economic mitigation policies The quantification of the economic value of the co-benefits is still hindered by a lack of common methodologies, though progress is being made. Moreover, not all benefits can be easily monetised, e.g. non-market assets like biodiversity. Assessments by IPCC, OECD and the WEA nevertheless indicate that co-benefits are substantial, particularly by reducing costs related to health effects from local and regional air pollution. The magnitude and scope of these co-benefits will vary with local geographical and baseline conditions, but under some circumstances may form a significant fraction of private (direct) mitigation costs or even offset mitigation costs (IPCC, 2001c).

3.11 What are main barriers and opportunities of a transition to a low carbon future?

Many barriers hinder the implementation of options to reduce CO_2 emissions. Some of these are related to the costs of mitigation measures, but many are not. The back-casting exercise performed during the COOL project revealed that the type of barriers also depend on the kind of world we will live in. In a market-oriented A1 world, the price of new technologies, the costs of their development, a lack of willingness of the public to adjust lifestyles and governments to intervene could be important barriers; however, in a B1-sustainable-development oriented world the social and environmental implications of some mitigation options, like large-scale biomass or CO_2 removal and storage could be major barriers.

At the same time, there were barriers identified of a more general nature or resulting from present trends. Important barriers include:

- A lack of problem awareness / 'sense of urgency' among the general public;
- Uncertainty about climate policies (in particular for the private sector);
- Vested interests of fossil-fuel producing sectors (in developed and developing countries);
- Social implications of reduced coal use (in both developed and developing countries);
- Fear of industrialised countries of becoming too dependent on energy imports, in particular natural gas, when shifting from coal to gas;
- Privatisation / liberalisation of energy markets (in particular, for the development of renewables / energy research investments).

The participants of the COOL project also identified important opportunities:

- by 2050 the existing energy capital stock will be fully replaced, while even more capital stock will be newly installed, particularly in developing countries;
- the growth of emissions can be reduced by pursuing sustainable development policies (in both developed and developing countries);
- highlighting the co-benefits of GHG mitigation measures will help to implement them;
- removal of fossil-fuel subsidies (as part of liberalisation of energy markets);
- reduction of the dependence on energy imports from a limited number of countries (developed countries) / the burden of oil imports (developing countries) by the development of biofuel use and other renewables;
- growing societal forces related to new 'green' industries and the introduction of the Kyoto mechanisms.

3.12 What are important conditions for a transition to a low carbon future?

During the project participants identified a number of important conditions for achieving a 15-25% reduction in global CO_2 emission by 2050, largely irrespective of the type of world we will live in:

1. *A broad public awareness of the climate change problem and a belief that there are feasible, acceptable and affordable solutions.*
   For the acceptance and implementation of climate policies public awareness of the seriousness of the problem and its potentially wide-ranging negative implications is essential. It will also be useful for convincing and supporting industries and governments to take action.

2. *The development of clear and effective global and national climate policies that provide incentives to companies and consumers to change their behaviour and put a price on carbon emissions, both nationally and internationally.*
   Clear policies are important for industries for making (alternative) investment decisions and for putting a price on carbon emissions. They should include the use of the Kyoto Mechanisms (KMs) to enhance the cost effectiveness of mitigation strategies. In addition, in order to enable developing countries to take on quantitative commitments in the future and make use of the KMs, it is essential to enhance the monitoring and policy assessment capacity of these countries.

3. *Developed countries will have to take the lead and show the way by developing and implementing new technologies (e.g. fuel- cell car, PV) and adjusting lifestyles.*
   This requires a reversal of the downward trend in energy research investments, as well as a redirection towards renewables and low-carbon or carbon-free fossil energy options. Policies on sustainable development will be important for achieving lifestyle changes needed.

4. *Wide-scale and effective transfer / diffusion of modern technological knowledge to developing countries and integration of climate policies into sustainable development.*
   The transition to a low-carbon future will require a dramatic change of technologies and related knowledge and service infrastructures supporting them. This poses a challenge to developing countries and is likely to succeed only if there is a will to be a major transfer of technologies and the development of the capacity in developing countries to absorb and develop efficient and sustainable technologies. International climate policy regimes are likely to face major implementation problems if there are insufficient local incentives in developing countries. The support of sustainable development policies in developing countries, as in the area of energy, urban planning, waste management, forestry and agriculture, can help in developing effective strategies in limiting GHG emissions.

5. *Some support to fossil-fuel dependent developing countries to restructure their economies, develop new energy resources and technologies and to soften the regional consequences of reduced fossil-fuel production.*
   While the overall economic costs of a transition to low carbon futures seem limited, some sectors and countries will be substantially affected and may effectively hinder mitigation policies if simply ignored. This relates, in particular, to the coal and oil industries. and to countries heavily dependent on coal and oil use and export revenues. To overcome this problem, attention is needed for developing policies that will stimulate and support these sectors and countries to adapt to climate change policies by developing alternative sources of income (economic diversification, other energy resources like natural gas or renewables). This is done by exploring fossil-fuel pricing mechanisms and CO_2 sequestration options.

4. Organising global co-operation

4.1 What is the challenge?

Global climate change poses one of the most difficult organisational challenges humanity has ever had to cope with. A challenge that is likely to be more difficult to manage than the challenge of finding affordable technological solutions for the mitigation of greenhouse gas emissions. The organisational challenge results from the special features of the problem (IPCC, 2001). First, unlike many other environmental problems, climate change is truly global in nature and requires the co-operation of many states. Second, these states are very heterogeneous in character and are affected by climate change and climate change policies in different ways. Third, the abatement of GHG emissions requires the efforts of a multiplicity of decision makers at a wide range of levels - within international organisations, national governments, local governments and communities, and private enterprises and individuals. Fourth, climate change is a long-term problem with long system delays in cause -effect relationships, leaving efforts without immediately notable results. Finally, the level of uncertainty about the magnitude of climate change and distribution of impacts is high.

At the same time, the institutional structures to deal with the problem are far from ideal. We have a United Nations Framework Convention on Climate Change (UNFCCC, 1992), ratified by almost all the states, which came into force relatively quickly (1994). The Convention contains a common goal - stabilisation of the GHG concentrations in the atmosphere at a level that prevents dangerous anthropogenic interference with the climate system- but this objective has not yet been quantified. Neither does the UNFCCC include legally binding emission limitations. Developed countries were asked to bring back their GHG emissions to their 1990 levels by 2000. Very few have been able to meet this goal. In 1997, the UNFCCC was followed by a supplemental agreement, the Kyoto Protocol (UNFCCC, 1998), defining binding quantified commitments for the developed countries for the 2008-2012 period. While the targets were set, the rules for implementation were left unsettled. These became object of ongoing negotiations. After an earlier failure during the sixth Conference of Parties (CoP6) in The Hague (2000), Parties eventually were able to reach final agreement on the rules for implementation at CoP7 in Marrakesh (2001), notwithstanding the US decision to withdraw from the Kyoto Protocol earlier the same year. This has made the prospects for ratification of the KP by enough states to have it enter into force favourable.

If ratified, the Kyoto Protocol will only be a first and minor step towards an effective control and eventual reduction of global greenhouse gas emissions. Much more difficult steps lay ahead. Developed countries will have to further reduce their emissions and at some time developing countries too will have to take on emission limitation or reduction targets if an overall stabilisation of GHG concentrations is ever to be achieved. While developing country CO_2 emissions presently constitute about 40% of anthropogenic CO_2 emissions, per capita emissions are on average about 5 times below those in the industrialised countries. It is expected that within a number of decades their emissions of developing countries will exceed those of the industrialised countries, even if the Kyoto Protocol does not enter into force (although per capita emissions would still be far below those in industrialised countries).

One of the most crucial issues for the development of an effective international climate change regime is the issue of the future differentiation of commitments for developed and developing countries, or to put it more simply: who should do what by when? This was one of the issues that has been explored and discussed during the global COOL dialogue project. It has turned out to be a contentious issue because it relates strongly to diverse views of equity or fairness. At the same time, the limitations and risks of the present ad hoc approach as adopted by the Kyoto Protocol were recognised. Especially if we want to bring global CO_2 emissions back to under the present levels before the middle of this century, dealing with the question of an equitable differentiation of commitments becomes an urgent issue.

