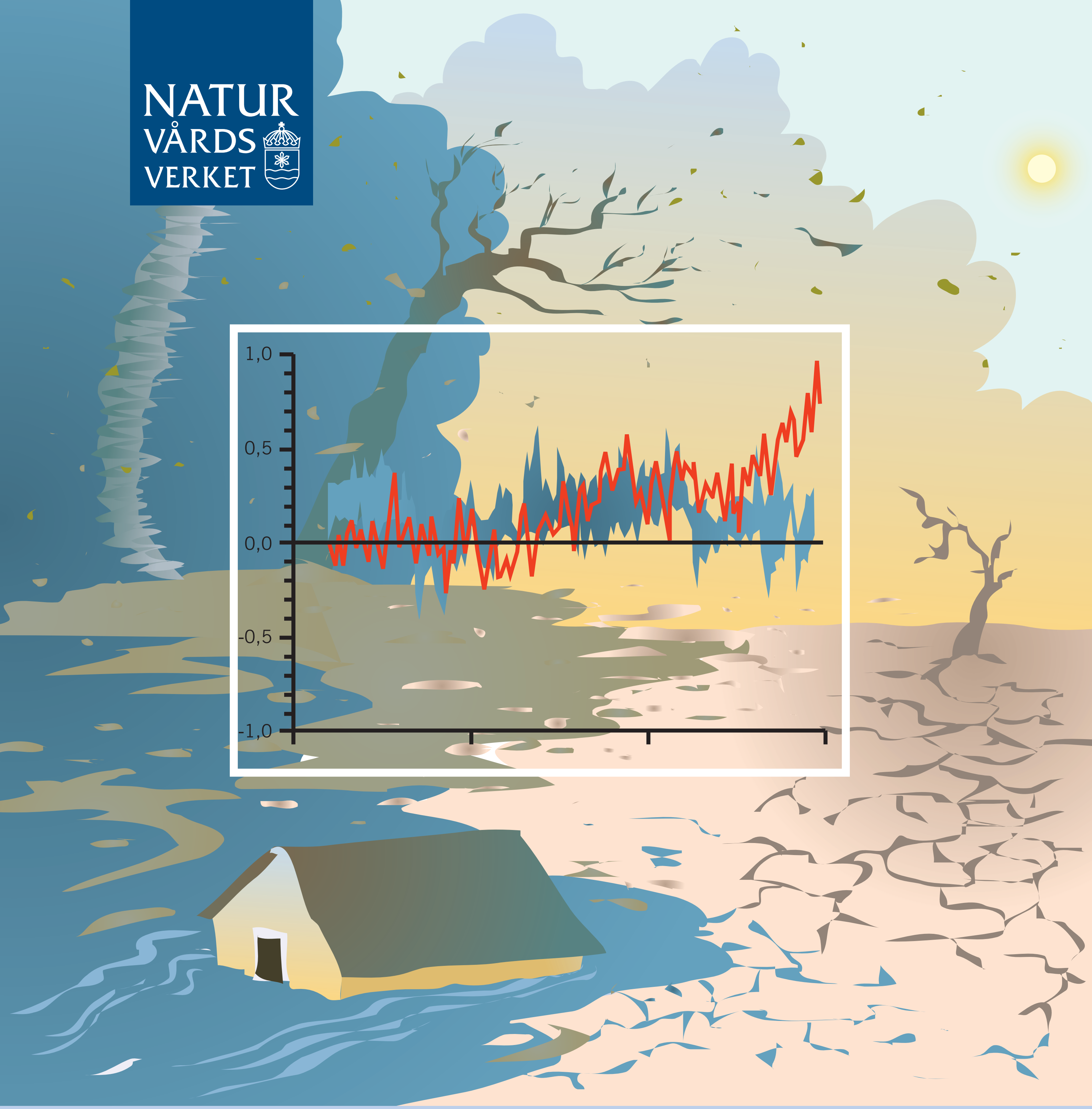

Kyoto and Beyond

Issues and Options in the Global Response to Climate Change

SWEDISH ENVIRONMENTAL PROTECTION AGENCY

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Foreword

In recent year's the focus of many of the worlds climate change policy makers and negotiators has been to see the Kyoto Protocol through to the stage where it can enter into force as an international agreement. With the Protocol now likely to enter into force in 2003 it is timely to raise the sights of the current debate and consider the question of what next? For those countries that have decided not to ratify the Kyoto agreement the question of what to do next is equally if not more relevant.

When looking at steps for further action, beyond those outlined in the Kyoto Protocol, it is important to set the problem of global climate change, and the possible international response to it, in a long-term context. How would we like the world's climate to be in 100 years time? What is achievable? What steps are needed now in order to achieve any long-term targets?

The Swedish Environmental Protection Agency (Naturvårdsverket) has prepared the following paper with a view to stimulating discussion and debate (in Sweden and internationally) around the issues and options for a long-term response to global climate change. The paper does not represent an agreed viewpoint or opinion of the Swedish Environmental Protection Agency. Rather it should be seen as a discussion paper.

In a subject as broad as climate change it is inevitable that not all subject areas will be addressed. This report focuses mostly on mitigation issues – how to reduce greenhouses gas emissions globally – and does not, for example, address the extremely important question of adaptation. It should also be noted that the paper has attempted to analyse many of these issues through an 'environmental economics' perspective.

Part of the input for this paper was provided though an international workshop hosted by the Swedish Environmental Agency in November 2001. The report has also benefited from comments by Christian Azar, (Chalmers University of Technology), Cédric Philibert (IEA), Jan Corfee-Morlot (OECD) and Asbjørn Torvanger (CICERO). The author of the report, Mark Storey, is solely responsible for the paper's contents, and opinions expressed.

Stockholm, November 2002-11-15
Naturvårdsverket

Förord

Under senare år har många av de beslutsfattare och förhandlare som sysslar med världens klimatförändringar haft som huvuduppgift att föra Kyoto-protokollet till det stadium där det kan träda i kraft som en internationell överenskommelse. När Protokollet nu sannolikt kommer att träda i kraft under år 2003 är det en lämplig tid att höja blicken över dagens debatt och fråga vad som händer härnäst. För de länder som har beslutat att inte ratifiera Kyoto-avtalet är den frågan lika viktig, om inte viktigare.

När man letar efter de steg som kan leda vidare, bortom dem som tecknas i Kyoto-protokollet, är det viktigt att sätta det globala klimatändringsproblemet, och de tänkbara internationella reaktionerna på det, i ett långsiktigt sammanhang. Hur vill vi att världens klimat ska vara om hundra år? Vad går att åstadkomma? Vilka steg behövs nu för att nå olika långsiktiga mål?

Det svenska Naturvårdsverket har utarbetat den här rapporten med syftet att stimulera diskussion och debatt – i Sverige och utomlands – kring frågor och möjligheter av vikt för en långsiktig reaktion på den globala klimatförändringen. Rapporten återspeglar inte nödvändigtvis Naturvårdsverkets åsikt, utan bör uppfattas som ett debattinlägg.

Inom ett så brett problemområde som klimatförändringar är det oundvikligt att man inte kan ta upp alla enskilda problem. Den här rapporten tar främst upp minskningsfrågor – hur man kan minska utsläppen av växthusgaser globalt – och behandlar till exempel inte den utomordentligt viktiga frågan om hur man kan anpassa sig till ett ändrat klimat. Det bör också framhållas att rapporten försöker analysera många frågor ur ett ”miljöekonomiskt” perspektiv.

Delar av underlaget för rapporten kommer från ett seminarium som anordnades av Naturvårdsverket i november 2001. Rapporten har också dragit nytta av kommentarer av Christian Azar, (Chalmers University of Technology), Cédric Philibert (IEA), Jan Corfee-Marlot (OECD) och Asbjørn Torvanger (CICERO). Rapportens författare, Mark Storey, är ensam ansvarig för rapportens innehåll och de åsikter den uttrycker.

Stockholm den 15 november 2002.
Naturvårdsverket

Introduction and Outline

The threat of global climate change has been described as the biggest environmental challenge of the 21st century. The latest projections of the IPCC are for global average surface temperatures to rise by between 1.4 and 5.8°C over the course of the next century. This is a projected rate of temperature change without precedent in the history of modern societies. The magnitude and rate of these changes will pose a major challenge for humanity. At the lower end of this projection, the warming trend is expected to cause significant impacts such as a rise in sea levels, an increased incidence of violent storms and impacts on ecosystems. At the upper end of the scale the impacts could be catastrophic. Furthermore, it appears likely that the countries that will be most adversely affected by climate change in the next 100 years are the countries that can least afford to take measures to combat it.

The threat of global climate change, and the challenge of how to respond to it, therefore is a problem of considerable complexity. It is a **global issue,** as ultimately it will require global collective action of all countries if efforts to lessen the threat are to be successful. It is an **inter-generational** issue, as the decisions and lifestyles choices of today's generation will affect the decisions and lifestyle choices of future generations. It is an **environmental issue,** but it also a **social, economic, political** and **ethical** issue.

In 1992 at the "Earth Summit" in Rio de Janeiro, the nations of the world acknowledged the global nature of climate change in signing the Framework Convention on Climate Change (FCCC). As the name suggests, the Framework Convention is the foundation for the global response to climate change. The FCCC specified that developed countries should bear the primary responsibility for reducing greenhouse gases, and set out a system of voluntary reduction commitments for these countries along with common monitoring and reporting requirements for all countries. In 1997 the Convention was given some "teeth" with the signing of the Kyoto Protocol. The Kyoto Protocol encompassed many key decisions, but of most importance was the decision for developed countries to accept emission reduction commitments that would become legally binding when the Protocol is ratified. Subsequent to 1997 negotiations on the rules for implementing the Protocol have continued, although the process was dealt a significant blow in 2001 by the decision of the US to withdraw from the Protocol.

At the time of writing this report, prospects are looking reasonable for the Protocol to be ratified in 2003, although the United Sates remains outside this process. It is widely accepted that the Kyoto Protocol is only a small step in the global effort to reduce emissions. The objective of this report is to look at the next steps – at the issues and options which need to be considered in shaping a **long-term global response** to climate change.

Section 1 of this report presents an overview of the **current scientific opinion on climate change**. In particular it discusses two questions: 1) *To what extent is the earth's climate changing?*; and 2) *To what extent can climate change be attributed to human activities?* It includes information on long-term projections for climate change and the predicted impacts of these changes in the next 100 years. While the section draws heavily on IPCC information it also summarises projections from non-IPCC sources and some of the key areas of divergent opinion.

The remainder of the report focuses on four key questions:

1) What global targets are we aiming for?
2) When should we act?
3) How should we share the responsibility for action equitably?
4) What frameworks are needed for future action?

Section 2, asks the question: **What global targets and at what level?** The stabilisation of atmospheric concentrations of greenhouse gases is generally accepted as the "ultimate goal" of international efforts to reduce emissions. The question then becomes – at what level? Questions addressed in this section include: What are the implications of stabilising emissions at different levels? What is a "safe" level? Is it meaningful to define goals in this way? Are there alternatives? What types of short and medium-term interim goals are needed?

Section 3 examines the discussion on timing of response – **when to act?** Should emissions reductions be taken now or deferred until later date? Decisions on timing are as influential as the choice of target in determining costs. This section reviews the literature on "least cost pathways" when the target is known, and "optimal pathways" when there is uncertainty about the ultimate target. Also discussed are the environmental impacts of decisions on timing and the role of technological change in this debate.

Section 4 looks at **equity issues.** Equity issues are at the very core of the climate change debate. Who bears the greatest responsibility for climate change? Who is at greatest risk? Who is best able to act? What responsibility do we have to future generations? What rights do we have to use the atmosphere? Equity issues are addressed in the FCCC and in the Kyoto Protocol and some important precedents have been set. However, it is generally acknowledged that the discussion on fundamental long-term equity issues, in particular the question of developing country commitments, has yet to occur.

Section 5 takes this discussion a step further and looks at possible frameworks for a future global agreement. Does the Kyoto Protocol provide a viable framework for a future agreement? If not what are the alternatives? What is needed to bring the US and developing countries into a global agreement?

Box 1: Outline of Report

1. **The scientific opinion on climate change – an overview.** An assessment of the global problem of climate change in the long-term. How serious will it/could it become? What is the current state of knowledge? In what areas is there on-going debate?
2. **How should we define long-term targets?** What is a "safe" level of atmospheric concentrations of greenhouse gases? Is it meaningful to define targets in this way? What are the alternatives?
3. **When to Act?** What are the alternative pathways to reach an agreed goal? How does this affect costs? What are the environmental implications?
4. **Equity issues – Sharing costs, effort and resources.** How should this effort be divided up amongst countries? What is an equitable solution? What is the role of developing countries?
5. **Looking ahead – Frameworks for global action**
6. **Discussion**

1. The Scientific Opinion on Climate Change – an Overview

This section provides background information to the report. It includes information on long-term projections for climate change and predicted impacts and the scenarios for global climate change warming in the next 20, 50 to 100 years. While the section draws heavily on IPCC information it also summarises projections from non-IPCC sources and some of the key areas of divergent opinion.

1.1 The scientific opinion on climate change

Climate Change as defined by the Intergovernmental Panel on Climate Change (IPCC) refers to statistically significant variations in climate that persist for an extended period, typically decades or longer. It includes shifts in the frequency and magnitude of sporadic weather events as well as the slow continuous rise in global mean surface temperature.

The debate on climate change can be separated into two main subject areas. The first area is the debate on what has happened to the world's climate to date. Is climate change happening and to what extent are the changes due to human activities? The second area of debate concerns projections for how the world's climate may change in the future.

1.2 What has happened to date?

This question too, can be further broken down into two key questions:

1. Is climate change happening? If so;
2. To what extent can any changes be attributed to human activities as opposed to natural processes?

The debate in both these areas has evolved considerably over the last 10 years and is discussed briefly below.