4.2 What are the limitations of the Kyoto Protocol approach?

In terms of differentiation of commitments, the Kyoto Protocol does not set a very good precedent for future negotiations. First, there is no clear principle or logic as to how Annex-I countries got their targets. The outcome of the negotiations seems to be mainly determined by what the various countries were willing to commit themselves to. In order to secure the participation of all developed countries, the negotiations resulted in situation where countries that bargained hard got exceptional allowances, while others committed themselves to lower targets than they were originally willing to accept. Thus, without accepted principles and rules for determining a fair differentiation of commitments, negotiations resulted in a watering down of the overall emission reduction target.

Second, the KP is based on a simple division between developed and developing countries, which will be problematic in future climate change negotiations. It has already resulted in resentment. Many developed countries are unhappy with the fact that some more developed non-Annex-1 countries like Singapore, South Korea and Mexico don’t have commitments under the KP, while Turkey has repeatedly requested to be removed from the Annex I list because it is not a high-income country. At the same time, the internal burden sharing arrangement within the EU, allowing some poorer countries like Portugal and Greece to substantially increase their emissions, has also led to resentment among other Annex-1 countries and accusations of inconsistency between internal and external EU climate policies. This has weakened the EU negotiation position versus other Annex-1 countries in demanding emission reductions.

Third, the negotiations on the KP resulted in an agreement on targets at CoP-3 (Kyoto), but left the ‘rules of the game’ unsettled. These rules concern many issues that have major implications for the effectiveness, stringency and costs of the agreed targets, like the use of the KMs and sinks in meeting the emission targets. As a consequence, in the post-Kyoto negotiations these more technical issues have become the subject of re-negotiating the commitments, in some cases resulting in (proposals for) ad hoc arrangements to promote ratification, which may prove an undesired precedence for the future. For future arrangements it seems wiser to first reach agreements on the rules of the game before setting targets.

Fourth, the way the KP was negotiated has been criticised by many developing countries. Much of the negotiating took place in informal and parallel sessions, which limited the access of developing countries to and transparency of the negotiation process (see Mwandosya, 1999 and Gupta, 2000). It has made the G-77 and China operate as a closed block, notwithstanding their internal differences of opinion and interests. For negotiations on future differentiation of commitments a more open and transparent negotiation process, allowing for a more equal participation of developing countries, will be important to overcome present block divides.

Finally, the Kyoto Protocol takes a decadal, short-term approach to commitments without a long-term perspective. This encourages near-term actions to meet the Kyoto target that may be incompatible with requirements for stabilising GHG concentrations in the long term.

4.3 What type of climate regime approach do we need?

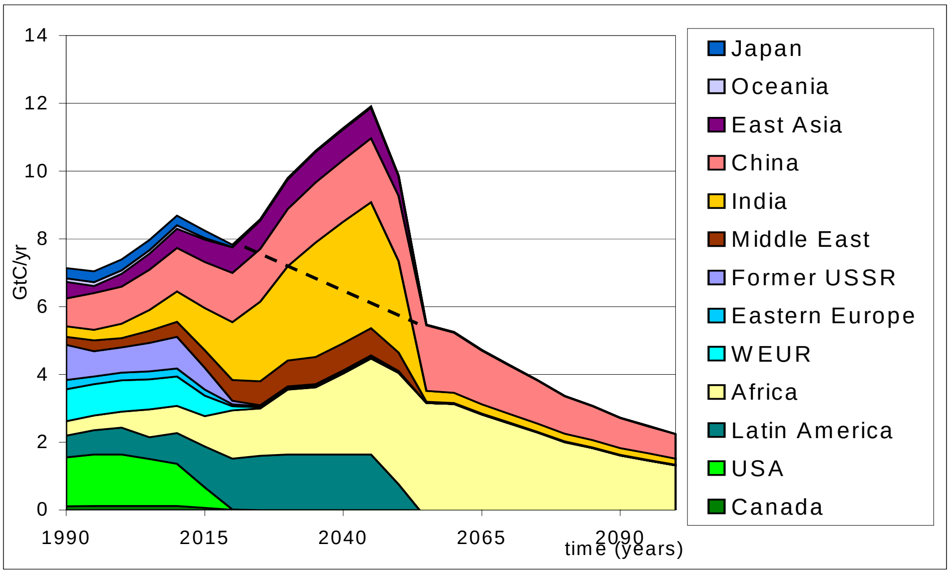
The lack of any systematic approach or architecture for the Kyoto targets poses a potential threat to the development of an effective and acceptable future climate regime. An incremental evolution of the climate regime in the form of a gradual ad hoc extension of the Annex-I group is unlikely to bring about the level of global emission control needed to keep the option of stabilising CO_2 concentrations open at 450 (550 ppmv equivalent).

In order to keep the option of stabilising CO_2 concentrations open at 450 ppmv, major developing countries (like China and India) need to start participating in global greenhouse gas emission control at much lower levels of income than the developed countries did at the time of signing the UNFCCC. This can be illustrated by analyses with RIVM's FAIR model (Framework to Assess International Regimes for differentiation of commitments) (Den Elzen et al., 2001)[2].

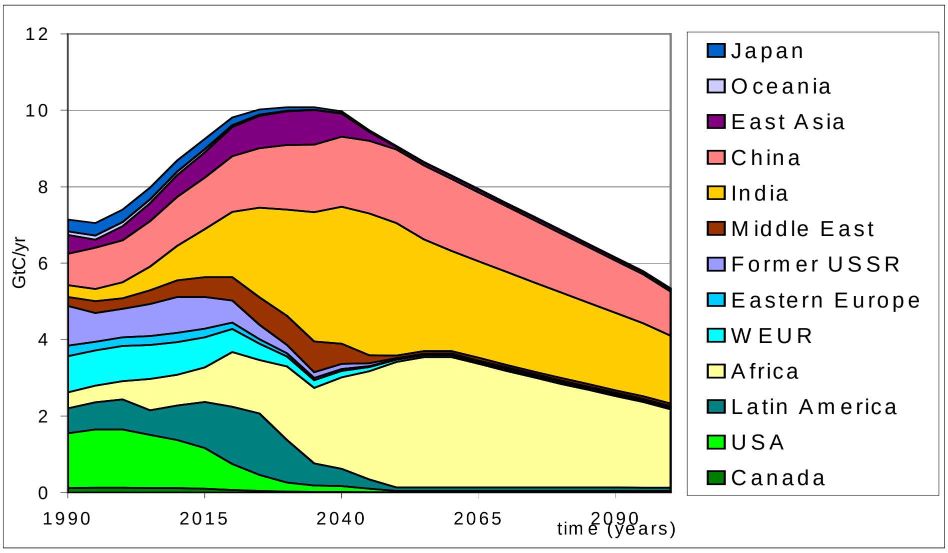
If the group of countries adopting quantified commitments after the first commitment period were limited to middle-income developing countries only, and these countries were initially only to take on efficiency improvements targets, CO_2 stabilisation levels of 550 ppmv or lower may be out of reach if this set a precedent for future extensions. The reason for this is that major, but relatively poor developing countries, like China and particularly India, then would start too late with controlling their emissions (see Figure 4.1).

Based on these insights many participants of the COOL Global Dialogue held the view that there was a need to develop a *comprehensive approach*: i.e. a regime that defines principles, criteria and rules for differentiating future commitments for all countries in a consistent and transparent way. This will make the adoption of future commitments predictable and legitimate, and will provide more guarantees for an effective control of global GHG emissions in order to meet the goals of the Climate Convention.

[2] The FAIR model is a tool to quantitatively explore a range of alternative climate policy options for international differentiation of future commitments and link these to targets for global climate protection. The FAIR 1.0 version is based on the IMAGE 2.1 model, includes 13 world regions and four parts: a scenario construction and evaluation mode and three modes for evaluating different approaches for differentiating commitments (increasing participation; convergence and triptych). The model is downloadable from the RIVM web site: http:\\ www.rivm.nl\fair



(a)



(b)

Figure 4.1: Global and regional CO_2 emission allowances for an increasing participation regime aimed at stabilising CO_2 concentrations at 450 ppmv (a) and 550 ppmv (b).

There is a participation threshold of 75% of 1990 Annex-I per capita income, and burden sharing is based on per capita CO_2 emissions. In the case of the IMAGE-SRES A1 scenario India and China only participate after 2040. Under this assumption it is not possible to meet the goal of stabilisation at 450 ppmv, and there is hardly any emission space for developed countries if the goal is to reach 550 ppmv. Note: the dotted line in (a) indicates the 450 emission profile. Source: FAIR model (Den Elzen et al., 2001)

All COOL participants realised that it will be difficult to agree on any such approach, and that it may take much time to get to agreement. Some participants were therefore sceptical about the chances of making much progress if negotiations were focused on reaching agreement on such an approach. They expect more results from an incremental approach that starts with involving developing countries on the basis of voluntary commitments with relative targets or technology agreements. This should allow developing countries to participate early and make use of the KMs without posing any risks for their economic development (see Hargrave, 1998; Baumert et al. 1999; Philibert, 2000). However, it was generally acknowledged that such an approach – if not part of a comprehensive one - might not be sufficiently effective to keep open the option of stabilising CO_2 concentrations at 450 ppmv. In any case, ratification of the Kyoto Protocol would provide time to develop a more comprehensive future regime without delaying action.

4.4 How to deal with equity in differentiating future commitments?

Equity will be an essential element of any future international climate regime that will be acceptable to all and thus most probably effective. The issue of equity in future climate regimes embraces a broader package than principles and rules for the differentiation of mitigation commitments. Equity also concerns the distribution of costs for adaptation to and impacts of climate change. IPCC (2001b) has indicated that particularly developing countries will be damaged by climate change because they are more vulnerable.

While the distribution of costs for adaptation to and impacts of climate change will probably be dealt with via other policy instruments (like an adaptation fund), the distribution is likely to also play a role in discussions on a fair differentiation of mitigation efforts. Moreover, climate impacts and adaptation costs will certainly play a major role in discussions on the 'adequacy of commitments' and thus on the (overall) stringency of reduction targets.

The COOL dialogue project demonstrated that perceptions about an equitable differentiation of future commitments differ widely; no common position on the issue could be found. Some view the agreement on equity principles between developed and developing countries as a precondition for effective international collaboration to combat climate change. It may be a difficult road but it is the only one. Others consider such an approach too idealistic and fear it may burden the climate debate so much that no real progress will be made. They generally believe in a more pragmatic step-wise approach rather than grand solutions.

Equity aspects were concluded to be an important element of future differentiation of commitments but should not become an overriding issue. In looking for acceptable climate change regimes it seems wise not to focus on any single equity principle, but instead to look for approaches embracing different equity principles. Principles, like differentiation rules can only be guiding, not decisive with regard to the differentiation of commitments. They may help by providing defaults for starting negotiations and a measure against which countries must argue for exceptions.

Moreover, focusing too much on principles of equity would also overlook the relevance of other aspects of future climate change regimes, such as environmental effectiveness, efficiency, operational requirements, institution-building, and the role of side-policies such as technology transfer.

Box 4.1 Other relevant dimensions of regimes for differentiation of commitments

In addition to equity principles, there are a number of other dimensions of the architecture of possible regimes for the differentiation of future commitments.

Problem definition: burden sharing or resource sharing (or focus on sustainable development)?
The climate change problem can be defined as a pollution problem or as a global commons issue. These different approaches have implications for the design of climate change regimes. In the first approach, the focus will be on defining who should reduce or limit their pollution and by how much; in the latter approach the focus is on who has what user rights; the reduction of emissions will be in line with the user rights.
Alternatively, the climate change problem can be viewed as part of our unsustainable development path and its solution an integral part of sustainable development policies. In that case the focus would no longer be on the development of a climate regime or defining climate targets, but instead the attention would be shifted to the development and distribution of sustainable technologies and lifestyles. Such an approach would go beyond the boundaries of the options for the differentiation of commitments presented here.

Overall emission limit or not?
One can define the emission reduction top-down by first defining globally allowed emissions and than apply ing certain participation and differentiation rules for allocating the overall reduction effort needed. Alternatively, one could allocate emission control efforts among countries in a bottom-up fashion, without a predefined overall emission reduction effort. In the top-down approach the question of adequacy of commitments is separated from the issue of differentiation of commitments. In the bottom-up approach, the two are usually dealt with at the same time.

Participation (thresholds/ timing).
A fourth dimension is that of the degree of participation: who should participate in sharing the burden and when does their obligation begin? This issue concerns discussions on both the type of thresholds for participation and the threshold level or the timing. At the same time, there is no need for all countries to participate in the same way. This points to yet another dimension: the form of the commitment.

Form of commitment.
The form of the commitment for countries can be equal for all, like the binding emission target in the Kyoto Protocol, but targets could also be defined in a differentiated manner (see e.g. Baumert et al., 1999; Claussen et al., 1998). Instead of absolute targets, commitments may be defined as relative or dynamic targets, such as a reduction in energy and/or carbon intensity levels, or in terms of policies and measures. There is also the option of non-binding commitments.

We can use these dimensions to identify differences between the various approaches presented.

Table 4.1: Comparison of differences approaches to international burden differentiation

Dimensions	**Multi-stage**	**Per capita convergence**	**Triptych**
Equity principles			
• Responsibility	X		
• Capability	X	(X)	X
• Need	X	X	X
Problem definition			
• Pollution problem	X		X
• Global commons issue		X	
• Part of sust. development			
Emissions limit			
• Top-down	X	X	
• Bottom-up			X
Participation			
• Partial	(X)		
• All	X	X	X
Form of Commitment			
• Equal		X	X
• Differentiated	X		

X= applicable; (X) = partly applicable

Nevertheless, whatever the principles and rules for differentiation adopted, there are a number of *outcomes* generally considered to be unacceptable:

- Pollution is being rewarded;
- Countries with the highest ability to pay have the smallest commitments;
- Climate change or climate change policies increase the present global inequality;
- Developing countries have to decrease their emissions immediately, and
- A group of countries, developing countries in particular, bear a disproportional or abnormal burden.

These can be considered important criteria for evaluating the acceptability of any proposal for future differentiation of commitments. In fact, they reflect widely accepted equity principles, which are also included in the UNFCCC (see below). The first criterion negates the 'polluter pays' principle. The second criterion negates the 'ability to pay' principle. The third and fourth criterion would be in conflict with the right to development, and the fifth criterion reflects the principle of proportionality, as laid down in Article 3.2 of the UNFCCC.

4.5 What are the relevant principles for distributive fairness?

Many different categorisations of equity principles can be found in the literature (see Banuri et al., 1996). In recent studies (Ringius et al., 2000), three main principles for distributive fairness are identified in reviewing the most relevant elements for a widely accepted approach to burden differentiation in future international climate negotiations. These are:

- *Responsibility*[3]*:* costs should be distributed in proportion to a country's share of responsibility for causing the problem;
- *Capacity:* costs should be distributed in proportion to country's ability to pay;
- *Need*: all individuals have equal rights with regard to pollution or using the atmosphere to secure basishuman rights e.g. the right to a decent standard of living.

These three elements are also reflected in the both the Rio Declaration and the UNFCCC, which states:

> "The Parties should protect the climate system for the benefit of present and future generations, on the basis of *equity* and in accordance with their common but differentiated *responsibilities* and respective *capabilities, …"* UNFCCC, Art. 3.1)

This simplified typology no longer includes the principle of sovereignty. This is a basic principle in international relations, stating that all states are equal and have an exclusive right to govern their territory. In international environmental negotiations, this principle is often used to claim status quo rights. This is the principle behind the rule of equal obligations (e.g. flat rate reductions), which seems to be the default option in international negotiations. However, the legitimacy of the principle of sovereignty is being eroded, particularly in international environmental law. According to international environmental law states should prevent transboundary damage resulting from activities on their territory. The sovereignty principle, therefore, no longer has sufficient legitimacy to defend unlimited GHG emissions. However, it is not necessary to resort to the sovereignty principle in international law to legitimate a claim of

[3] Ringius et al. use the term 'guilt'. Since this is a highly moralistic term and the term 'responsibility' is used in the UNFCCC, we prefer the latter term.

historical rights or entitlements. These can be legitimately argued for on grounds of equity considerations independent of the sovereignty principle. The claim of status quo rights and related proposals for a flat rate reduction or grand-fathering of GHG emission permits thus still have some bearing and cannot be easily dismissed (Müller, 1999). The relevance of historic rights is also illustrated in the per capita convergence approach (see below). Nevertheless, in case of conflicting principles the principle of acquired rights no longer seems to have the same leverage as the three above-mentioned principles of responsibility, capability and need.