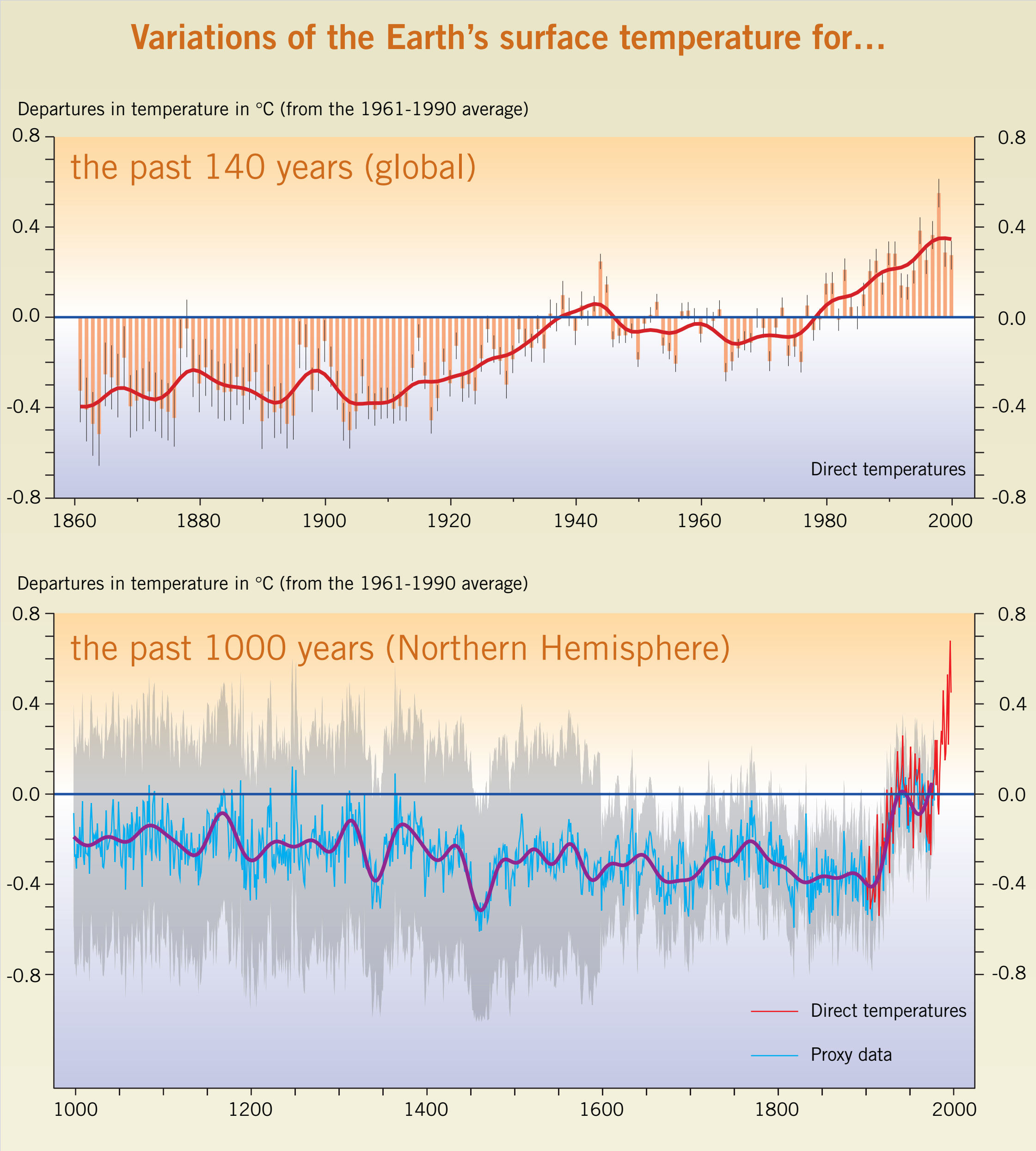
1.2.1 Is climate change happening?

The IPCC Third Assessment Report (TAR) (IPCC, 2001 a) highlighted the following observed changes in climate indicators:

- *The global average surface temperature has increased over the 20th century by about 0.6°C.* Globally, it is very likely that the 1990s was the warmest decade and 1998 the warmest year in the instrumental record, since 1861 (See Figure 1). Furthermore, when the instrumental record is extended using proxy data for the Northern Hemisphere this indicates that the temperature increase during the 20th century is likely to have been the largest of any century.
- *Snow cover and ice extent have decreased* – satellite data show there are very likely to have been decreases of about 10% in the extent of snow cover since the late 1960s.
- *Global average sea level has risen and ocean heat content has increased.*
- *Precipitation patterns have changed.* It is very likely that precipitation has increased by 0.5 to 1% per decade in the 20h century over most mid and high latitude of the Northern hemisphere continents. It is also likely that rainfall has increased by 0.2 to 0.3% per decade over tropical land areas.
- *Ocean temperatures.* Global ocean heat content has increased since the late 1950s, the period with adequate observations of sub surface ocean temperatures.

Overall, the IPCC conclude that: **"The Earth's Climate System has demonstrably changed on both global and regional scales since the pre-industrial era."** This conclusion is broadly supported by the United States National Academy of Science's Review of Climate Change Science (National Academy of Sciences, 2001), commissioned by the White House.[1]

Figure 1. Variations of the Earth's Surface Temperature



Source: IPCC (2001 a)

1.2.2 To what extent can these changes be attributed to human activities?

The answer to this question remains more contentious than the first, but in this area too there have been considerable developments in the past decade. In 1992, the IPCC predicted that it would be at least a decade before a causal link between human activities and climate change could be established. Three years later in its 1995 Climate Change Report, the IPCC concluded that there was a **"discernible human influence"** on the earth's climate. Most recently, in the TAR the IPCC have further strengthened their statements expressing greater confidence that human activities are altering climate patterns:

- "There is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities."

Furthermore,
- "... it is very likely that the 20th century warming has contributed significantly to the observed sea level rise through thermal expansion of sea water and widespread loss of land ice."
- "Human influences will continue to change atmospheric composition throughout the 21st century."

The NAS report generally agrees with this assessment, stating that:
- "Greenhouse gases are accumulating in the Earth's atmosphere as a result of human activities, causing surface air temperatures and subsurface ocean temperatures to rise." "The changes observed over the last several decades are likely mostly due to human activities, but we can not rule out that some significant part of these changes are also a reflection of natural variability."

1.2.3 Areas of uncertainty
The degree of confidence in the IPCC assessment is higher today than it was 10 or 5 years ago but uncertainty remains.

The NAS report identified 3 major areas of uncertainty:
1. The level of natural variability inherent in the climate system on time-scales of decades to centuries.
2. The ability of models to accurately simulate natural variability on these long time-scales.
3. The degree of confidence that can be placed on reconstructions of global mean temperature over the past millennium based on proxy evidence.

In addition to these points two further points of debate are often raised.
4. There is an apparent discrepancy between observed surface temperature measurements and atmospheric measurements over the past two decades. Climate models predict that temperature levels in the troposphere (at an altitude of roughly 4 km) should rise at least as much as surface temperatures. While surface temperatures have increased in the last 20 years, measurements at the troposphere level from both weather balloons and more recently satellites have often revealed warming trends that are much less than could be expected.[2] The IPCC note in their TAR that this discrepancy has been reduced using recent models but not totally resolved.[3]
5. Furthermore, some researchers argue that natural factors such as sun spot activity may be responsible for a large part of the warming in surface temperatures that have been experienced in the last 100 years.[4] These arguments can not be excluded but are considered to be highly speculative by many scientists.[5]

In summary while there are remaining uncertainties, The IPCC's conclusion that most of the observed warming over the last 50 years can be attributed to human activities, is supported by the majority of the scientific community. As noted in the NAS Report (referring specifically to the first three areas of uncertainty listed above): "despite these uncertainties there is general agreement that the observed warming is real and particularly strong within the past 20 years."

1.3 Projections for the future
1.3.1 Emission Scenarios
The IPCC in 2000 published a Special Report on Emissions Scenarios (SRES).[6] These scenarios were based on four different narrative storylines. Each storyline assumes a distinctly different direction for future developments, demographic, social, economical, technological and environmental, over the next 100 year. From these four storylines six different groups of scenarios were produced comprising of, in total, 40 scenarios for future development (See Box 2).

No single scenario was considered by the IPCC as being more or less probable than the other. However, within each group, one scenario was chosen as a *marker* scenario. The marker scenarios are not

Box 2: Main Characteristics of the IPCC Storylines and Scenario Families

The A1 storyline describes a future world of very rapid economic growth, low population growth, that peaks in the mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building and increased social and cultural interactions, with a substantial reduction in regional differences in per capita income. The A1 scenario develops into three groups that describe alternative directions of technological change in the energy system: Fossil intensive (A1F1), non-fossil energy sources (A1T), or balanced across all sources (A1B).

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

The B1 storyline describes a convergent world with the same population pattern as in the A1 storyline but with rapid changes in economic structures towards a service and information economy.

The B2 storyline describes a world in which the emphasis is on local solutions to economic, social and environmental sustainability. It is a world of continuously increasing global population at a rate slower than A2, intermediate levels of economic development and less rapid and more diverse technological changes than in the B1 and A1 storylines.

Source: IPCC (2000)

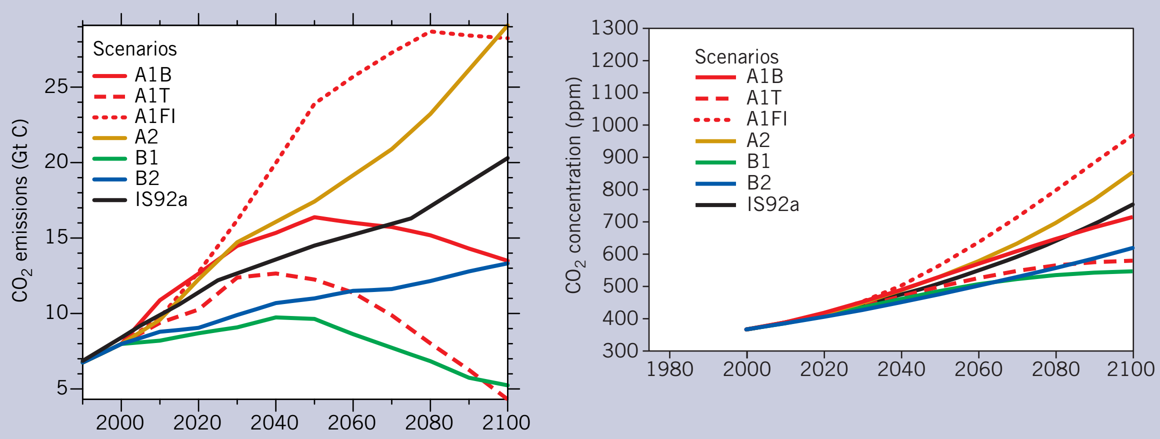
mean or median scenarios but were selected because they were considered to be illustrative of a particular story. Illustrative scenarios were also chosen for the sub groups of family A1. Therefore, there are in total six *illustrative* scenarios for each of the scenario groups (See Figure 2).

All six illustrative scenarios show growth in CO_2 emissions from energy and industrial sources through to 2020 ranging from 86% to 285% above 1990 levels. The range increases further in the projection for 2050 to 2100, with two of the marker scenarios projecting emissions to fall below 1990 levels by the end of this century (by 28% and 13%) and the other 4 scenarios projecting annual emissions remaining above 1990 levels.

More significant than actual levels of yearly emissions in future years however, is how emissions accumulate over time in the different scenarios. For example, while the A1B and B2 marker scenarios project similar emission levels in 2100 the dynamics of the path are so different that they result in different cumulative emissions. The implications of different pathways to an emissions target are discussed further in Section 3.

By way of comparison, the OECD's Environmental Outlook Reference Scenario projects that World CO_2 emissions will increase substantially in the medium-term rising 61% above 1995 levels by

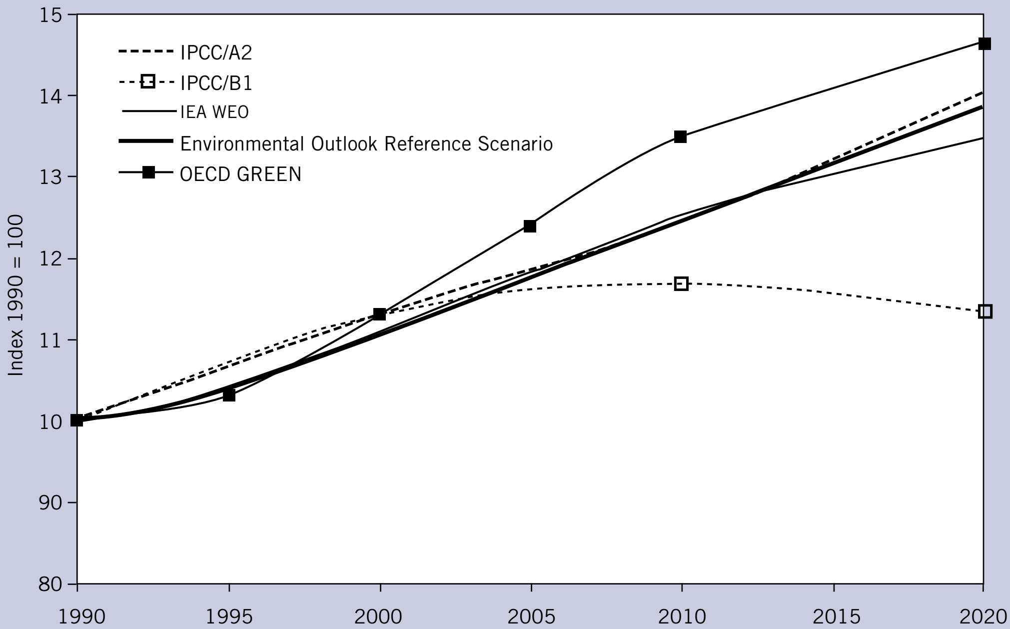
Figure 2. IPCC Emission Scenarios



Source: IPCC (2000 a)

2020. This scenario projects that in OECD (developed countries) emissions will increase by 33% in this time period while in the rest of the world emissions will increase by almost 100%. The main driver for this projected increase will be an increase in worldwide total energy use of about 52% in this period (OECD, 2002).

Figure 3. Comparison of CO_2 Emissions Scenarios to 2020.



Source: OECD (2002)

1.3.2 The link between emissions and concentration levels

A precise relationship between emissions and concentration levels is difficult to establish. Nevertheless, in the short to medium-term, the proportion of a given emission which remains in the atmosphere is thought to decline following a roughly exponential path over time as it is absorbed by various “sinks” – oceans, the soil, forests (OECD, 1999). The rate at which different greenhouse gases are removed from the atmosphere varies. Methane is almost entirely removed in a decade, whereas carbon dioxide may persist for 200 years and certain perfluorocarbons for many centuries. Knowledge about the rates of exponential decay can be used to project concentration levels based on assumed emissions paths. However, establishing such projections is complex given remaining uncertainties about sources and sinks as well as atmospheric and oceanic circulation (OECD, 1999).

1.3.3 Global concentration of greenhouse gases

All the IPCC SRES scenarios project an increase in the atmospheric concentration of CO_2. The projected concentrations of CO_2 in 2100 range from 540 to 970 ppm, compared to the pre-industrial concentration of 280 ppm and the current concentration of 367 ppm (See Box 3).

Box 3: Atmospheric concentrations of CO_2

Pre-industrial	➡	**280 ppm**
Current	➡	**367 ppp**
2100	➡	**540 to 970 ppm**

1.3.4 Climate Change predictions

Global average temperature and sea level are projected to rise under all IPCC SRES scenarios.

- The globally averaged *surface temperature* is projected to increase by **1.4 to 5.8°C** over the period 1990 to 2100. The projected rate of warming is much larger than the observed changes in the 20th century and it is very likely to be without precedent during at least the past 10,0000 years.[7]
- Global average **water vapour concentration and precipitation** are projected to increase during the 21st century.