4.6 What are the options for comprehensive climate change regimes?

The choice for a comprehensive approach leaves open the question of what future climate regimes may actually look like. One can image many options. During the COOL Dialogue project a number of different comprehensive climate change regimes were discussed without reaching any conclusions about what type of regime would be preferred. These were Increasing participation/Multi-stage approach, per capita Convergence and the Triptych approach. These do not constitute a complete set of options. Other options and also combinations of options could be thought of as well. However, these represent different approaches that have been proposed in international climate policy debates.

Increasing (level of) Participation / Multi-Stage approach:
One type of regime that remains close to the present climate regime is 'Increasing (level of) participation' or the Multi-stage approach. In this approach, the level and type of commitments is differentiated amongst countries on the basis of (alternative) participation and burden-sharing rules (Gupta, 1998; Den Elzen et al., 1999). This results in an increase in the number and level of participation of countries over time. The various levels of participation could be organised as different annexes to the UNFCCC.

The main equity principle behind this approach is responsibility / polluter pays principle. However, by defining one or more thresholds for different levels of participation, the approach also accounts for the principles of need and capability. It was originally developed as a global application of the Brazilian proposal to relate countries' relative contribution to emission mitigation to their relative contribution to (realised) global warming (Berk and Den Elzen, 1998; Den Elzen et al., 1999). Later, the approach was extended to a Multi-stage one, according to the ideas from Gupta (1998). Altogether, the increasing participation approach, as adopted in the FAIR model, now offers a four-stage regime to differentiate commitments among countries over time, which can be summarised as follows (Den Elzen et al., 2001):

Stage 1: Reference scenario: Non-participating countries (non-Annex I) first follow their baseline emission scenario (reference scenario) until they meet a de-carbonisation threshold;
Stage 2: De-carbonisation targets: The countries then enter a stage in which their allowable emissions are controlled by de-carbonisation targets, defined by the rate of reduction in the carbon intensity of their economy (C/GDP). A region leaves this stage when it attains any of the selected participation thresholds.
Stage 3: Stabilisation of emissions: The countries enter an emissions stabilisation period, in which they stabilise their absolute or per capita emissions for a user-defined number of years before actually entering the burden-sharing regime.
Stage 4: Emission reduction sharing regime: The emission reduction rules then determine the emission reductions for each of the participating regions.

Ideally, the de-carbonisation stage results in a reduction of the increase in allowable emissions. The stabilisation stage, then, acts as an intermediate stage between an increase and subsequent decrease in allowable emissions.

Illustrative case: What might a Multi-Stage approach for stabilising CO_2 concentrations at 450 ppmv look like?

As indicated previously, stabilising atmospheric CO_2 concentrations at 450 ppmv, will require participation of developing countries in global emission control at much lower per capita income levels than average Annex-1 levels of 1990. In order to have early participation, while leaving room for an increase in emissions for economic development, the following Multi-stage approach case was explored (see also: Berk and Den Elzen, 2001):

- until 2013 Annex B countries fulfil their targets under the Kyoto Protocol, while Non-Annex B countries follow their baselines (IMAGE 2.1 IPCC SRES A1 emissions scenario) (see Chapter 3);
- after 2012 all Non-Annex B countries adopt de-carbonisation targets (3% per year);
- Non-Annex B countries join the Annex B countries when their per capita CO_2 emissions reach the world average level.
- Annex B countries share the efforts of limiting global emissions below the ceiling of the emission profile for stabilising CO_2 concentration at 450 ppmv
- Differentiation of commitments within Annex B is based on per capita emission levels.

The use of a participation threshold based on world average per capita emissions rewards both emission reductions by the industrialised regions as well as efforts by developing countries to control the growth in their emissions (e.g. by improving their energy efficiencies and/or developing renewable energy sources). As a rule for the differentiation of commitments we have selected per capita CO_2 emissions, but per capita temperature increase may have be selected as well[4].

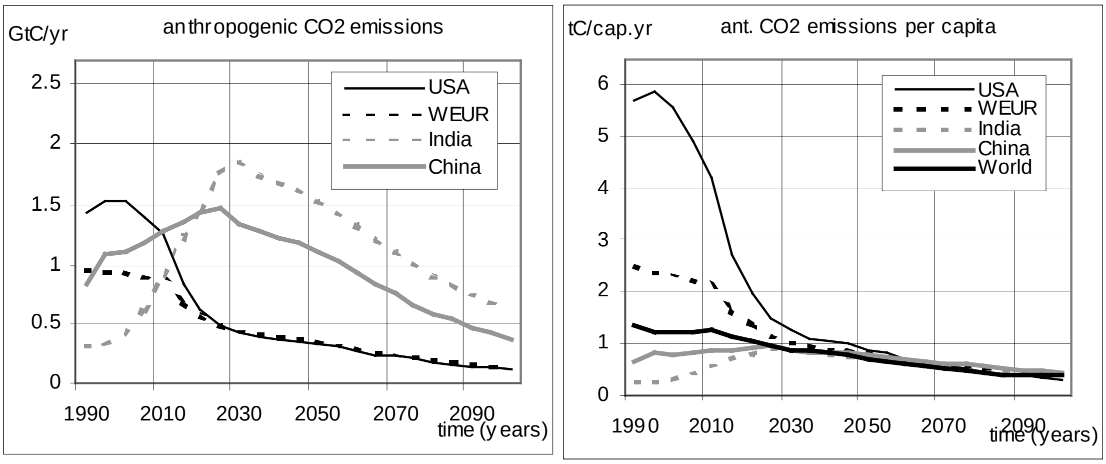


Figure 4.2: Regional absolute and per capita emission space under an increasing participation regime with a global CO_2 emission profile for stabilising CO_2 concentrations at 450 ppmv with burden differentiation based on per capita CO_2 emissions.
Source: FAIR model RIVM (Den Elzen et al., 2001)

[4] With per capita temperature increase a developed region's per capita permits would be lower and be reduced to well below the world average due to their larger historical emissions.

This case would imply that Latin America would have to participate in the emission reduction regime from the second commitment period onwards, while China, India and Africa would first be allowed to increase their emissions until 2025, 2030 and 2040, respectively. At the same time, the emission space for the EU, Japan and, in particular, the USA and Oceania would diminish sharply. However, the emission profile and resulting allocation of emission space will not only demand substantial efforts from developed countries, but also from developing countries, when compared to their baseline developments.

Per capita Convergence approach:
An alternative approach, that would be a major shift away from the present Protocol approach is the so-called 'Contraction and Convergence' approach of the Global Commons Institute (GCI)[5], which defines emission rights on the basis of a convergence of per capita emissions under a contracting global emission profile. In the per capita Convergence approach all countries participate immediately in the emission control regime (after the first commitment period). The per capita emission convergence approach is a combination of sovereignty/status quo rights and the need / egalitarian equity principle. It leaves aside differences in historical contributions to the problem[6]. The approach was first introduced by the Global Commons Institute as 'Contraction and Convergence'. Early results of the approach were published to good effect at the Second Conference of the Parties (CoP-2) and have been distributed widely since then. (Meyer, 2000). Later, the Indian Centre of Science and Environment (CSE) suggested a variant in which the concept is combined with basic sustainable emission rights related to both the idea of survival emissions as well as the idea of global commons as natural sink for CO_2 (in particular the oceans).

Illustrative case: Convergence under a CO_2 emission ceiling for stabilising at 450 ppmv

We used the FAIR model to analyse the regional distribution of emission allowances resulting from a linear convergence of per capita CO_2 between 2012 and 2030 with a CO_2 emission profile for stabilising CO_2 concentrations at 450 ppmv (Figure 4.3).

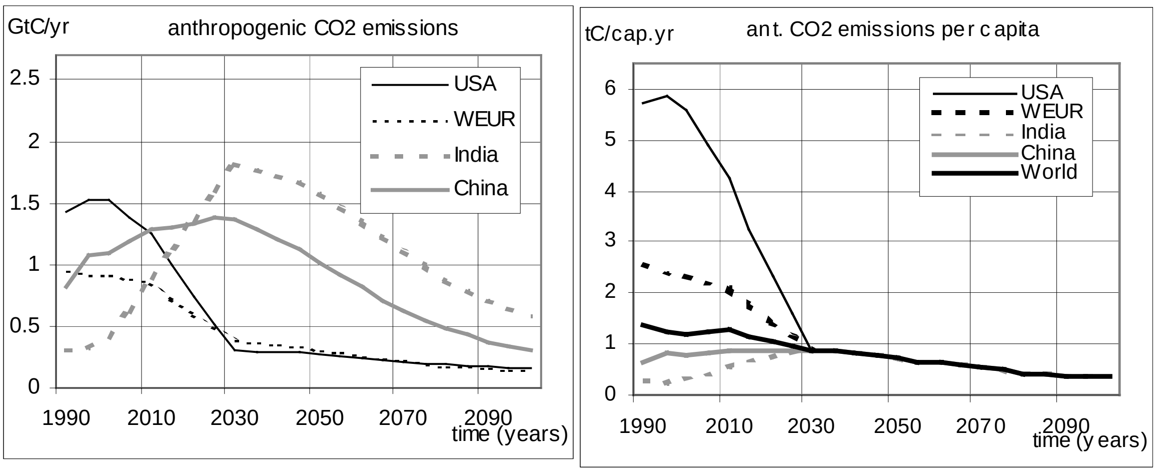


Figure 4.3: Regional absolute and per capita emissions with a linear convergence of CO_2 emissions between 2013 and 2030 under a global CO_2 emission profile for stabilising CO_2 concentrations at 450 ppmv. Source: FAIR model RIVM (Den Elzen et al., 2001).

[5] The GCI website can be found on the Internet through: http://www.gci.org.uk.
[6] The principle of responsibility could be combined with the convergence approach if the criteria were per capita contribution to the CO_2 concentration or temperature increase, but this has not been suggested.

Under a global emission constraint for stabilising CO_2 concentrations at 450 ppmv by 2100, convergence in per capita emission allowances will imply a strong reduction in Annex B regions' allowable emissions after the first commitment period under the Kyoto Protocol. This holds, in particular, for North America, Oceania and Western Europe (75%, 75% and 60% reduction, respectively, by 2050 compared to 2010 levels). At the same time, for stabilising at 450 ppmv there is only limited space for Non-Annex B regions to still increase their per capita emissions. In fact, the per capita emission space of Latin America already shows a decrease during the 2013-2030 period. In some developing regions, like India and Africa, allowed emission levels could exceed actual emission levels (given the projected baseline levels), resulting in surplus emission permits. However, the level of surplus permits is dependent on baseline projections and with stringent stabilisation targets is likely to occur only for a limited time period. Over the longer term, after full convergence in per capita emission allowances, the gap between baseline emissions and emission allowances is usually larger for developed than developing regions.

A sector- and technology oriented approach: Triptych

A quite different approach to the previous ones would be a type of regime that is sector- and/or technology-oriented in differentiating commitments. These regimes could be based on common technology standards or common policies and measures. Such approaches would be more bottom-up in character, although they could be combined with specific overall emission targets. One such approach explored during the COOL Dialogue project is the so-called Triptych approach (Blok et al., 1997; Phylipsen et al., 1998; Groenenberg et al., 2001). This approach was used within the EU to help define its internal differentiation of targets for the Kyoto Protocol. For the COOL project this approach was applied at global level.

The Triptych method is a sector approach to burden sharing, which allows different national circumstances to be taken into account. The approach embraces considerations of fairness related to both equity, capability and need. In the Triptych approach three categories or sectors of emission sources are distinguished:

- *Domestic sectors:* the residential sector, the commercial sector and sectors for transportation, light industry and agriculture.
- *Industrial sectors:* the internationally oriented industries, such as the iron & steel industry, non-ferrous metals, pulp & paper industries, the chemical industry and refineries.
- *Power sector:* the electricity production sector.

The selection of the Triptych categories is based on the main issues encountered in negotiations on international burden sharing in emission control: differences in standard of living, fuel mix, economic structure and the competitiveness of internationally-oriented industries. Different criteria are used for each of the categories to calculate the emission allowances. In the domestic sectors regional allowable CO_2 emissions are assumed to be primarily related to population size. Therefore a per capita approach is assumed appropriate here. Differences in development are taken into account by allowing convergence of per capita CO_2 emissions over time. For the industrial sector, allowable CO_2 emissions are calculated on the basis of the projected growth in industrial output, and targeted improvement rates for energy intensity of the industrial production and for the carbon-intensity of industrial energy consumption (carbon emissions per unit if primary energy use). For the energy-intensity levels it is assumed that regions converge over a period of time in the direction of the most efficient region.

The allowable CO_2 emissions from the power sector are defined by the projected demand in electricity and targeted improvements in the efficiency and the carbon intensity of the power sector. The carbon intensity of the power sector is defined by two factors: (1) the share of CO_2-free sources in the primary energy use (i.e. by use of renewables and/or nuclear energy) and (2) the carbon intensity of the fossil-fuel based share in primary energy use related to the fossil fuel mix. Based on historical experience, the growth in electricity demand is linked to the projected growth of GDP. This growth is corrected for end-use energy efficiency improvement in other sectors of the economy.

Overall national emission allowances are then calculated by adding up the emission allowances for each sector. Sector allowances are only used for calculating the overall emission allowances and not intended to be binding for the sectors.

4.7 What are the strengths and weaknesses of the various approaches?

In evaluating the strengths and weaknesses of the various approaches, we used the following evaluation criteria:

- comprehensiveness regarding equity principles;
- environmental effectiveness;
- flexibility and exclusiveness;
- simplicity and operational requirements;
- economic efficiency.

The findings are summarised in Table 4.2 (see also Berk et al., 2001).

Comprehensiveness regarding equity principles
The Multi-stage and Triptych approach are based on more than one equity principle. The Convergence approach is mainly based on the egalitarian equity / need principle, but also on the status quo / historical rights principle, by allowing for a transition period.

Table 4.2: Evaluation of different approaches to international burden sharing

Dimensions	Multi-Stage	Convergence	Global Triptych
Coverage of different equity principles	+	-	+
Level of environmental effectiveness	+(++)*	++	- (++)*
Level of flexibility / openness	+	-	++
Level of simplicity / ease of implementation	+/-	+	-
Level of economic efficiency	+/-	++	++)**

Legend: ++ = very good; + = good, +/- = fair; - = moderate; -- = poor
*) : ++ if used in combination with a global emission ceiling
**) : if all countries participate immediately

Environmental effectiveness
In principle, environmental effectiveness is best secured if a climate regime is based on global emission targets and all countries participate in binding quantitative emission limitations, provided sufficient compliance is achieved. Therefore, a typical top-down approach like the per capita convergence approach and also the Multi-stage approach - when combined with a global emission ceiling - provide a better guarantee for environmental effectiveness than a bottom-up global Triptych approach.

Flexibility and exclusiveness
Flexibility of a regime approach is important to take account of special circumstances of certain (groups of) countries and to adapt to new circumstances created by new scientific information. With respect to the first, the bottom-up Triptych approach offers the most flexibility in taking differences between countries into account, while the top-down per capita convergence approach disregards differences other than per capita emission levels, and thus offers the least flexibility. However, a convergence approach could also account for special circumstances by adding correction factors to the overall per capita distribution of emission rights, e.g. account for physical circumstances related to geography or climate. The flexibility of the Multi-Stage approach is mainly based on a differentiation of the type of commitments during the various stages and the selection of different thresholds for switching from one to the other stage, but also here introducing grounds for exemptions could increase flexibility. The exclusiveness of regimes indicates to what extent future regime changes are excluded. Of the various approaches, the per capita convergence approach is the most exclusive because it implies a shift of policy paradigm: from a pollution problem to a distribution problem related to the use of global commons. The per capita emission convergence approach would also imply that the issue of historical responsibility is definitely left aside. The Multi-Stage approach and Triptych approach are more open to future regime change, although here too there will be a strong interest in sticking to the approach adopted due to raised expectations and perceptions of fairness.