  By the second half of the 21st century, it is likely that precipitation will have increased over northern mid to high latitudes and Antarctica in winter. At low latitudes there are both regional increases and decreases over land areas.
- It is likely that warming associated with increasing greenhouse gas concentrations will cause an increase of Asian summer monsoon precipitation variability.
- In the Northern Hemisphere snow cover and sea-ice extent are projected to decrease further. Glaciers and ice caps are projected to continue their widespread retreat during the 21st century.
- The Antarctic ice sheet is likely to gain mass because of greater precipitation, while the Greenland ice sheet is likely to lose mass because the increase in runoff will exceed the precipitation increase.
- Global mean sea level is projected to rise by 0.09 to 0.88 metres between 1990 and 2100, for the full range of SRES scenarios. This is due primarily to thermal expansion and loss of mass from glaciers and ice caps.[8]

The NAS report generally supports these projections.

1.3.5 Areas of uncertainty

Attempting to project future world climate change is an extremely complex task and there are inevitably large uncertainties at various levels of analysis. The first step in making projections of future climate change is to estimate how economic activity will unfold over the next 100 years or so. This involves making assumptions about variables such as population growth, economic development, technological change, etc. This in turn enables scientists to forecast future emissions of greenhouse gases (often referred to as future climate forcings[9]). The next level of analysis is to predict how the world's climate will respond to these changes, and at this level there remains much uncertainty. For example, the response of clouds and water vapour to increased radiative forcing is one area of considerable uncertainty in global warming models. An alternative hypothesis to those of the IPCC is that the atmosphere will counteract the CO_2 increase and mitigate any changes in global temperature.[10]

"Predictions of global climate change will require major advances in understanding and modelling (1) the factors that determine the atmospheric concentrations of greenhouse gases and aerosols and (2) the so called 'feedbacks' that determine the sensitivity of the climate system to a prescribed increase in greenhouse gases." (NAS, 2001).

Climate change projections will always be far from perfect. A point stressed in the NAS report is that confidence limits should always be considered as an integral part of the information that climate scientists provide to policy makers. Without them there is a risk of giving an impression that the science of global warming is "settled", even though many uncertainties remain.

Nevertheless, uncertainties cut both ways. Future temperature increases and their impacts may turn out not to be as serious as predicted. On the other hand, they could turn out to be much worse. Developing appropriate policy programmes in the face of this uncertainty is an issue that is addressed further in Section 3 of this report.

To conclude this section on the science of climate change, there is widespread scientific support for the findings of the IPCC. Climate change is happening; these changes are most likely due to human activities; and projected global warming will probably have serious negative consequences both for society and the world's environment, especially if temperature increases approach the upper end of the IPCC scenarios.

2. Setting Global Targets

The debate on efforts to prevent or limit climate change inevitably leads to discussion on the ultimate objective of these efforts. The stabilisation of atmospheric concentrations of greenhouse gases is generally accepted as the "ultimate goal" of international efforts to reduce emissions. The argument is then focused on the question – at what level? Questions addressed in this section include: What are the implications of stabilising emissions at different levels? What is a "safe" level? Is it meaningful to define goals in this way? Are there alternatives? What types of short and medium-term interim goals are needed?

2.1 Setting global targets – the approach to date

Determining a global goal in relation to climate change, and specifically the human contribution to it, is a complex task. The ultimate objective of the Framework Convention on Climate Change (and any related legal instruments) is to stabilise greenhouse gas concentrations at a level *"that would prevent dangerous anthropogenic interference with the climate system"*.[11] The real difficulty, however, lies in determining what **levels** of concentration would prevent "dangerous anthropogenic interference" with the climate system, and in what **time frame** they should be achieved.

A concentration level of atmospheric CO_2 in the range of 550 ppm is often spoken of as a target for the end of the 21st century. This level has been adopted by the EU as a target and roughly corresponds to a doubling of CO_2 concentration levels compared to pre-industrial times (1750). The Swedish Government has adopted a more ambitious goal, that the six greenhouse gases specified in the Kyoto Protocol (not only CO_2) be stabilised at approximately 550 ppm CO_2 equivalent (Klimatkommittén, 2000). This roughly equates to CO_2 concentrations being stabilised at 500 ppm (See Box 5).

Before discussing the implications of different targets it is helpful to first review a few points on the science of stabilisation.

2.2 The science of stabilisation

Time frames are a critical component in any discussion on global targets and strategies to reach these targets. Three points related to climate science are relevant to take into consideration.

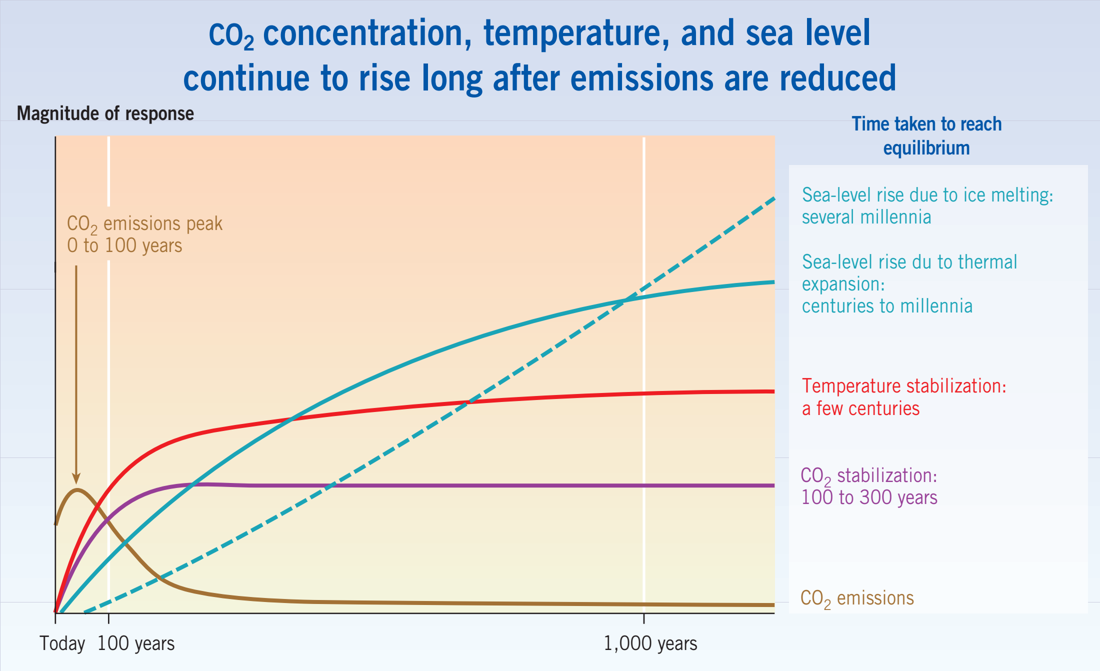
1. Once emissions are stabilised, atmospheric concentrations will continue to increase for many centuries, primarily because of the slow exchange of carbon dioxide between the atmosphere and the deep ocean (See Figure 4). Therefore, in order to stabilise atmospheric CO_2 levels, emissions will need to first stabilise and then drop well below current levels.
2. After stabilisation of the atmospheric concentration of GHGs, surface temperatures will continue to increase for more than a century due to the large thermal capacity of oceans.
3. Following stabilisation of the atmospheric concentration, sea level will continue to rise for many centuries.

It is the first point above which is most critical to this discussion. To achieve a stabilisation of atmospheric concentrations of GHGs at **any kind of reasonable level** will require (1) deep global emission reductions and (2) lead times of a ½ century or more (OECD, 1999). If emissions were frozen at current day levels (which would itself be a significant achievement) this would only postpone the doubling of CO_2 concentrations until 2100 and would not be enough to prevent a continuing rise thereafter.

This inertia, or delay in the response of climate systems to human efforts to reduce emissions, means that efforts to reduce the long-lived greenhouse gases such as CO_2 have long lasting benefits. The atmospheric concentrations of short-lived gases such as methane (CH_4) respond rapidly to emissions reduction.[12]

An important point to clarify is that these goals refer to **eventual** stabilisation levels. The atmospheric levels of CO_2 could be stabilised at level of 550ppm within about a 100-year timeframe. However, stabilisation at 1000 ppm would not occur before 300 years (See Figure 4). Long-term targets for 2100 therefore are not necessarily stabilisation targets as such but can be more accurately described as targets "to be on track" (in the year 2100) to reach an eventual stabilisation level.

Figure 4: Time scales of response to reductions in CO_2 emissions



Source: IPCC (2001 a)
The curves illustrated are based on stabilisation of atmospheric CO_2 at 550 ppm

2.3 Global concentrations of emissions – what is a "safe" level?

There is no "black or white" scientific answer to the question of whether there exists a "safe-level" of atmospheric greenhouse gas concentrations. This point is stressed by the IPCC in their TAR, which specifically avoids endorsing any particular level as "safe". The answer requires a value judgement as to what concentration levels constitute an *acceptable level of risk* to human welfare and ecosystems. This value judgement will vary between countries, communities and individuals.[13] Determining an *acceptable level* of risk in turn involves consideration of several factors including: the potential impacts of different concentration levels; threshold levels; the degree of effort required; and costs.

2.3.1 Impacts on the Environment

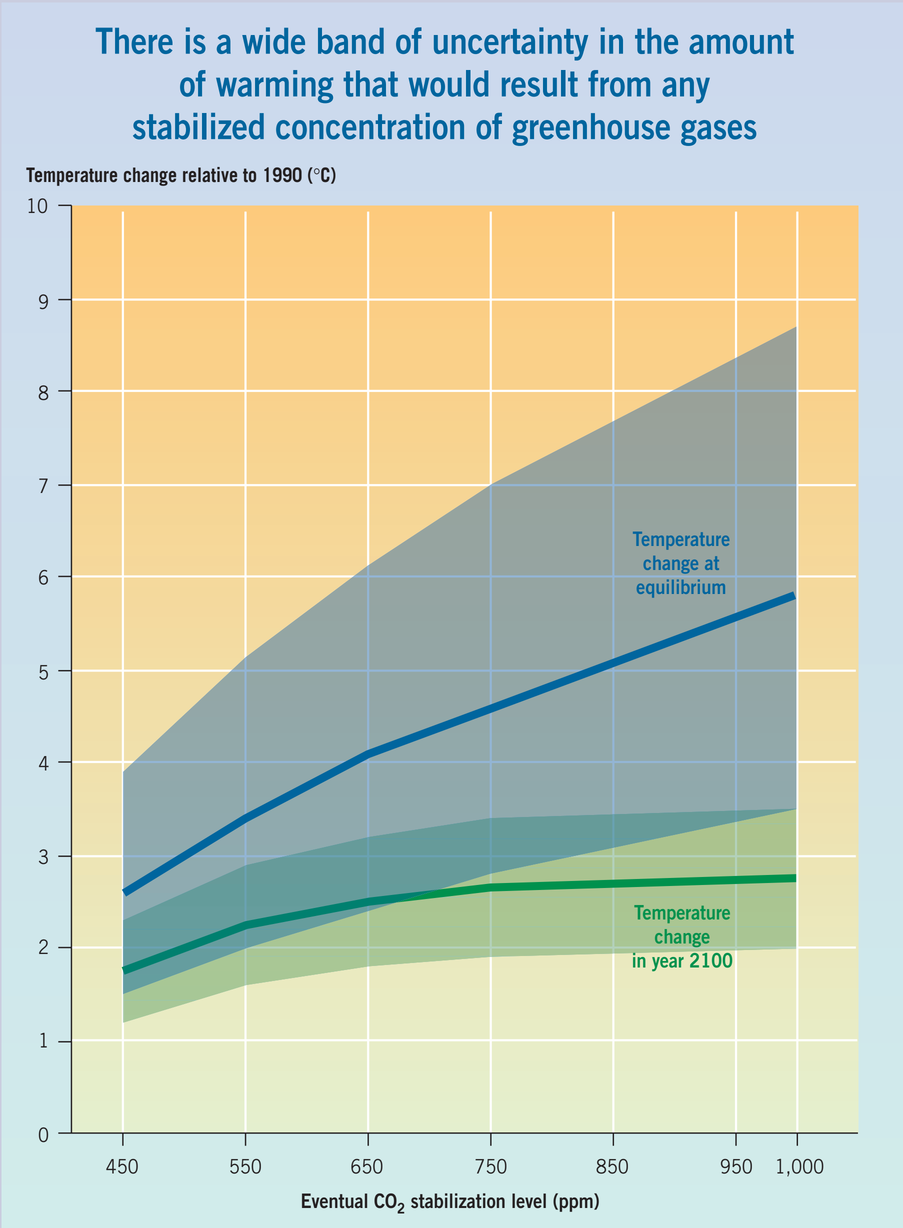
Only a few studies have directly evaluated the environmental benefits of stabilising concentrations at different levels in the atmosphere.[14] The approach used to do so can be described as involving two steps. The first is to estimate projected changes in temperature for the different stabilisation targets. The second step is to relate this to predicted environmental impacts of different temperature ranges. Both areas of research involve considerable uncertainties, and the results therefore, can at present only be expressed in very general terms.

Step 1: Concentration levels and temperature change

Figure 5 maps different CO_2 stabilisation levels against the corresponding range of temperature change that is expected in 2100. At a stabilisation level of 450 ppm, the estimated range of temperature increase by the year 2100, is 1.2 to 2.4°C. At 550 ppm the estimated range is an increase of 1.6 to

2.9°C. At 1000 ppm, the estimated range is an increase of 2.0 to 3.5°C. In comparison, if no measures are taken to reduce greenhouse gas emissions, the IPCC scenarios project that temperature levels could increase by up to 5.8°C in 2100. Figure 5 also shows projected long-range equilibrium temperature levels associated with the different concentration targets.[15] This illustrates that in the long-term the different stabilisation targets have potentially very different temperature ranges. For example stabilisation at 450 ppm could lead to a long-term temperature increase of between 1.4 to 4.0°C. Stabilising emissions at 1000 ppm could lead to a long-term temperature increase of between 3.4 and 8.9°C.

Figure 5. Temperature Change in 2100 for different stabilisation levels



The low and high estimates for each stabilisation level assume a climate sensitivity of 1.7 and 4.2°C respectively. The centre line is an average of low and high estimates.

Source: IPCC (2001 a)

Step 2: Environmental impacts of temperature change

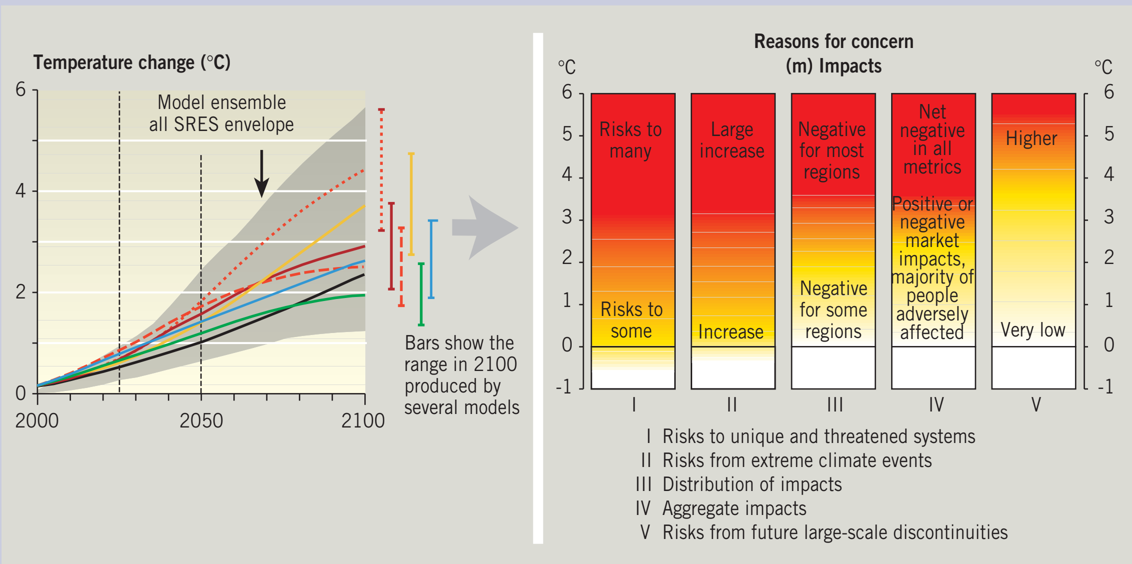
The risks of impacts associated with different global temperature levels are depicted in figure 6 taken from the IPCC Synthesis Report to the TAR. These risks are sorted into five main areas of concern: the risks of large scale singular events (such as the shut down of the North Atlantic thermohaline circulation); aggregate impacts; the distribution of world impacts among world regions; the risk of extreme weather events; and risks to unique and threatened ecosystems.