Simplicity and operational requirements
Simplicity is a desirable asset of a regime for differentiation of commitments. A simple regime design makes its implications easier to assess and to communicate and is often also easier to implement and to monitor. Of the various approaches, the Convergence approach is the most simple and easiest to communicate. The complexity of the Multi-Stage approach is somewhat dependent on the participation and burden-sharing rules chosen: accounting for historical contributions to climate change introduces data and model uncertainties (as in the Brazilian proposal). In a technology-oriented approach like the Triptych approach there is the need to determine baseline developments for target-setting, in contrast to the per capita convergence approach where targets are set independent of baselines. Moreover, the Triptych approach requires detailed sector information. However, policy makers may not regard this as an important obstacle because the advantage of more bottom-up approaches is that they provides policy makers with a better insight into the efforts required and the fairness of the distribution of efforts among all countries. This has been a major factor in the successful application of the Triptych approach in the EU[7].

With respect to operational requirements it is obvious that any comprehensive regime that

[7] At the same time, it is unlikely that countries would like to be bound by sector-oriented goals, as this would reduce their flexibility in meeting their targets.

defines quantified commitments for less developed countries with poor statistical registration and verification systems will run into substantial operational problems with respect to monitoring of compliance. In approaches that exempt the least developed countries from any quantified commitments, like the Multi-Stage approach, this will be less of a problem.

Economic efficiency
The adoption of the Kyoto Mechanisms (KMs) in the Kyoto Protocol has drastically changed the context for discussing the economic efficiency of various regimes for burden sharing in global greenhouse gas control. In principle, their introduction would offer the possibility of attaining a high level of economic efficiency regardless of the burden-sharing arrangement. Even emission reduction options in countries without emission targets can then be used via the Clean Development Mechanism.

A Convergence regime offers the best opportunities to explore the cost-reducing options, as all countries can fully participate in global emission trading. First, there may be excess emissions, but this will not affect the efficiency of the regime, only the distribution of costs. Second, there will be no carbon leakage to developing countries without emission targets, as possibly occurring in a Multi-stage regime. In a Multi-stage approach, and in the Triptych approach, countries adopting de-carbonisation and or efficiency targets may also join emission trading as far as their improvements exceed their targets. For countries without any quantitative targets the option of CDM projects remains. However, over time, this will result in complex accounting and target-setting for each subsequent commitment period, since real values will have to be corrected for emission reductions sold to other countries.

4.8 What about the political feasibility of the various approaches?

Since the beginning of the climate negotiations many developing countries, in particular, have supported a ‘per capita approach’ in discussions on commitments. Support for the per capita approach should, however, not be confused with the per capita convergence approach: the latter implicitly also accepts status quo / historic rights by accepting the need for a transition period. Nevertheless, over the years the political support for the convergence approach has grown as well, and not exclusively in developing countries (see website GCI). More recently, there is also a more open mind for the convergence approach in various European countries. Apart from a French proposal during the Kyoto Protocol negotiations, the convergence approach was also part of the Triptych approach used for arriving at an internal EU burden-sharing agreement (Torvanger and Godal, 1999). The lack of support from other industrialised countries is not very surprising given the fact that - except for Japan - per capita emissions are usually much higher than in the EU. Apart from economic reasons, there is also resistance for political reasons: some view the per capita convergence approach as an attempt to try to deal with unequal development as well. They oppose such a linkage, as it would make the climate problem irresolvable. Moreover, the convergence approach would imply a shift of policy paradigm from a pollution / burden-sharing problem to a global commons / resource sharing issue. There may be fears that acceptance of the resource-sharing paradigm may spill over to other resource issue areas. Overall, it seems that while the political appeal of the per capita convergence approach is growing, there is still major political resistance to be overcome.

Discussions on a Multi-stage approach will tend to focus on principles of responsibility and capability. Politically, the approach fits in well with concept of ‘common but differentiated responsibilities’ in the Climate Convention (Art. 3) and the basic approach of adding protocols and annexes to the Framework Convention, specifying commitments and groups of countries to which these apply. The element of (historical) responsibility, which is not part of the per capita convergence approach, is considered important by many developing countries. One problem with a comprehensive Multi-stage approach is that there are many policy issues to be negotiated, both related to different participation triggers and to criteria for the distribution of commitments. Compared to the convergence approach, this not only increases the complexity of the negotiations, but also makes it more difficult to communicate the rationality and the idea of fairness of the regime to political constituencies.

The Triptych approach is not likely to encounter many fundamental political objections. Of all approaches, it is the most technocratic or pragmatic. It is partly based on the egalitarian equity / need principle, but not as the basic rule. While the sector approach makes the Triptych approach rather complex, it has the political advantage of substantiating policy claims and giving insight into the distribution of effort required. This has proven to be very fruitful in the internal EU discussions on burden sharing, both prior to and after the Kyoto Protocol agreement. However, global application involving many more countries will be more complex.

An important difference between the various approaches is the position of the least developed countries. In the convergence approach, these countries may be given more emission allowances than their actual emissions, which will provide additional income. Under a Multi-stage or Triptych regime, developing countries taking on quantified commitments will have to pay for their own efforts and can only sell what they do in excess of their commitments. Many least developed countries fear that they will profit less from the CDM than more developed developing countries, because they have fewer emission reduction opportunities to offer. For the least developed countries the convergence approach is therefore not only more attractive than the other approaches, but also better than what they would get under the Kyoto Protocol or when being exempted from emission targets.

At the same time, as indicated previously, the economic impacts for developing countries in the long term could be larger than for developed countries, in particular if they follow high emission development paths. A convergence approach would thus not only provide the least developed countries with means to pursue sustainable development and adapt to climate change, but also be an incentive to all developing countries to avoid unnecessary high emissions in the future and pursue a sustainable development path from the start.

5. Short-term implications and actions

5.1 What are the short-term implications of leaving open the option of stabilising CO_2 concentrations at 450 ppmv?

From the assessment during the COOL global project we can conclude that a 15-25% reduction in global CO_2 emissions is technically feasible within a time frame of 50 years at probably limited economic costs. However, this will require a major transition in the energy system towards high end-use efficiency and a low carbon-intensive energy supply; this will not come about easily. Many technologies are currently available at moderate or competitive costs (IPCC, 2001c), but there are few policy drivers in place to ensure their implementation. In addition, technologies projected to become available still need further development and need to be made available at competitive costs to be widely implemented. Moreover, the assessment has indicated major economic, social and institutional barriers that will have to be overcome, and conditions will have to be met.

Timing will be an issue of crucial importance because of inertia in the both natural and human systems. The inertia in the human system can be easily demonstrated by looking at the long turnover in rates of capital stock (Figure 5.1). Many system components have turnover rates in the order of 20-40 years, such as power plants, industrial complexes and means of transportation, while most infrastructures (e.g. roadways) have even much longer lifetimes. The long turnover rates of the infrastructure related to energy imply that a full energy transition will take many decades. It also means that in 50-100 years there will be one or more full replacements of all capital stock, offering unique opportunities for change. However, if we want to avoid costly adjustments due to a premature retirement of capital stock, we need to start anticipating the need for future emission reductions as soon as possible. Every day many decisions are being made around the world that impact on the levels of GHG emissions for many decades to come, like the construction of new energy infrastructure or urban planning. Thus, opportunities for preparing for a low GHG emission future are present today provided that decisions are being made on the basis of a long-term climate strategy.