Bringing these two areas of research together enables some assessment of the potential environmental impacts of different stabilisation targets. In undertaking such an assessment however, much depends on whether a *long-term* (100 years) or *very long-term* (two to several centuries) perspective is taken.

If the analysis is confined to a 100 year time fame, the IPCC projections (illustrated in Figure 5) suggest that that efforts to reach an eventual stabilisation target of 1000 ppm or below, would through the period to 2100 be likely to limit global mean temperature increase to below 3.5°C and therefore avoid the more severe impacts associated with warming above this range. They also suggest that there would be little difference in terms of environmental impacts between a stabilisation target of 750 ppm and 1000 ppm. There are more clear differences in terms of projected impacts when comparing targets at 750 ppm and below in this time frame. Moving from 750 ppm to a target of 550 ppm for example would deliver a range of temperature change that is significantly lower. While adopting a target of 450 ppm would lower this range still further and probably ensure that warming is limited to less than 3°C.

If the perspective is changed to impacts 100 years and beyond, however, the picture changes markedly. In the case of 1000 ppm the upper range of temperature increase is projected to be as high 9°C, in which case the environmental impacts would likely be catastrophic. The average rate of temperature increase at this temperature level is projected to be 6°C, which would imply negative impacts for all the areas of concerns illustrated in figure 6. Therefore, it is in the longer-term time frame that the real risks of moving towards higher stabilisation targets become apparent.

Figure 6. Risks of climate change damages



Note: In the right part of the figure each panel corresponds to a reason for concern; colours correspond to severity of impact or risk. White means no or virtually neutral impact or risk, yellow indicates negative impacts for some systems or low risks, and red means more negative impacts or higher risks.

Source: IPCC (2001 a)

Box 4: The impacts of the different stabilisation targets

The impacts of the different stabilisation levels depend on the degree of climate sensitivity. Climate sensitivity is the degree to which a system is affected either adversely or beneficially by climate related stimuli.

- **Stabilisation at 750 to 1000 ppmv. For low climate sensitivity, stabilisation in this range may lessen or possibly avoid some of the impacts anticipated for warming above 3 to 4°C. However, significant impacts associated with warming of up to 3°C would not be prevented. In the case of average to high climate sensitivity, warming would exceed 4°C and result in many severe effects (e.g. extensive coral death, loss of many valuable and unique ecosystems) as well as market sector effects that would be negative for most countries. Stabilisation at these levels would also risk large scale, high impact events in future centuries.**
- **Stabilisation at 550 to 650 ppmv. Stabilisation in this range may significantly lessen or possibly avoid some of the impacts associated with warming greater than 3°C for average to low values of climate sensitivity. However, significant impacts associated with warming up to 3°C would not be prevented. These include: the loss of some unique vegetation systems; extensive coastal wetland loss; decreases in crop yields in most regions; and many adverse impacts to which developing countries would be most vulnerable. Also there is a risk of effects that would occur at warming greater than 3°C for high values of sensitivity.**
- **Stabilisation at 450 ppmv. Stabilisation at 450 ppmv is projected to limit warming to less than 3°C even for high values of climate sensitivity. Many of the impacts listed for 3°C warming may be significantly reduced.**

Source: IPCC (2001 a)

Clearly, adopting more ambitious targets will reduce the risk of severe climatic impacts. Further information, however is needed before taking a position on an acceptable level of risk. For example, at what temperature levels will impacts on the environment cross critical thresholds or become irreversible? What are the costs of reaching different targets and the tradeoffs that society must face? These questions are addressed in the next few sections.

2.3.2 Limits and Thresholds

An important reference point in the discussion of impacts is the level at which an environmental limit or threshold is reached. A threshold may be the point at which change becomes irreversible or it may be a "trigger point" for extreme climatic events to be set in motion. The IPCC defines two types of irreversibility.[16] The first is one where natural processes can eventually return to their pre-disturbance level, but only after many centuries or millennia. An example of this type of threshold is the projected rise in sea level. Sea level rise is now clearly an unavoidable consequence of past actions, irrespective of what action we take from this point. The second definition represents the crossing of a threshold, beyond which the system can no longer return to its previous state. An example of this is the loss of a species. Similarly there are thought to be thresholds in climate systems which, if exceeded, could trigger large scale singular events such as the disintegration of the west Antarctic ice sheet or a partial (or even complete) shutdown of the North Atlantic thermohaline circulation.

Greater knowledge as to where certain **threshold levels** lie would greatly assist the task of determining global targets. If politicians, other decisions makers, and the public at large knew that a certain target was necessary to avoid crossing a critical threshold level it may be much easier to reach an agreement on the need to reach that target. For some species there is very good knowledge as to where critical threshold levels lie. For example, it is known that warming of up to 1°C will have severe consequences for some species. In general, the greater the rate and magnitude of temperature change the greater the likelihood that critical thresholds of systems will be surpassed.[17] However, it is the risk of climatic events and large-scale discontinuities, which appear to capture public attention. Determining possible threshold levels for large-scale changes in the earth's climate system, is very uncertain as scientific research in this area has to date been limited. The IPCC TAR (IPCC, 2001 a) concludes that large-scale discontinuities are unlikely below a 2°C warming but relatively plausible for a sustained warming of 8-10°C. The relatively small set of investigations to date suggest that a warming range of 4-5°C seems to represent a critical level where macro-discontinuities may arise.[18]

2.3.3 Costs

The cost of meeting a stabilisation target will play a strong role in society's decisions on the level of acceptable risk. Long-term studies analysed by the IPCC show that the costs of stabilising greenhouse gas concentrations in the atmosphere are determined by the stringency of the stabilisation target, the distribution of emission reductions over time, policies and measures employed, assumptions about the discount rate, and the choice of reference scenario (IPCC, 2001 c). For any given reference scenario the costs of stabilisation at 450 ppm are substantially greater than those of stabilising at 750 ppm, **with a strong increase if moving from 550 to 450 ppm.** In figure 7 these costs are estimated in trillions of US dollars. The costs of stabilising the atmospheric concentration of CO_2 at 450,500 and 650 ppm are estimated to be in the range of 2.5-18 trillion USD, 1-8 trillion USD and 0.5-2 trillion USD respectively.

The IPCC TAR also presents estimates of the cost of reaching different stabilisation targets measured as a reduction in the **relative level of GDP** (that is to say the difference in GDP in a given year between a scenario where no action is taken compared with a scenario where action is taken to meet a certain stabilisation target) through to 2050. In the case of the most ambitious target level considered, 450 ppm, the annual reduction in GDP ranged from just over 1% to just over 4%. A target level of 550 ppm on the other hand is predicted to result in a reduction in GDP from 0.2% to 1.7%.[19]

How should these figures be interpreted? A figure of 18 trillion USD is an enormous sum – the annual output of the global economy in 1990 was estimated to be 20 trillion (1990) USD[20], while figures of a 1-4 % percent loss in relative GDP would alarm many decision makers. It is interesting however, to view these figures in the context of expected global income growth over the time in which these measures are taken. Azar and Schneider (2002) argue that although trillion dollar costs are significant they will only have a marginal impact on the overall pattern of global income growth. This is because the global economy will continue to grow even if the more ambitious stabilisation targets are undertaken. For example, reducing global emissions by 50% by 2050 is projected to cost some 1-4% of relative GDP. However, as global income is still expected to grow by 2-3% these abatement costs will be overtaken after a few years of income growth. The main conclusion of Azar and Schneider (2002) is that low stabilisation targets can be met at the same time as the global economy grows several-fold over the next century.

Several more caveats to these projections should be noted. The projected losses vary considerably across regions and time (the maximum reduction in any one year across all the stabilisation scenarios was predicted to be 6.1%). The models used do not incorporate carbon sequestration and other gases into their calculations (if they were to do the costs of meeting certain targets are likely to be lower). Neither do the models estimate the economic benefits of environmental damages avoided.

For the reasons noted above, not too much emphasis should be placed on the absolute levels of costs projected in these models, but rather how they are projected to increase or decrease in relation to the different target levels. The main conclusion to be drawn from the IPCC analysis is that regardless of scenarios, costs will increase markedly when moving from a 550 ppm to more ambitious targets such as a 450 ppm target. Therefore, there will need to be sound arguments in favour of the benefits to be reached by undertaking these more ambitious targets if there is to be international political consensus.

2.3.4 How big is the gap – How much effort is required?

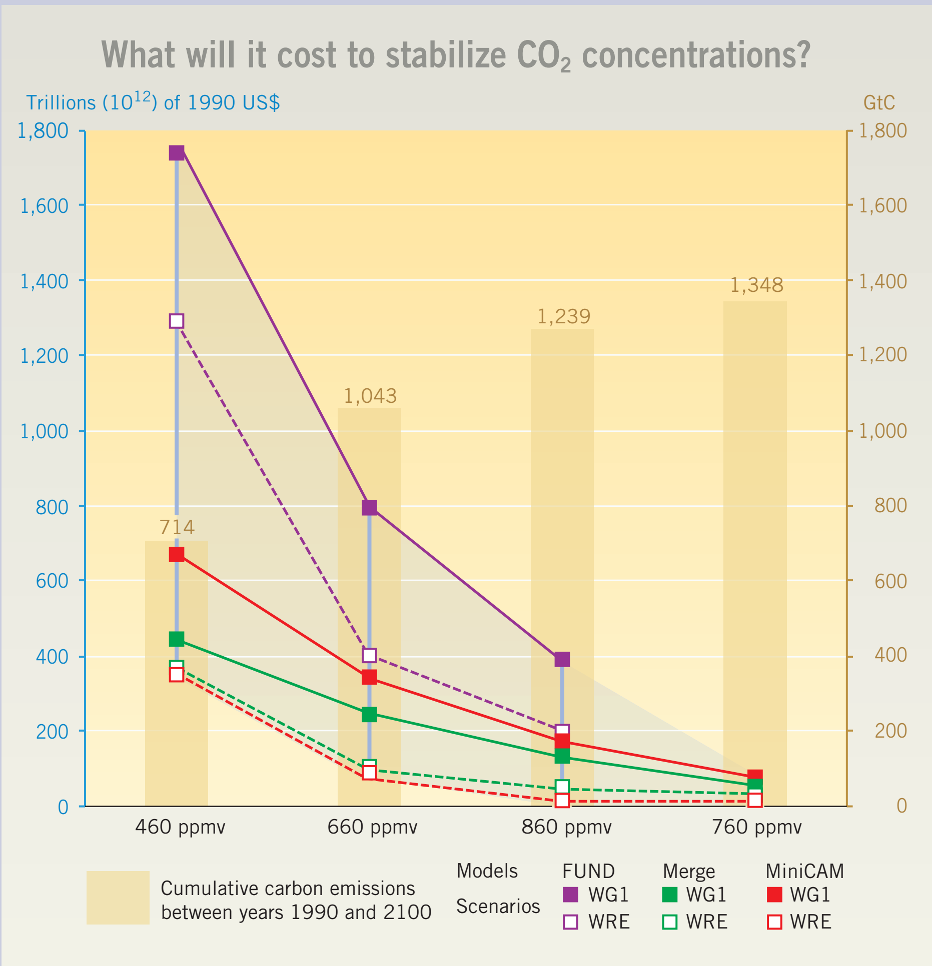
The amount of effort to reach a stabilisation target has major implications for its feasibility. If a target is so ambitious that it would require a complete transformation of energy systems in a short time-frame it is unlikely to be acceptable to society. The degree of difficulty and its effect on the daily lifestyles of society will in turn influence society's perception of *acceptable risk*. Costs are clearly one important indicator of effort. However, there are other indicators that can also be used to paint a picture of the feasibility of a target. These include: the required changes in economic activity; the timing in which it must occur; and the technical capability to reach a certain target.

To achieve a stabilisation of atmospheric concentration at any reasonable level is going to require major change. Even relatively high concentration levels such as 750-1000 ppm, would require emissions to be **less than half current levels** per unit of economic activity in the coming century and thereafter. Reaching lower stabilisation levels (350-500ppm) by 2100 would require earlier and more significant reductions, especially for the longest lived GHGs (e.g. CO_2, HFC, SF_6).[21] For example, carbon cycle models indicate that in order to stabilise atmospheric concentrations of CO_2 at 550 ppm, emissions would have to decrease by 60 to 80% below current levels by 2100 – and potentially decrease further thereafter.[22] Stabilising at 450 ppm would require very rapid emission reductions over the next 20-30 years (see Table 1).[23]

To stabilise GHG concentrations at any level below 600 ppm would require either the rate of energy intensity or the rate of carbon intensity (carbon per unit energy produced) to improve at a ratio much higher than has been historically achieved. The annual rate of energy improvement has traditionally been 1.0 to 1.5% per anum.[24]

Model analysis suggests that a target of 550 ppm, 450 ppm or lower is achievable with current technology but the implementation of this technology would require significant socio-economic changes.[25] Critically in the case of energy there would need to be an introduction of efficient technologies for both energy use and supply and of low or "no carbon" energy. The more ambitious targets are therefore probably achievable in a technical sense. The economic and political reality, however, may be quite different.

Figure 7. Costs of Stabilising CO_2 Concentrations



Source: IPCC (2001 a). (1990 US$, present value per year for 1990-2100).

Table 1: Comparison of Atmospheric concentrations and implications in terms of impacts, timing and degree of effort required

Stabilisation concentrations by 2100 (CO_2)	Projected rate of temperature change by 2100	Required limit on fossil fuel carbon emissions Current level 6.29 billion tonnes	Per capita carbon emissions in 2100 T/capita/year* Current level: 1t/capita/year	Total cumulative carbon emissions 1990 to 2100 (1000tC)	Timing when CO_2 emissions must drop below 1990 levels and steadily decrease thereafter**
1000 ppm	2.0-3.5°C				Two centuries
750ppm	1.9-3.4°C	12 billion tonnes	1.2	1200-1300	
650 ppm	1.7-3.2°C	9 billion tonnes	0.9	1030-1190	Within the period 2090 and 2150
550 ppm	1.6-2.8°C	6 billion tonnes	0.6	870-990	Within the period 2040 to 2100.
450 ppm	1.2-2.3°C	3 billion tonnes	0.3	630-650	Within the period 2010 to 2040

Sources: IPCC (2001) TAR

** Assuming a world population stabilised at 10 billion people*

*** IPCC (2001 a)*

2.4 "Tolerable windows" and "safe landing approaches"

Rather than seeking a single optimal path, "tolerable windows" or "safe landing approaches" seek to delineate the complete array of possible emissions paths that satisfy defined climate impact and emission cost constraints. The name of the safe landing analysis is derived from an analogy with aviation, namely that a plane should stay within a safe landing corridor hitting the ground neither too quickly nor too late.[26]

The IPCC's TAR discusses "tolerable windows" and "safe landing approaches" as alternatives to GHG stabilisation targets.[27] These approaches analyse GHG emissions, as they would be constrained by *long-term* and *medium-term* climate targets – rather than a GHG concentration stabilisation target. For example the constraints may be related to changes in global average surface temperature between 1990 and 2100 and a rate of temperature change per decade. The objective of this approach is to determine levels of *short-term greenhouse gas emissions* that are compatible with intermediate and long-term climate goals.

Results indicate that delaying near term emission reductions can drastically reduce the future range of options for relatively tight climate change targets, while tight targets offer more near term flexibility. This is a subject discussed further in section 3.

2.5 Discussion

1. Are long-term targets needed?

From a research and policy making point of view it would be extremely helpful to have long-term targets. Defining a long-term objective, for example, a stabilisation target for global concentrations of greenhouse gases can then be broken down into medium-term (e.g. 2050) and short-term (e.g. 2010) targets. This increases the likelihood that emission reduction strategies can be implemented in a cost-effective and fair way. It also provides a reference point for setting short-term targets and strategies. This has been the experience in Sweden, where the adoption of long and medium-term targets has been influential in a recent political decision to revise Sweden's national target for 2008-2012 (See Box 4).

On going research into, and debate on long-term targets is therefore needed to set a context for short and medium-term policy actions. Achieving an ***international consensus on*** long-term stabilisation

Box 5: Sweden's goal focused climate strategy

Sweden's climate strategy is very much focused on reaching a series of goals over different time frames. In 2001 the Swedish Government adopted a long-term goal of stabilising emissions of all the major greenhouse gases at 550 ppm. This is a global target that Sweden wishes to see achieved through the efforts of all countries. To be on track to reach this target, it was calculated that by 2050 per capita emissions of CO_2 and other greenhouse gases of developed countries must be reduced to below 4,5 tonnes of CO_2 equivalent by 2050 and increasingly reduced thereafter. This is now a government endorsed medium-term goal, for Sweden, compared with the current level of 8.3 tonnes per capita.

Within the EU's internal burden sharing agreement (the agreement on how the EU's Kyoto target would be allocated amongst the EU member states), Sweden had negotiated a target which allowed them to increase emissions by 4% relative to 1990 during 2008-2012. In 2001 the decision was taken by the Swedish Government to adopt a more ambitious national target of - 4% compared to 1990 levels (to be achieved domestically). This decision was in part influenced by advice given to the Swedish Government that more aggressive short-term action is needed by Sweden, and other countries, if the medium-term goal (2050) is to be reached.

targets, however, will be very difficult to achieve at any point in the near future. As has been mentioned earlier in this section, what is considered to be a 'safe' level of climate change will vary widely between countries and regions. The more immediate and realistic task should instead be to develop some degree of international consensus around short and medium-term targets that keep future options open. Such short and medium-term targets will probably be expressed in terms of emissions rather than global concentrations of greenhouse gases.

This has been the approach recommended by the Climate Options for the Long-term (COOL) Project.[28] This project identified a medium-term target (2050) target that would keep options open for reaching a long-term stabilisation of stabilising CO_2 emissions at 450 ppm. They estimated that to do this, global CO_2 emissions would need to be reduced by 15-25% compared to 1990 levels. Such a medium-term target can in turn be more easily be translated into strategies for short-term action.

2. What role should costs have in setting medium and long-term targets?

The IPCC's TAR in a discussion on long-term targets states that mitigation costs "play only a secondary role in establishing the target" and that "they play a more important role in determining how the target is to be achieved" (IPCC, 2001 c). This reluctance to compare the potential mitigation costs of a long-term target with the potential benefits (i.e. the environmental impacts avoided) stems partly from the difficulty in forecasting costs over such long time periods. However, costs inevitably do play an important role in any discussion on long-term targets. For example, economic analysis to date, has been relatively consistent in suggesting that the costs of moving from a 550 ppm to a 450 ppm target would be considerable. This is inevitably a factor in why the EU's long-term target has been set at 550 ppm and not at a more ambitious level.

Despite the metodological difficulties there is a need to bring economic arguments more explicitly into this debate. This can be more readily accommodated in the case of short and medium-term (e.g. through to 2050) strategies that keep future options open. At the same time there is a need for considerable improvement in the methodologies and assumptions used by economists to undertake this analysis. Some of these issues are taken up in section 3 of this report.

3. When to Act?

Another major factor in the international community's response to climate change is the decision of when to act. Should emissions reductions be taken now or later? Current analysis suggests that decisions on timing are as influential as decisions on targets in determining costs. This section reviews the literature on "timing" issues, including environmental and economic considerations. Key concepts that are introduced include, "least cost" and "optimal" pathways to a global target, hedging strategies in the face of uncertainty, and the role of induced technological change.

3.1 Introduction

The timing of action to reduce emissions is a major factor in the climate change debate. Because a particular concentration of CO_2 in the atmosphere is determined more by cumulative than year-by-year emissions, a concentration target can be reached through a variety of **pathways**. The IPCC's TAR (IPCC, 2001 c) describes the choice of emission pathways as a **carbon budget allocation problem**. "*Choosing a certain stabilisation target is in effect defining an allowable amount of carbon that can be emitted into the atmosphere between now and some point in the future.*"

The challenge for policy makers is how to best allocate this budget over time. The choice of pathways will have both environmental and economic effects. There are also political and social questions. Deferring action may in some cases be the best approach from an economic viewpoint, but this means shifting costs onto another generation. Furthermore, the more action is deferred the greater the risk that necessary measures will be avoided and that targets are continuously revised and pushed back. Technological change is another factor in the debate. How should climate policies be timed to promote technological change and what effect will this have on costs? These issues are discussed in the following sections.

3.2 Environmental issues

Different pathways to a stabilisation target will yield different time-paths of temperature change. For example, a pathway which defers emissions abatement until later is likely to result in a more rapid rate of warming initially compared to an "early action" pathway to the same target. This can have important implications because the faster the rate of temperature change the more difficult it is for plant and animal species to adapt.[29] For example a temperature change of 2°C occurring within a decade would have a more profound impact than one occurring over a century.

3.3 Economic arguments

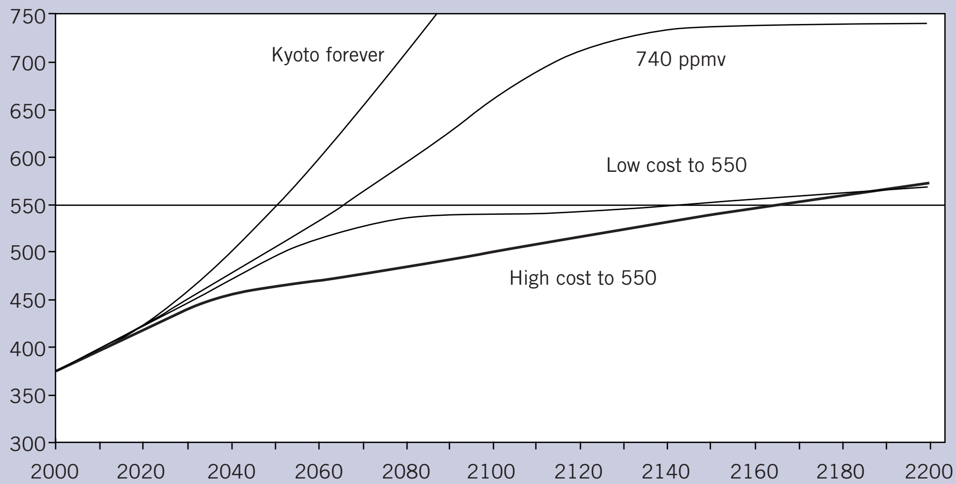
The timing of emission reductions is as important as the choice of target itself in determining costs. Economic analysis of pathways has distinguished between "least cost pathways" when the target is known and optimal pathways when a target is not know with certainty.

3.3.1 Least cost pathways

Most studies that have attempted to identify the least cost pathway for meeting a particular target conclude that least cost pathways tend to depart gradually from a models baseline in the early years with more rapid reductions later on. Often quoted in discussion on pathways are stabilisation scenarios produced by Wigley, Richels and Edmonds (Wigley *et. al*, 1996) referred to as the WRE scenarios. These scenarios suggested that it be would less costly if abatement action were deferred. The results of this work have been widely interpreted by many policy makers as favouring a "wait and see" approach, although the authors stress this was not their conclusion.[30] The OECD has produced similar results. Figure 8 illustrates two alternative pathways to reach a long-term target of stabilising GHG concentrations at 550 ppm. One is a "low cost scenario" where emission reductions are phased in gradually over the next 50 years. The second is a "high cost scenario" where more drastic emissions reduction are undertaken in the short-term (OECD, 1999).

There are several reasons why economic models produce these results. A gradual near term transition towards emission reductions allows for technology development and avoids the premature replacement of expensive capital stock (such as power plants, buildings and transport). It also avoids premature lock-in to early versions of low emissions technology. There is also the effect of time discounting. Discounting is the method used by economic models to account for the value of a unit of currency being higher, in terms of spending power, today than it will be in the future. Economic models therefore, commonly discount the value of future expenditures or returns. The result being that the overall costs of reducing emissions are less when they are shifted towards the future.[31]

Figure 8: Alternative CO_2 concentration pathways



These pathways focus on actions that would be taken in the next 50 years. They include:

1. **A Kyoto for ever scenario**
2. **A low-cost 550 ppm scenario, emission reductions are phased in so as to let concentrations rise towards 500 ppm of CO_2 in 2080, and then broadly stabilise at that level.**
3. **A high cost 550 ppm scenario, more drastic emission reductions are introduced prior to 2050 in order to keep concentrations well below 550 ppm over the next century.**
4. **Concentrations rise to 740 ppm.**

Source: OECD (1999)

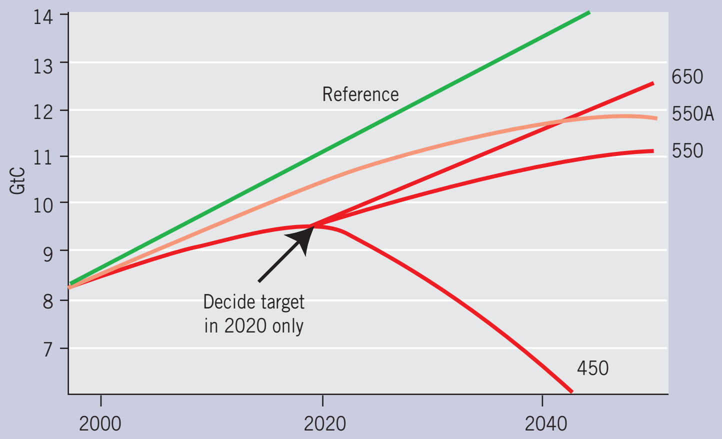
The extent to which these models present an argument in favour of delayed rather than early action is hotly debated by many analysts. Some counter-arguments to these results are discussed in section 3.4. The arguments for appropriate timing also have a different perspective, when there is uncertainty about the ultimate objective.

3.3.2 Pathways to uncertain targets

The arguments concerning "optimal pathways" become more complex when uncertainty about the ultimate target is considered.[32] A plausible example is as follows. Assume the international community agrees to a global target of 550 ppm and then in twenty years time decides the target must be moved to 450 ppm based on new information about the extent and impacts of climate change. If action has been delayed the cost of an abrupt reduction in emissions would be much higher than if early action had already been implemented. The reverse is likely to be true if it is decided that a less stringent target is needed. In sum, an optimal strategy will involve a near term hedging strategy, "one that balances the risks of acting too slowly to reduce emissions with the risks of acting too aggressively." [33]

Figure 9 presents the results of an analysis by Ha Duong *et. al* (1997) of an optimal hedging strategy assuming that certainty about the long-term target is not reached until 2020.[34] In this case they assign equal probability to a target of 450 ppm, 550 ppm and 650 ppm. The solid line (550A) corresponds to the optimal pathway when the target is known to be 550 ppm from the outset. In comparison, a hedging strategy that leaves open the possibility to revise long-term targets requires more determined action to reduce emissions in the short-term.

Figure 9. A Hedging strategy



Source IPCC (2001 c)

The desirable amount of hedging depends upon an assessment of the stakes (how severe will the impacts associated with a certain stabilisation target be?), the odds and the costs. Once again the risk premium – the amount that society is willing to pay to reduce risk – is ultimately a political decision and will vary between countries.[35]

3.4 The role of technology change?

In a subject area such as climate change policy that encompasses great uncertainty one issue on which there is widespread agreement is the need for technology change. It is generally accepted that without technological change it will not be possible to make the transition to a low carbon economy necessary to stabilise greenhouse gas concentrations at a "safe" level, however this is defined.

That technological change is needed therefore, is not disputed. More contentious are the factors which are thought to drive technological change, the effect of technological change on costs, and in particular, the implications of this for the **timing of action** to abate emissions.[36] As mentioned earlier, conventional economic models tend to favour delayed abatement, one reason being that technological change is expected to make the costs of abatement cheaper in the future relative to the present. However, a counter argument is that early action to reduce emissions will stimulate technological change, which will in turn bring costs down quicker than they otherwise would occur.

Part of the reason for this difference in views is that most economic models of GHG abatement options and costs assume that technological change is exogenous or external to the model and therefore unaffected by changes in energy prices or policy.[37] Real world experience, however, suggests that the rate of technological change is influenced by changing prices that have in turn been bought about by policy measures.[38] This is referred to as *induced technical change* (ITC). For example, a carbon tax may create an incentive to increase research and development into non-carbon based fuels. This can set in place a dynamic process of innovation and invention that can reduce costs further and open up further opportunities for development. The economic viability of a developing technology can quickly change. In recent years there has been considerable discussion about the potential for ITC to substantially lower or even eliminate the costs of CO_2 abatement.[39]

While the phenomenon of policy-induced innovation has long been recognised by some economists, incorporating ITC into economic models has proven to be problematic in the past.[40] However, new models incorporating ITC suggest that it could make addressing climate change quite cheap in the long run. These models offer an economic formalisation of the "Porter Hypothesis" i.e. that environmental regulation can improve economic competitiveness by stimulating the development of better technologies.