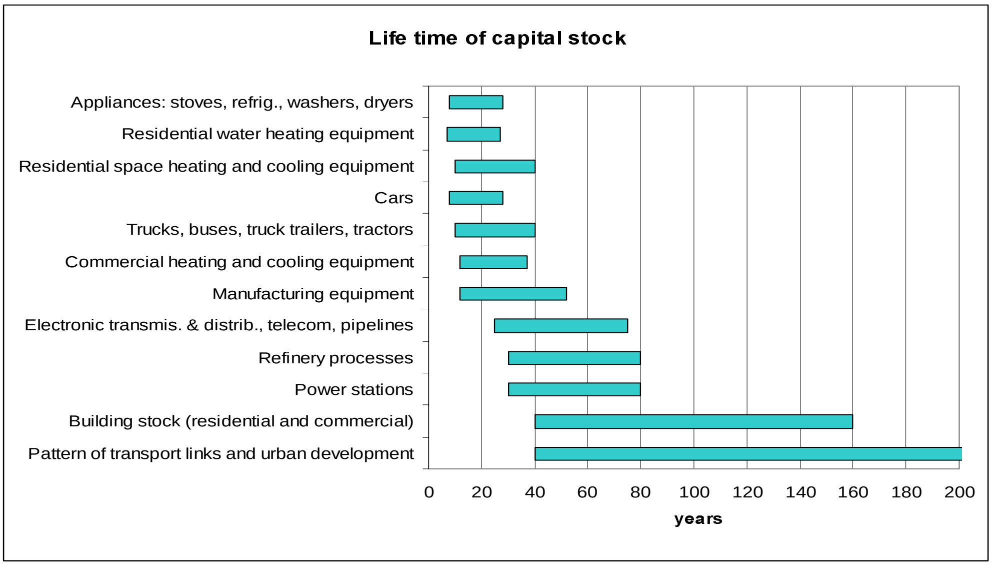


Figure 5.1: Energy capital-stock turnover rates (IEA, 2000).

This brings us to another major system delay: policy development and implementation. Legislation and decision making at the national level often take several years and maybe half a decade or more before measurable results can be witnessed. In the case of climate change, however, national policy development and implementation is strongly dependent on international policy making; here then, the legislation and decision making usually take a number of decades.

The establishment of the UNFCCC, realised by1992, was remarkably rapid (taking about 10 years), but it did not contain binding emission reduction and limitation commitments. The treaty that does contain such commitments, the Kyoto Protocol of 1997, will not enter into force before 2002, if ever. If it does not survive it may well take another decade before any alternative regime will enter into force, with probably an equal delay in the first commitment period to allow for the national implementation of climate policies.

In the absence of clear (international) climate policies, there is the risk that in the meantime many near-term decisions, both private and governmental, will lock us further into fossil fuels by the installation of new fossil-based energy infrastructure, the exploration of new fossil-fuel reserves or investment into the improvements of fossil combustion technologies. These actions will make it all the more difficult and costly to get away from fossil fuel use in the future. For this reason, preparing for the future now is very important.

At the same time, there is also the risk of locking into the wrong solutions, like technologies that turn out to be more costly, or less suitable or acceptable, than expected. It could also mean a premature exclusion of options, like CO_2 removal and storage. The assessment points to some robust technology strategies, although section 3 also indicates that we probably will need many options to keep the stabilisation of CO_2 concentrations at 450 ppmv an open one, particularly, if the world develops according to higher emission baselines.

5.2 Do we need long-term climate targets?

One of the issues discussed during the COOL global dialogue project was the question of the need for long-term climate targets. On the basis of the precautionary approach some feel that it would be useful to elaborate the objective of the UNFCCC into some provisional quantified (range of) long-term stabilisation targets and time frames, taking into account scientific uncertainties and intermediate impacts. This would provide a clear reference for evaluating the adequacy of short-term climate policies. The clear example is provided by the EU: in 1996 the EU Council adopted as a long-term climate target, a global average temperature change of less than 2 °C compared to pre-industrial levels and a stabilisation level for CO_2 concentrations well below 550 ppmv[8]. However, others think it is still too early to set any (provisional) climate targets, because of scientific uncertainty.

In any case, it will be very difficult to reach international consensus on long-term targets, as both their adequacy and implications are hard to access. Furthermore, views about a 'safe' level of climate change and tolerable impacts will differ widely and be influenced by the regional distribution of impacts, differences in the ability to adapt and the time frame taken

[8] Note that these two quantitative targets are not necessarily compatible: only if the climate sensitivity were at the lower end of the IPCC range (1.5- 4.5) and the future contribution of non-CO_2 gases is assumed to be small, could this be the case.

into account. It is therefore more likely that the evaluation of the adequacy of commitments will be an evolutionary process with policy adjustments made over time on the basis of a regular review of scientific insights and change in societal concerns.
However, given the system inertia discussed above, this entails the risk of being too late in preparing for any major technological and societal changes needed if the level of climate change and/or its consequences turn out to be more severe than presently known. Therefore, a key element of climate policy making should be to constantly reflect on whether certain policy options that cannot yet be excluded are still within reach at acceptable costs. As suggested by one participant, this could be called a ‘mirror-approach’: reflecting on short-term policy decisions as a check to seeing if they keep the range of long-term policy options open that may be required to meet the objective of the Climate Convention.

5.3 What are short-term policy priorities?

Generally, a number of actions, given below, seem particularly crucial in the next decade:
- Have developed countries take the lead and make a start with limiting greenhouse gas emissions, e.g. implementation of the Kyoto Protocol and its mechanisms.
- Develop a more comprehensive regime for a future differentiation of commitments, defining rules for a broader and more transparent future participation of countries in global greenhouse gas emission control.
- Invest heavily in the development, demonstration and adoption of new technologies needed by developed and developing countries for taking on substantial emission reduction targets in future commitment periods.
- Establish stronger public awareness of the seriousness of the climate change problem to secure public support for more substantial future emission reduction efforts.
- Develop further methodologies for evaluating the adequacy of commitments and possible subsequent steps under the Climate Convention, and
- Incorporate climate protection goals into sector-oriented sustainable development strategies in both developed and developing countries.

5.4 What short-term actions will be important to keeping the option open of stabilising CO_2 concentrations at 450 ppmv?

During the COOL project a number of short-term actions were identified as important to keeping open the option of stabilising CO_2 concentrations at 450 ppmv. These are related to a transition to a low-carbon intensive economy (de-carbonisation), on the one hand, and the development of the international climate change policy regime on the other.

Short-term actions to enhance de-carbonisation:

- *Efficiency*: the introduction of policies to increase energy efficiency, such as the development of international (minimum) standards for both products and production processes, energy subsidy reforms and the greening of taxes.

- *Renewable energy*: the introduction of (increasing) national targets / regulation for minimum market or production shares of renewables, the promotion of green electricity (e.g. by certificates, energy tax exemptions).

- *Natural gas*: support for closing leaks in natural gas systems and enhancing the development of international gas-infrastructure. This is essential for increasing the access of, particularly, developing countries to natural gas as a substitute for coal.

- *Coal:* here there are two options: (1) substitution of coal-fired power plants by gas-fired ones or renewable energy (wind energy, biomass), enhanced by the removal of coal subsidies; the introduction of a carbon tax, and tax exemptions for use of green energy and (2) increased R&D into the option of CO_2 removal and storage in combination with the development of hydrogen-based energy systems.

- *Transportation*: support for the development of public transport (to reduce congestion, pollution and air travel) and the use of biofuels (e.g. carbon tax exemptions for biofuels / biofuel content, removal of import levies on ethanol) and an acceleration of the introduction of fuel cells in cars, buses, trucks and ships.

Short-term actions to enhance international climate change regime development:

- Ratification of the Kyoto Protocol - preferably with US participation but if need be without it - to keep up the momentum for action; to show that developed countries take the lead and, by giving carbon a price, to provide the proper signals to the private sector.

- An early start of discussions about more comprehensive regimes for the differentiation of future commitments. These could start informally and later on be formalised within the context of the FCCC. The EU could start an internal discussion and one with its new member states.

- Begin discussions with international sectors on (voluntary) global technology standards and the option of special international sector agreements with international companies on limiting greenhouse gas emissions or technological standards. These include: the aviation and maritime sectors (not yet covered under the KP), and the steel, chemical, power generation and car industries.

- The development of a climate impact assessment for bilateral and multi-lateral investment portfolios of development banks and foreign investments. This should promote the integration of climate policy considerations into various sectors.

- The organisation of national and international campaigns for increasing public understanding of the climate change problem and the need for tasking measures, combined with international networking to exchange good ideas and experiences.