There is as yet little consensus amongst economists about the implications of these arguments for the optimal timing of emission abatement. One important caveat is that policies which aim to promote research and development, and therefore technological change, in one sector, are likely to come at the expense of reduced investment in research and development in another sector. However, one general conclusion that can be drawn from this discussion is that conventional economic models that treat technical change as autonomous may well overstate the costs of complying with abatement policy in general, and of early action strategies in particular.[41]

3.5 Political realities

A further limitation of economic models that map out "optimal" pathways to a stabilisation target is that they assume that future generations will act in accordance with the recommendations of the model. However, if a strategy was taken to delay short-term action and instead rely on making rapid and deep cuts in emission at a later date (for example in 2050 or 2060) the decision makers at that point in time could find such a requirement to be politically unfeasible. Delaying action increases the risk that the required action will not be taken. There are also clearly inter-generational equity issues linked to this debate on timing. Some of these issues are discussed in Section 4.

3.6 Discussion

Economic opinion on timing is uncertain

Conventional economic analysis of the least cost pathway to a certain stabilisation target tends to favour delayed over early action. The main explanation behind this analysis is that delaying action will give more time to develop new technologies and to gradually replace existing energy infrastructure. The effect of discounting costs is also a major contributor to these results. However, a number of economists are challenging these results. While there is no clear consensus amongst economists on the question of when to act, there appears to be growing empirical evidence that conventional models are overstating the costs associated with early action.

Knowledge about the magnitude and impacts of future climate change is uncertain

In the face of uncertainty as to the long-term environmental impacts of climate change the arguments in favour of early action become much stronger. "Safe" long run targets can not be determined with a high degree of confidence. There is every likelihood that society's decision on what is a "safe" level will change over time. Earlier action allows society to keep its options open. Delayed action would make the realisation of more ambitious target levels, such as 450 ppm, practically impossible.

Uncertainty in these two areas point to the merit of strategies which keep future options open

In summary there are four main arguments in favour of early action.

1) Early action strategies are likely to slow the rate of temperature increase, which will increase the chances of species adapting to climate change.
2) There is a need to keep options open in the face of uncertainty as to long-term impacts of climate change. Early action allow for this.
3) Delaying action push costs onto future generations, which increases the likelihood, that the desired level of action will not occur.
4) Early action can promote the technological progress needed to effect a transition to a low carbon economy.

4. Acting Fairly – Sharing Cost, Effort and Resources

Equity issues are at the very core of the climate change debate: Who bears the greatest responsibility for climate change? Who is at greatest risk? Who is best able to act? What responsibility do we have to future generations? What rights do we have to use the atmosphere?

This section provides an overview of equity issues associated with climate change with a particular focus on the question of how to share the international effort to reduce emissions among countries. To some extent these issues have been addressed in the FCCC and the Kyoto Protocol. However, it is generally acknowledged that the discussion on fundamental long-term equity issues, in particular the question of developing country commitments, has yet to occur.

4.1 Climate change and equity

In common language equity can be defined as "the quality of being fair or impartial" or "something that is fair and just".[42] There are a variety of meanings of equity and philosophical approaches to it.[43] Equity issues exist at both national and international levels, as well between (inter-generational) and within (intra-generational) generations. Furthermore, equity issues are often categorised as being procedural issues (how decisions are made) or consequential (the outcome of decisions).

The phenomenon of climate change and the international response to it presents a mass of equity issues. Key equity questions include:

- How to cope with and adapt to the impacts of climate change? (International and national equity) *"The impacts of climate change are likely to fall disproportionately upon the poorest countries and the poorest persons within countries, and thereby exacerbate inequities in health status and access to food, clean water and resources."*[44]
- How should the effort needed to prevent or minimise climate change be distributed amongst the various nations of the world, rich and poor? (international equity)
- What are the rights of future generations? (intergenerational equity)
- What are the equity and social issues that need to be addressed within countries? (intra-national equity).

The IPCC Second Assessment Report (IPCC, 1996) summarised the equity issue thus: *"The challenge of climate change mitigation from an equity perspective is to ensure that neither the impact of climate change nor that of the mitigation policies exacerbates existing inequities both within and across nations."*

4.1.1 How is equity addressed at present?

Equity is a prominent theme in the **UNFCCC**. The first principle of the UNFCCC (Article 3.1) 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. Accordingly the developed country Parties should take the lead in combating climate change and the adverse impacts thereof."

Further references relevant to equity issues include:

- "the share of global emissions originating in developing countries will grow to meet their social and developmental needs."
- "industrialised countries are required to assist developing countries in coping and adapting with the impacts of climate change (various paragraphs in Article 4)."
- "Economic development and poverty eradication are the first and overriding principles of sustainable development."

Furthermore, under the Kyoto Protocol:

- Currently non-Annex I countries are exempt from specific mitigation obligations.
- National commitments to reduce or limit emissions are differentiated between the Annex I countries.
- The Clean Development mechanism (CDM) was established to assist developing countries in achieving sustainable development while contributing to the ultimate objectives of the UNFCCC.

In sum, aspects of equity have been addressed within the FCCC and Kyoto Protocol process, and important precedents have been set. Perhaps most significant is the requirement that developed countries should act first in reducing emissions. However, it is generally acknowledged that when looking beyond the first commitment period (2008-12), and the need to involve all countries in a co-operative strategy to reduce global GHG emissions, equity issues have a key role to play and much more discussion is needed.

4.2 Sharing the global effort

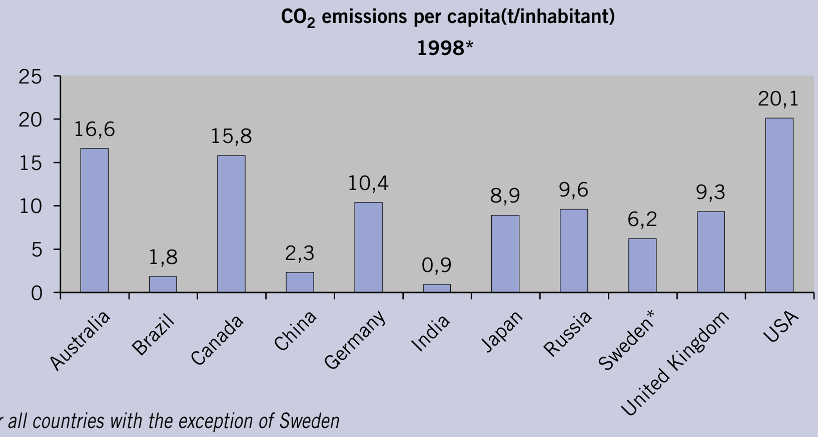
The focus of this remainder of this chapter is on **international equity** issues associated with the **global response** to limit climate change. In particular, how should the international effort to reduce emissions be shared amongst countries (often referred to as burden sharing), and the role of developing countries? **Section 4.2.1** outlines the nature and magnitude of the challenge facing international negotiators and the global community. **Section 4.2.2** goes further into the debate as to how to define and measure equity, introducing a number of **equity principles** that can be taken into consideration. **Section 4.2.3** evaluates a range of proposals or formulae for burden sharing in the context of how they satisfy equity and other criteria.

Use of the term "burden sharing" itself has been criticised by many because it implies that there is only a cost or negative effect associated with reducing global emissions of greenhouse gases. An alternative is to refer to "responsibility sharing" or simply, ways of sharing the global effort, which is the preferred terminology of this report.

4.2.1 Nature of the Challenge

Currently it is estimated that **the global average for emissions per capita per year equates to about 3.7 tonne of CO_2** (total CO_2 emissions are in the range of 23 billion tonnes). To achieve a 450 ppm concentration target, average CO_2 emissions per capita globally need to drop to **about 1 ton per capita in 2100**.[45] This task is made more onerous if ones considers that some "business as usual" scenarios predict cumulative emissions between now and 2100 to double, with annual average emissions of 7 tonnes of CO_2 per capita per year.

Figure 10. CO_2 emissions per capita



Source: UNFCCC, for all countries with the exception of Sweden

** Sweden's data is for the year 2000 and was sourced from Statistics Sweden (SCB)*

Achieving reductions in global concentrations of greenhouse gases will ultimately require emission reductions in both developed and developing countries. The major issue facing all countries is how the task of reaching this goal should be distributed. At present in the context of the FCCC there is a political agreement that developed countries will act first. When and how developing countries would play a part has not yet been determined. The fact that the Kyoto Protocol excludes developing countries from reduction commitments in the first commitment period was one of the key reasons cited by the US for their withdrawal from the Protocol in 2001.

The question of how to distribute the responsibility for reducing global emissions of greenhouse gases amongst different countries, often referred to as "burden sharing", underpins international negotiations on climate change. The quantified emission reduction commitments agreed to in Kyoto were a first agreement on burden sharing. These differentiated targets were not founded on any specific method but rather, were the result of negotiations taking into consideration various interests and the national circumstances of parties. It is generally accepted that a much wider debate on burden sharing still has to occur, as the focus moves beyond the first commitment period and the role of developing countries once more comes up for discussion.

4.2.2 Principles of equity

As indicated in the opening section, there are many ways of looking at and defining equity. What is seen to be fair by one person is not necessarily seen to be fair by another, and this problem magnifies itself in any discussion on global climate change. It is necessary therefore to establish some basic norms or principles of equity that are commonly agreed to. Four commonly discussed principles of equity are used here. These are "need", "responsibility" "opportunity" and "capacity".[46]

The principle or criterion of **need** can be translated as the minimal requirement, in terms of the right to emit greenhouse gases, all humans need in order to secure a decent standard of living.

Responsibility or "guilt" means that the cost of solving or alleviating a problem should be distributed in accordance to a party's share of responsibility for causing the problem. A dozen countries control 95% of conventional carbon-based energy resources, while 15 nations emit more than 75% of the world's annual carbon emissions.[47] In the Kyoto Protocol at present the onus is on developed countries to take actions because of their responsibility for historical emissions. However, the criterion of responsibility can also apply to current and future emissions.

The criterion of **capacity** refers to the ability of a country to pay. The conventional yardstick for measuring capacity is **GDP per capita**. While ability to pay can be seen as one aspect of fairness, it also has a strong bearing on the feasibility of an approach.

A further distinction can be made between countries where responsibility and standard of living may be similar but the **opportunity** to make real cost effective reductions varies. For example, some countries have high levels of energy efficiency while other countries with similar income levels produce energy much less efficiently.[48] Those countries with less energy efficient economies will have more potential to reduce emissions at low cost. The energy efficiency or energy intensity of an economy is often taken as an indicator of opportunity.

A further question is whether it is possible to establish any hierarchical order between these principles? The answer is probably not, however, it appears clear that for an international framework to be politically feasible it must be compatible with a basic interpretation of need.[49]

4.2.3 Other criteria

Ultimately, to assess the suitability of a certain approach, criteria such as **cost-effectiveness, environmental effectiveness** and **political acceptability** also need to be addressed.

Cost effectiveness can be described as minimising the cost of reaching a certain environmental objective. Alternatively, if there is uncertainty as to the environmental objective it can be described as how to achieve a better environmental outcome at a given cost.[50] In economic terms cost effectiveness is reached by equalising abatement costs within and between countries. Given the breadth and depth of emission reductions that will be required if the UNFCC is to reach its objective the cost effectiveness of a global regime will be crucial. In the long run the cost effectiveness of the global approach chosen may in turn determine its environmental effectiveness.

4.2.4 Ideas for sharing the global effort

The following section evaluates a number of formulae or proposals for burden sharing that have been discussed both in the past climate change negotiations and looking ahead to future agreements. The formulae or rules discussed are largely theoretical means of allocating responsibilities, and are not necessarily suggested as a framework for global action itself (which is discussed in the next section).

1. Flat rate targets

One of the simplest formulae for burden sharing would be for each country to commit to reduce their emissions by the same percentage. While this approach could arguably ensure some "equalisation" of effort it takes no account of need, capacity or responsibility and is most unlikely to be politically feasible.

2. Equalising Per Capita Emissions

A good starting point in the search for equitable solutions is the proposal to equalise per capita emissions at some point in time, meaning in effect, to assign everyone the same property rights to the atmosphere. Equalising or converging per capita emissions is the stated objective of the "Contraction and Convergence" proposal developed by the Global Commons Institute (see Box 6) and has been further encapsulated in several proposals put forward in the negotiating process. Argawal and Narain (1991) take this method a step further to recommend the use of per capita "net emissions" – that is emissions that exceed the per capita absorptive capacity of global carbon sinks.[51]

As noted earlier in figure 10, the disparities in per capita emissions between developed and developing countries are huge. Developing countries have generally promoted discussion of per capita emissions because it highlights these disparities in emissions and the associated individual lifestyles.

There is clearly a strong equity argument in favour of the concept of using per capita emissions as the basis for defining commitments. Equal rights for everyone is a common basis for fair actions, and such an approach goes a long way to address the criterion of **need**. The disadvantages of this indicator from an equity perspective, are that it does not take into account historical or future emissions. Furthermore, it has been suggested that using this criterion alone may create a perverse incentive for population growth.[52]

The main obstacle to the per capita emissions approach, however, is its **feasibility**. While undeniably a fair outcome it is unlikely to be supported by developed countries as part of a "contraction and convergence" approach because of the enormity of the challenge it would entail. Several proposals for convergence have set the bar at around one tonne of carbon dioxide per capita. As noted by Claussen and Mc Neilly (1998) if enough people think of such a proposal as impractical, even if it is fair, the chances of implementing any international mitigation standards are reduced.

Nevertheless, equalising per capita emissions is a good analytical reference point against which other equity proposals can be judged. It is also important to recall that virtually all stabilisation trajectories show a narrowing of the gap between per capita emissions of various countries and regions, so per capita emissions will be an important indicator of progress, or lack there-of, under any scenario.

Box 6: Contraction and Convergence

Contraction and Convergence is a proposal that was developed by the Global Commons Institute (GCI) several years ago. It is a proposal for burden sharing which has been promoted as an alternative framework for global action on climate change (Evans 2001). "Contraction" refers to a global emissions reduction trajectory designed not to exceed a specific greenhouse gas concentration in the atmosphere. "Convergence" refers to national emission entitlements designed to converge at an agreed date at equal per capita emission entitlements for all countries. Emission entitlements would be proportional to population from then on. GCI suggest that the contraction target should be a CO_2 atmospheric concentration level of 450 ppmv, stressing that this target should be reviewed at five year intervals. The year 2100 has been suggested as the convergence date.

Some parties have suggested other convergence criteria, although it remains the position of the GCI that per capita equality of emission entitlements is the simplest and most equitable proposal.

3. Cumulative Emissions

As mentioned in Chapter 3 it is *cumulative past emissions* that account for the current levels of greenhouse gases in the atmosphere. Calculating cumulative emissions is therefore a method aimed at estimating a country's *historical responsibility* for contributing to climate change. The International Institute of Applied Systems Analysis (IIASA) developed an extensive database of cumulative emissions of CO_2 and CH_4 dating back to 1800. Their results show that the industrialised countries account for about two thirds of cumulative emissions.[53]

Brazil tabled a proposal based on this concept at the Ad Hoc Group on the Berlin Mandate (AGBM) in 1997. The proposal was designed to apply to all parties including developing countries. A method of allocating responsibility based on cumulative emissions, scores highly against criteria such as responsibility, specifically **historical responsibility**, and could be said to be the guiding rationale behind the current international process. However, it gives little indication of future responsibility, ability to pay, or need.

4. Intensity targets

Intensity targets are formulated relative to economic output, often in terms of gross domestic product (GDP). In the case of greenhouse gas emissions, intensity targets can be defined which specify a certain level of emissions per unit of GDP. An alternative to measuring emissions intensity is to measure energy efficiency, the use of energy per unit GDP.

There are two main arguments in favour of using intensity targets. The first is an equity argument – that they reflect a country's **opportunity** to reduce emissions. A country with a low level of energy efficiency has greater potential to cost-effectively reduce emissions than a country that has already attained a high level of efficiency. The second argument is an economic one – primarily that an agreement based on intensity indicators provides flexibility in the way countries can react to economic growth. For this reason it has been proposed as a feasible approach to encourage developing countries to undertake commitments.

The main downside with intensity targets is that they provide no guarantee that a given level of environmental protection will be achieved. Intensity targets are a central part of the United States policy programme and have been put forward as alternative international framework to Kyoto. For this reason there is more in-depth analysis in section 5.

5. Ability to pay

The conventional indicator of "ability to pay" is GDP per capita. On equity grounds, basing or differentiating commitments according to GDP per capita is seen as fair, in as much as it reflects a country's **"capacity"** – those that can afford to do the most should do the most. An assessment of the GDP per capita of the signatory countries to the UNFCCC (Claussen & Mc Neilly, 1998) shows a wide disparity with a lowest annual GDP per capita of US$460 and a highest level of US$26,000.[54] The average GDP per capita was US$ 6,700. Interestingly the same report noted that 39 countries lie above the average GDP per capita but not all of these are Annex I countries (those with binding emission reduction commitments).

A formulae based on GDP per capita could also be said to go some way towards meeting the criterion of **"need"** and perhaps indirectly the criteria of **responsibility**, as it is mostly the wealthier countries that are responsible for historical emissions.

6. Multi-criteria formula

Several proposals have been suggested that are combinations of indicators.[55] For example Claussen and McNeilly (1998) proposed a "hybrid" formula which differentiates between countries based on three criteria , responsibility for past and present emissions, ability to pay and the opportunity to reduce emissions. The result is a division of countries into three groups: those that "Must act now" (including most Annex I countries); those that "Should act now but differently" (including mostly developing countries but also Finland, Iceland and Sweden); and those that "Could act now" (containing developing countries of extremely low income). Beyond identifying these three groups however, this proposal does not attempt to describe how targets should be set or the burden shared within these groups.

7. Multi-sectoral formula

Multi-sectoral approaches attempt to determine a burden sharing formula that takes into account emission producing activities among the member states. Two examples of this approach include the EU's Triptique method[56] and the Multi-sectoral Convergence method (MSC) developed by CICERO/ECN.[57] This latter method divides the global economy into sectors and then determines global sector emissions targets. The final result contains national emissions targets after adjustment for allowance factors.

4.3 Discussion

Finding a fair and feasible outcome

The question of how to design a system to ensure that the international effort to reduce greenhouse gas emissions is shared equitably remains perhaps the greatest challenge facing climate change negotiators. The challenge is not made any easier by the fact that there are many different ways of judging whether or not a certain outcome is equitable or not. Even if agreement could be reached on which criteria of the four discussed in this paper (need, responsibility, opportunity and capacity) should be given most priority, further criteria then come into play, including costs effectiveness, environmental effectiveness, and political feasibility. Table 2 below provides a summary of the evaluation of this report of different proposals for sharing international responsibility.

Table 2: Evaluation of Burden Sharing Proposals with respect to equity and other selected criteria[58]

	Equity Criteria				Political acceptability
	Need	Responsibility	Opportunity	Capacity	
Flat rate targets	*	*	*	*	*
Per capita emissions	***	**	*	**	*
Cumulative emissions	**	***	*	**	**
GDP per capita	**	**	**	***	**
Intensity targets	*	*	**	*	*

** indicates this criteria is only weakly fulfilled, or not fulfilled at all by the proposed measure.*

*** indicates this criteria is partially fulfilled by the proposed measure.*

**** indicates this criteria is largely fulfilled by the proposed measure.*

How should equity issues be addressed in a global climate change agreement?

The threat of global climate change and the question of how to respond to it, generates equity issues at many levels. Focusing on the latter question, the IPCC has stated that a global response to climate change should, at a minimum, not make matters worse from an equity perspective. Many commentators have suggested that global framework should have as much focus on improving international equity as on improving climate. This raises an important question – To what extent can equity issues be addressed through the global response to climate change? Sachs[59] has suggested that it is possible future climate negotiations will gain in equity but lose in terms of ecological sustainability. In other words there may be convergence but no contraction. There will inevitably be trade-offs to be made between equity and ecological sustainability. Not all solutions will be "win-win". Many environmentalists argue that in such cases, ecological sustainability must be the priority – because improving equity is only meaningful if it is on a sustainable level.

Could per capita emissions provide the basis for negotiating a future global climate agreement?

Discussing per capita emissions as a basis for negotiating a future climate agreement is a contentious subject. It meets some criteria of fairness but not necessarily all. Developing countries see it as a way of addressing the existing inequalities between developed and developing countries. It would however, (if taken to the point of equal entitlements) imply a huge transfer of resources from high to low emitters. Therefore, the political feasibility of such an approach is often questioned. Nevertheless, a narrowing of the gap between the per capita emissions of developed and developing countries is essential if stabilisation of emissions is to be achieved at any reasonable level. This indicator provides an important reference point to evaluate both the fairness and environmental effectiveness of any future agreements.

5. Looking Ahead – Frameworks for Global Action[60]

The Framework Convention on Climate Change and the Kyoto Protocol have established a structure for global action to mitigate the threat of climate change. Proponents of the Kyoto Protocol widely acknowledge that it is only a first step in the international effort to reduce emissions. At the same time the Protocol has come in for severe criticism from some parties. Does the Kyoto Protocol provide a viable framework for the future? If not what are the alternatives? Furthermore, what is needed to bring the US and developing countries into a global agreement? These questions are addressed in this section.

5.1 Introduction

At the time of negotiating the Kyoto Protocol, it was described as a first step in the international effort to curb emissions of greenhouse gases and limit the effects of global climate change. The Protocol stipulates emission reduction commitments for the period 2008 and 2012. It was foreseen that this would be followed by subsequent commitment periods, encompassing a wider range of countries with commitments (of some kind) to reduce emissions.

At the time of writing, the Protocol has not yet come into force although recent developments suggest that it will do so in 2003. The focus of most policy makers who support the Agreement to date, has been, first and foremost, to reach this step. If successful, the focus must very quickly switch to the next step. Is the Protocol the best basis for future action? If the answer to this is considered to be yes the Protocol itself stipulates that negotiations for a second period must start no later than 2005. Furthermore, it is critical that there be some agreements on a 2nd Commitment Period before the 1st Commitment Period commences because penalties for non-compliance in the 1st period are defined as an extension of targets agreed to in the second period.

If the answer to the above question is no, or the Protocol does not come into force, the question of what step to take next remains. An alternative framework would be needed. The following section begins by examining the key characteristics that can be said to define the Kyoto framework, and then examines possible modifications and alternatives to this model.

5.2 The Kyoto framework

5.2.1 Characteristics of Kyoto

There are four defining characteristics of the Kyoto Protocol:

1. **Developed countries** agreed to commitments to reduce emissions
2. These commitments entered into by the developed countries are **legally binding** (if the Protocol comes into force)
3. The commitments are in the form of **absolute targets** or emissions caps (the size of the target was negotiated to take into account the particular circumstances of each country)
4. There is provision for some flexibility in achieving these targets through the use of the so-called **"flexible mechanisms"**.

In economic terms, the Protocol is described as a **quantitative instrument**. In other words, a fixed quantity of global emissions was decided upon (a quantity 5% less than 1990 levels for developed countries), and this total quantity was then divided up into quantified emissions levels for each of the various Annex I countries.

The main advantage of a quantitative approach is that, assuming full compliance, there is relative certainty as to the environmental outcome – more specifically, there is certainty as to by how much emissions from Annex I countries will be reduced in this time period.

5.2.2 Criticisms of Kyoto

The Kyoto Protocol has come in for its fair share of criticism from all corners of the political spectrum. As is to be expected with any global agreement such as this, there are parties who think it does too little in terms of trying to prevent climate change, and others who believe it tries to do too much. The most notable criticisms of the Kyoto structure in recent time have come from the US Administration who in 2001 decided to withdraw from the Kyoto agreement. The main reasons put forward by the US Administration are summed up in a US Cabinet Review of the Kyoto Protocol which states that the agreement is "fundamentally flawed" because (1) "it fails to establish a long–term goal based on science", (2) "poses serious and unnecessary risks to the US and world economies", and (3) is "ineffective in addressing climate change because it excludes major parts of the world."[61]

These points were emphasised again in President Bush's statement of 13 March 2001 when he said *"..I oppose the Kyoto Protocol because it exempts 80 percent of the world, including major population centers such as China and India from compliance, and would cause serious harm to the US economy."*

It is relevant to draw attention to point (1) in the context of the discussion on long-term targets in section 2. However, the two points of concern raised by the US that are most relevant to this section are points (2) and (3). The US is not the only Annex B country to express concern about these issues.[62]

5.3 Alternatives to Kyoto

Very few detailed alternatives to the Kyoto structure have been proposed, but elements of an alternative structure have been proposed both in the research community and recently by the US administration. Alternatives that have been suggested fall into several categories.

(1) Co-ordinated policies and measures
(2) Non-binding targets
(3) Price-based commitments
(4) Price cap proposals
(5) Dynamic (and intensity) targets

The following section discuses each of these options in turn. It should be noted that in most cases these proposals have been made with a view to bringing developing countries into a global agreement.

5.3.1 Co-ordinated policies and measures

A proposal to co-ordinate policies and measures amongst different countries was debated at length early in the Kyoto negotiation process. The argument at the time was led by the EU and strongly resisted by the US and other countries. Their arguments were that co-ordinating policies and measures would be insufficient because it would not adequately reflect national diversities and would infringe upon national sovereignty regarding the appropriate choice of instrument.[63] Furthermore, it was generally accepted that such an approach would be insufficient to provide countries with any real incentive to reduce emissions.

5.3.2 Voluntary targets

Non-binding targets were the basis of the FCCC agreement. This approach has already been tried and was deemed to be insufficient by the international community when they negotiated the Berlin Mandate to urge more stringent action. However, non-binding quantitative targets have been suggested as a practical way of bringing developing countries into the global framework.

One of the advantages of such a system is that it could be possible for developing countries to participate directly in an international emissions trading market. From a global perspective this could improve cost-effectiveness. In effect, this would mean that developing countries could sell any surplus of emission rights on a carbon market but not be required to buy credits to cover any deficit.[64] The main downside of this proposal is that if the targets adopted by the developing countries were too "easy" this would risk introducing a lot of hot air into the "global market" and thereby undermine the environmental effectiveness of this approach.

5.3.3 Price instruments

A price instrument is a tax. In general, the main distinction between a price-based instrument, such as a specified tax on CO_2, and a quantitative instrument, such as that envisaged under the Kyoto model, is that the price based instrument provides certainty about the costs of abatement, while it generates a range of possible abatement levels and emission outcomes. A quantitative system on the other hand, provides greater certainty about the environmental outcome, but much greater uncertainty concerning costs.[65] Precisely because price-based instruments remove this uncertainty about the level of abatement costs, they are the preferred approach of many economic analysts, and to some extent have experienced a revival of interest due to the USA's stated concerns about costs.[66]

Proposals for a global CO_2 tax regime also date back to the very early stages of negotiations, and these proposals at the time were rejected in favour of a quantity-based approach. There were a number of reasons for this, notably the greater certainty as to the environmental effect of a quantity based approach, and the fact that several countries (including the US) were reluctant to commit themselves to anything resembling a global emissions tax. There are several obstacles to the idea of a global tax regime being put back on the political agenda. One of the most important being that developing countries would be most unlikely to agree to such a tax, because they have such high emission intensity per unit of output.

5.3.4 Introduction of a ceiling price

An increasingly popular alternative in the research literature is to discuss hybrid approaches linking quantitative targets with a price cap. One such hybrid system is to allow an initial distribution of GHG units (referred to as Assigned Amount Units (AAUs) in the Protocol) leading to a common market price. If the market price rises above a predetermined threshold, additional GHG units would be issued at that threshold price.[67] In other words, the price of CO_2 would be capped at a certain level.

A price-capped CO_2 trading system has already been established in Denmark for the electricity sector. The price cap has been set at 40 Danish crowns or approximately US$5 per tonne CO_2. This level has been set to avoid Danish coal–fired power stations becoming uncompetitive in the liberalised Nordic energy market.[69]

Obviously, the major advantage of such an approach is that it provides an assurance that the costs of complying with an international agreement will not exceed a certain level. However, there are a number of disadvantages with a price a price-capped system if it were to be applied in an international context. These are discussed in Müller *et. al* (2001) and summarised below.

- A price cap can in theory be set at either a national or international level. If applied at the national level, trading between countries would become almost impossible due to arbitrage – i.e. AAU would flow out from the country with the lowest price cap. Therefore price caps would probably have to be harmonised. Negotiating the level of price caps would probably be a very difficult process (although perhaps no more difficult than many other negotiation issues).
- Under a low price cap, the banking of AAUs would have to be limited. Otherwise in the expectation of a rising threshold price there would be an incentive to buy large volumes of AAUs and sell them at high prices in the future.
- Depending on the level of the price cap there is likely to be a reduced incentive to invest in technologies with costs slightly above the price cap.
- A high price cap would give some certainty that prices would not climb too high (addressing some of the concerns stated by the US). However, political pressures are likely to exert a downward pressure on the cap level. If the cap was very low, both domestic action and investment flows would be reduced.

In sum, the proposal for price caps is seen as a way of providing assurance that the costs of complying with an international agreement will not climb too high. Practically it would be difficult too administer in an international context. Its effect depends on the level at which it is set. If it is set at a low level, the environmental effectiveness of the regime would be significantly reduced.

5.3.5 Dynamic (and intensity) targets

Dynamic or intensity targets were introduced in section 4.2.3. Dynamic targets are generally formulated relative to economic output (e.g. emissions per unit GDP). The chief advantage being that they limit costs in the case of unexpectedly high economic growth. It is foreseeable for example that a country with a fixed emissions cap experiencing stronger than expected growth may be forced to stifle, if not stop, economic growth in order to comply with a fixed target – a scenario which would be particularly unfeasible for developing countries. In the case of an intensity target, depending on how it is specified, a country experiencing unexpected economic growth may only be required to reduce emissions in proportion to their overall economic output, and therefore not necessarily reduce absolute levels. For this reason it has been proposed as a feasible approach, and perhaps the best option, to encourage developing countries to undertake commitments.[69] More controversially, intensity targets are the central feature of the US Administration's climate change strategy announced in February 2002 (See Box 7).