6. Summary of the main findings

The Climate Convention has as its ultimate objective: stabilising the concentration of GHGs in the atmosphere at a level that would prevent 'dangerous anthropogenic interference with the climate system' (art. 2). However, it is difficult to determine what level of GHG stabilisation is considered safe. Views differ because of diverse perceptions about the risks, costs and values involved, and about how to deal with scientific uncertainty.

The COOL global dialogue project took the stabilisation of CO_2 concentrations at 450 ppmv (or 550 CO_2 equivalent) around 2100 as its starting point. The participants did not consider this level to be necessarily 'safe'. Some participants considered it not safe enough, as it could entail the risk of substantial and irreversible climate impacts, while others considered it prematurely strict given the uncertainty about impacts and costs involved. At the same time, it was acknowledged that it could not be excluded that stabilisation at a rather low level would be necessary to avoid unacceptable climate change risks. Therefore, it was accepted as a starting point for exploring its short-term implications by way of a back-casting exercise.

The starting point of stabilising CO_2 concentrations at 450 ppmv was translated into an emission reduction of 15-25% (depending on the timing of emission reductions) by 2050 compared to 1990 levels. This level is congruent to the 50-80% emission reduction adopted in the national and European COOL Dialogues for the industrialised countries if a convergence in per capita emissions by the middle of this century is assumed.

The challenge of such a global CO_2 emission reduction is twofold. First, reduce the carbon intensity of the global economy (C/GDP) by lowering the energy intensity (E/GDP) of production and consumption through efficiency improvements and energy saving, and reduce the carbon intensity of energy supply by a shift to low and non-carbon energy resources. Second, establish a comprehensive international climate regime that is environmentally effective, cost-effective and politically perceived to be fair.

The transition in the energy system needed is unlikely to come about without substantial climate policies. However, the emission reduction effort required to stabilise CO_2 concentrations at 450 ppmv strongly depends on the way the world will develop. It will be much easier to realise this in a generally prosperous and open world and/or a world oriented to sustainable development than in a divided, materialistic and economically unbalanced developing world.

The findings of the COOL global dialogue indicate that emission reductions needed for stabilising at 450 ppmv around 2100 for such world types (A1b and B1, as labelled by IPCC-SRES) seem technologically feasible. The economic costs involved can then also be considered limited (less than a few percentage points of the world GDP) given the large increase in welfare projected in these worlds. However, an early involvement of developing countries in global emission control is required, along with the establishment of a global emission trading system to reduce emissions cost-effectively.

The regional distribution of the economic impacts will mainly depend on the allocation of allowable emissions. Global CO_2 mitigation is likely to affect fossil-fuel dependent countries particularly negatively; these include coal- and oil-exporting countries and countries that rely heavily on (domestic) coal. While it was acknowledged that low-income oil-exporting developing countries may, in particular, be significantly affected, compensation was not considered the proper strategy. The matter was considered mainly an issue of economic adaptation to a new market reality; however, support to low-income developing countries for adaptation policies was not excluded. A (relatively) rapid shift away from coal to other energy sources may be particularly difficult in coal-intensive countries for social and political reasons. Physical carbon sequestration could be an important option to limiting carbon mitigation costs and reducing the resistance of these countries to global GHG emission control.

In order to obtain a stabilisation at 450 ppmv no (further) delay of action seems economically attractive when societal discount rates are used. CO_2 emission reductions will also result in substantial co-benefits, particularly by reducing costs related to health effects from local and regional air pollution.

Many barriers hinder the implementation of options to reduce CO_2 emissions, such as a lack of awareness among the general public, uncertainty about climate policies (in particular, for the private sector), resistance from vested interests, social problems resulting from reduced coal use, increased dependence on gas imports and the liberalisation of energy markets. At the same time, the participants identified important opportunities, like the full replacement of existing energy capital stock on the long-term, co-benefits of GHG mitigation measures, including a lower burden of oil imports for developing countries, and growing societal forces related to new ‘green’ industries.

The project identified a number of important conditions for a transition to a low carbon-intensive future:

- A broad public awareness of the climate change problem;
- The development of clear and effective global and national climate policies;
- Developed countries taking the lead and showing the way;
- Wide-scale and effective transfer / diffusion of modern technological knowledge;
- The integration of climate policies into sustainable development;
- Some support to fossil-fuel-dependent developing countries to facilitate the restructuring of their economies and the development of new energy technologies.

The differentiation of future commitments is one of the most crucial issues for the development of an effective and fair international climate regime. The negotiations on the Kyoto Protocol do not set a good example for the development of such a regime. They are characterised by an ad hoc approach, with no clear basis for the differentiation of commitments and a non-transparent negotiation process based on block formation.

An incremental evolution of the climate regime in the form of a gradual ad hoc extension of the group of countries taking on binding commitments is unlikely to bring about the level of global emission control needed to keep open the option of stabilising CO_2 concentrations at 450 ppmv (or 550 CO_2 equivalent).

Many participants in the COOL Global Dialogue therefore hold on to the view of the need to develop a *comprehensive approach:* i.e. a regime that defines principles, criteria and rules for differentiating future commitments for all countries in a consistent and transparent way. This will make the adoption of future commitments predictable and legitimate; it will also provide more guarantees for an effective control of global GHG emissions in order to meet the goals of the Climate Convention. At the same time, it is acknowledged that it will be difficult to agree on any such approach and that it may take considerable time to reach agreement.

Equity is considered to be an essential element of any acceptable, effective future climate regime. However, the COOL global dialogue demonstrated the broad differences in perceptions about equity. In looking for acceptable climate change regimes, it would seem wise for us not to focus on any single equity principle, but instead to look for approaches embracing different equity principles. Moreover, focusing too much on principles of equity would overlook the relevance of other aspects of future climate change regimes, such as environmental effectiveness, efficiency, operational requirements, institutional capacity building and the role of side-policies such as technology transfer.

There are many options for a comprehensive regime. During the COOL Global Dialogue a few different approaches were explored without reaching any conclusions about what type of regime would be preferred. These include the ‘Increasing participation / Multi-stage approach, Per Capita Convergence and a global application of the Triptych approach. Important criteria for evaluating future regimes are comprehensiveness on different equity principles, environmental effectiveness, economic efficiency, flexibility, simplicity and operational requirements. Each approach has its strengths and weaknesses. The Per Capita Convergence approach differs fundamentally from the other two approaches by defining the climate problem as a ‘resource sharing’ problem instead of a ‘burden sharing’ one. This points to a paradigm conflict that may not be easily resolved.

Strategically, the key question with respect to short-term actions is how to keep the option of stabilising CO_2 concentrations at 450 ppmv open, or put differently, how to avoid locking into high stabilisation levels. Timing is of crucial importance because of inertia in both the natural and human systems. Every day many decisions are being made that impact on the levels of GHG emissions for many decades, like the construction of new energy infrastructure or urban planning, and decisions that make it easier or more difficult to reduce future emissions. Opportunities for preparing for a low GHG-emission future are present today provided that decisions are being made on the basis of a long-term climate strategy.

In order to make the long-term perspective part of short-term decision making there is a need for clear national and international climate policies that provide the right signals and incentives to business, consumers and local policy makers. Climate policy making also has to start from a longer term perspective. This could be done by formulating provisional long-term climate targets, but alternatively, it can be secured by systematically reflecting on short-term policy decisions to check if they keep open the range of long-term policy options that may be required to meet the objective of the Climate Convention (the mirror approach).

For the next decade a number of actions seem particularly crucial:

- Have developed countries take the lead and make a start with limiting greenhouse gas emissions, e.g. by implementing the Kyoto Protocol and its mechanisms.
- Develop a more comprehensive regime for a future differentiation of commitments, defining rules for a broader and more transparent future participation of countries in global greenhouse gas emission control.
- Invest heavily in the development, demonstration and adoption of new technologies needed by developed and developing countries for taking on substantial emission reduction

targets in future commitment periods.

- Establish stronger public awareness of the seriousness of the climate change problem to secure public support for more substantial future emission reduction efforts, and
- Develop further methodologies for evaluating the adequacy of commitments and possible subsequent steps under the Climate Convention;
- Incorporate climate protection goals into sector-oriented sustainable development strategies in both developed and developing countries.

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