Box 7. The US Proposals for intensity targets

The US has set a target to improve GHG emission intensity by 18 percent over the next decade. These goals have been criticised by many parties because they allow for a substantial increase in net emissions over this time period.[70] It has been estimated that the US intensity targets would still allow for an increase of emissions by 12 percent by 2012, and by 30% above 1990 levels. In order to stabilise global greenhouse gas concentrations, emissions will need to be reduced to far below today's levels.

The main downside with intensity targets is that they provide no guarantee that a given level of environmental protection will be achieved. A GHG intensity target can lead to a net reduction in emissions but only if it is significantly stringent. Intensity targets will only be able to deliver such emissions reductions if the required reduction of intensity is greater than the output growth.[71] Improvements in energy intensity in developed countries over the last 10 years have generally occurred at around 0.5% of GDP growth. In other words, for every 1% increase in economic growth, emissions have increased by a ½ percent. Rates of improvement of energy intensity would have to more than double these historical rates if absolute levels of emissions are to be decreased.[72]

In addition to these concerns, Müller *et. al* (2001) note a number of other drawbacks with intensity targets:

- Intensity growth rates are highly sensitive to the choice of economic output measures.
- While providing some measure of protection in the case of higher than expected economic growth they are more difficult to comply with in the case of reduced growth. If growth is reduced then the only way to improve the intensity is to reduce emissions at a rate faster than the decline in economic output.[73] While this would largely avoid creating "hot air" (which would be seen to be a positive outcome by many parties) there is a concern that the effect of such a measure on countries experiencing negative economic growth would be extreme.
- There are difficulties in incorporating relative targets into an emissions trading scheme. In theory there is little to suggest that trading with dynamic targets would be more difficult or complex than trading with fixed targets.[74] The problem arises if one group of countries or sectors has fixed targets and the other has relative targets. This has been the experience of the United Kingdom in administering their domestic emissions trading scheme which includes sectors with both absolute and relative targets.

5.4 Discussion

The Kyoto Protocol – far from perfect but not to be lightly discarded

The Kyoto Protocol represents a vast investment of intellectual and negotiating effort. Since the Protocol was launched in 1997, there has been much negotiation and refinement. As noted by Grubb *et. al* (2001) much has been agreed by over 180 countries that have a huge diversity of views interests and understanding – "such achievement should not be lightly discarded".

Trade-offs in the choice of policy instrument.

The preceding discussion highlights that there will advantages and disadvantages associated with the various instruments that could be used to define targets and commitments for international action. The Kyoto Protocol in it's current form (based on quantitative targets and an emissions trading regime) has the strong advantage of providing some certainty as to the environmental outcome. The main disadvantage of the Kyoto agreement is that there is uncertainty as to the costs countries will eventually face in fulfilling these commitments.

Proponents of *non-binding targets and dynamic targets* consistently return to two key arguments. Firstly, such measures are the best way of bringing developing countries into a global agreement. Secondly, if there is less uncertainty as to costs, it is possible that countries will adopt more ambitious targets. To this extent there may be trade-offs to be made between the certainty of environmental outcome, the potential stringency of the targets, and wider global participation.

Is the Kyoto framework a viable alternative in the future?

The answer to this question depends on an interpretation of whether a proposed alternative is seen as a substantial departure from the Kyoto framework, or simply a modification. The view of this paper is that an option to rely on either voluntary targets, co-ordinated policies and measures, price instruments or technology approaches, as the main form of commitment would represent a substantial departure from the Kyoto Framework. On the other hand, it is foreseeable that dynamic targets, price caps or deferred targets could be accommodated within the Kyoto model.

At present the Kyoto Protocol divides countries into two groups – those with quantified binding commitments and those without. In the future it appears likely that Parties to the Protocol could be split into at least three or four groups based on a mixture of criteria as discussed in section 4 of this report. One group of countries may have quantified binding targets as at present, while many countries could be allocated binding dynamic targets. It is certainly probable that a group of the poorest developing countries would have non-binding (voluntary) targets.

Figure 10: A framework for the future?

Country group	Type of target
The Industrialised countries (Group 1)	Binding fixed targets, as they are applied at present,
Developing countries (Group 2) *– grouped according to criteria of capacity and opportunity as discussed in section 4*	Binding dynamic targets
Developing countries (Group 3) *- grouped according to criteria of capacity and opportunity as discussed in section 4*	Non-binding fixed targets
Developing countries (Group 4) *– the poorest developing countries (measured in terms of GDP per capita)*	No targets

A time-frame for change?

When discussing possible future commitments for developed and developing countries it is important to clarify a time frame in which these changes may take place. From an environmental perspective it would be preferable to have as many countries as possible accepting binding targets to reduce emissions, as soon as possible. Political reality however, and the need to identify equitable solutions is likely to see a more gradual evolution. In the immediate future when discussing commitments for a proposed 2nd commitment period (e.g. 2016-2020) the most likely scenario may be to see the current Annex I countries undertaking deeper commitments, with some developing countries taking on non-binding fixed or dynamic targets. Perhaps by a third period (e.g. 2024-2028) there may be a further evolution of commitments along the lines illustrated in Figure 10.

Emissions Trading – a fundamental feature of a future global regime

Whatever the mixture of targets and tools, there appears to be an emerging consensus (amongst developed countries at least) on one point – any future framework must be compatible with an emissions trading regime. This in itself is a major development as the concept of emissions trading was controversial at the outset. However, as policy makers and other stakeholders have grown more familiar with the concept of emissions trading it has become one of the most favoured policy instruments to address climate change.[75] Many economists consider the true value of Kyoto to be that it will create a carbon price that will drive policy and technological change, in a so-called 'carbon constrained economy'.

Concluding Comments

In the introduction four key questions were identified as the focus of this report:

1. What global targets are we aiming for?
2. When should we act?
3. How should we share the responsibility for action equitably?
4. What frameworks are needed for future action?

The following section summarises some of the main points that were raised in each discussion.

1. What global targets are we aiming for?

Defining long-term targets for climate change policy provides a valuable reference point for implementing policy in the short-term. Without an idea of where we want to be in the long-term, there is a risk that policy actions implemented in the next 10 to 20 years will turn out to be either seriously inadequate, or extremely costly. Many researchers and policy makers would like to see an international agreement on long-term targets, defined in terms of the stabilisation of atmospheric concentrations of greenhouse gases at some 'safe' level. However, experience to date has shown that reaching an international agreement on a long-term target, defined in this manner, is extremely difficult to achieve and this is likely to remain the case for the foreseeable future.

On-going research into, and debate on long-term targets is needed to set a context for short and medium-term policy actions. However, an agreed direction is more important than an agreed absolute target. The more immediate task should be to develop some degree of international consensus around short and medium-term targets that keep future options open.

Determining medium to long-term targets requires reaching an agreement on an acceptable level of risk. This in turn requires consideration of several factors including: the potential environmental impacts; threshold levels; the degree of effort required; and costs.

How to account for costs in determining long-term targets is a contentious issue. For economists the challenges associated with evaluating the costs and benefits of climate change action are complex. This is primarily because the costs of measures to reduce emissions will be borne in the near term, whereas the benefits of this action (in terms of environmental impacts avoided) will not be experienced until decades (or even centuries) later. The methodological difficulties of estimating and comparing costs and benefits which occur in different time periods, explains why there has been a reluctance to include an analysis of costs in discussion on long-term targets. However, costs inevitably play a large role in this debate, if not accounted for explicitly then allowances will be made implicitly.

There is a need for economists to develop and improve methodologies for estimating and evaluating the tradeoffs between costs and benefits in different time periods, and for this work to be increasingly bought into the debate on long-term targets.

2. When should we act?

The timing of action to reduce emissions is a major factor in the climate change debate. Because a particular concentration of CO_2 in the atmosphere is determined more by cumulative than by year-by-year emissions, a concentration target can therefore be reached through a variety of 'pathways'. If a long-term target was known with certainty the challenge for policy makers is then to choose the best pathway. If there is no agreed 'absolute' target, determining an 'optimal' pathway becomes much more complex. In either case, decisions on when to act will have both environmental and economic effects. There are also political and social considerations.

Economic models which attempt to map out the least cost pathways to a known long-term target have tended to favour delayed action - phasing in emission reductions gradually with more drastic emission reductions in later years. However, some economists are now questioning the assumptions and methods used in these models. For example, models that allow for some degree of ***induced technical change*** tend to promote the value of early action compared to more conventional models. Furthermore, models which attempt to predict an optimal strategy when there is uncertainty about the ultimate target (as there is in reality) also place greater emphasis on early action.

Economic arguments over timing point to the need to balance the degree and rate of abatement – not its deferral.

Environmental arguments point strongly towards the benefit of early action, for reasons associated with the rate of temperature change, and also the need to keep options open in the face of uncertainty.

Delaying action pushes costs onto future generations, which increases the likelihood that the desired level of action will not occur.

3. How should we share the responsibility for action equitably?

The question of how to design a system to ensure that the international effort to reduce greenhouse gas emissions is shared equitably remains perhaps the greatest challenge facing policy makers and climate change negotiators. The underlying challenge is to ensure that efforts to address the problem of climate change ***at a minimum*** do not lead to a deterioration in the existing inequities between developed and developing countries. To the extent possible efforts to address climate change should aim to reduce global inequities. However, at times tradeoffs between improving equity and ensuring ecological sustainability will need to be made.

A wide range of suggested formulae for sharing the global effort to reduce emissions have been reviewed in this paper using a range of criteria. ***No one approach or indicator is likely to the form the basis of a future global agreement. Nevertheless, per capita emissions of greenhouse gases will be one key indicator for evaluating both the fairness and environmental effectiveness of proposals as they are developed.***

4. What frameworks are needed for future action?

There are four defining characteristics of the Kyoto Protocol:

1. **Developed countries** agreed to commitments to reduce emissions.
2. These commitments entered into by the developed countries are **legally binding** (if the Protocol comes into force).
3. The commitments are in the form of **absolute targets** or emissions caps (the size of the target was negotiated to take into account the particular circumstances of each country).
4. There is provision for some flexibility in achieving these targets through the use of the so-called **'flexible mechanisms'**.

Looking ahead, modifications to the Kyoto framework are inevitable. A key question to be posed is: **Does the Kyoto framework provide a viable alternative in the future?** The answer to this question depends largely on an interpretation of whether proposed alternatives are seen as a substantial departure from the Kyoto framework, or simply a modification. The opinion reached in this paper is that an option to rely on either voluntary targets, co-ordinated policies and measures, price instruments or technology approaches, as the main form of commitment would represent a substantial departure from the Kyoto Framework. On the other hand, it is foreseeable that dynamic targets (for developing countries), price caps or deferred targets could be accommodated within the Kyoto model.

The Kyoto Protocol does provide a viable framework for a future global agreement. However,* modifica-*tions to the Protocol will be needed to allow for different types of commitments to be taken by developing countries.

The Kyoto Protocol in its current form (based on quantitative targets and an emissions trading regime) has the strong advantage of providing some certainty as to the environmental outcome. The main disadvantage of the Kyoto agreement is that there is uncertainty as to the costs countries will eventually face in fulfilling these commitments. Proponents of *non-binding targets* and *dynamic targets* consistently return to two key arguments. Firstly, such measures are possibly the best way of bringing developing countries into a global agreement. Secondly, if there is less uncertainty as to costs, it is possible that countries will adopt more ambitious targets. To this extent there may be trade-offs to be made between the certainty of environmental outcome, the potential stringency of the targets, and wider global participation.

Dynamic targets are one way of bringing developing countries into a global agreement.

A possible future global agreement could entail a combination of (1) fixed, binding emission reduction targets for developed countries, (2) binding dynamic targets for the wealthier developing countries and (3) voluntary targets for the least developed countries.

Any future global agreement must be compatible with an international emissions trading system.

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Endnotes

1 Reference is made to this report because part of its brief was to identify areas in the science where there are the "greatest certainties and uncertainties".

2 Robinson *et. al* (1998)

3 IPCC (2001 a)

4 Spencer, (2000)

5 See National Academy of Sciences (2001), and IPCC (2001) Climate Change 2001 Synthesis Report.

6 IPCC (2000)

7 See IPCC (2001) Climate Change 2001 Synthesis Report. Temperature increases are projected to be greater than those in the SAR, which were about 1.0 to 3.5°C. The higher projected temperatures and the wider range are due primarily to the lower projected sulphur dioxide emissions in the most recent scenarios relative to the earlier scenarios.

8 The sea level projections in the TAR are slightly lower than in the SAR, despite the higher temperature projections. This is primarily due to the use of improved models, which give a smaller contribution from glaciers and ice sheets.

9 A climate forcing can be defined as an imposed perturbation of the Earth's energy balance, this includes natural forcings such as volcanic eruptions and human made forcings (National Academy of Sciences, 2001)

10 See Robinson *et. al* (1998)

11 Article 2 of the FCCC states "the ultimate objective of the Framework Convention on Climate Change and any related legal instruments…. is to achieve in accordance with the relevant provisions of the Convention, stabilisation of green-house gas concentrations at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner."

12 For a detailed discussion on the role of inertia and time scales in the climate system see the IPCC (2001 a) Synthesis Report to the TAR, question 5.

13 See National Academy of Sciences (2001)

14 See IPCC (2001 a) Synthesis Report to the TAR

15 The theoretical equilibrium temperature would take many centuries to reach. See IPCC (2001 a) Synthesis Report to the TAR, section 6.

16 See IPCC (2001 a) Synthesis Report to the TAR, pp57

17 See IPCC (2001 b) TAR WGII pp 68

18 See IPCC (2001 b) TAR WG II pp 952.

19 These absolute costs are very sensitive to the factors listed above, in particular the choice of reference scenario. Studies using the IPCC SRES scenarios as baselines show that the average GDP reduction in most of the stabilisation scenarios is under 3% of the baseline value. The maximum reduction across all the stabilisation scenarios was 6.1% in a given year. Some scenarios (especially in the AIT group) showed an increase in GDP compared to the baseline year. See IPCC (2001 c)

20 See Azar & Schneider (2002)

21 OECD (2002)

22 See Pew Center (2001)

23 IPCC (2001 c)

24 IPCC (2001 a)

25 IPCC (2001 c)

26 See Kreileman & Berk (1997)

27 Alcamo and Kreileman (1996) and Swart *et. al* (1998) are cited for their work on the safe landing approach, while Toth *et. al* (1997) are cited for their work on the tolerable windows approach, see IPCC (2001 c)

28 Berk *et. al* (2001)

29 IPCC (2001 b)

30 It should be stressed that the Wrigley Richards and Edwards did not wish their model to be interpreted as favouring a "wait and see" approach. Instead they stressed the importance of near term energy investments (Schneider & Azar, 2001).

31 For example, assuming a net rate of return on capital of 5% and that it costs \$50 to remove a tonne of carbon regardless of the year in which the reduction occurs. It will cost \$50 to remove the tonne today but only \$19 needs to be invested to provide the resources to remove the tonne in 2020 (IPCC, 2001 c)

32 For a comprehensive discussion on uncertainty and it affects the level and timing of mitigation policies see Schneider & Azar (2001).

33 See IPCC (2001 c) ch 10

34 Cited in IPCC (2001 c) ch 10

35 See IPCC (2001 c) CH 10

36 One driver of technological change is learning by doing (LBD) – the incremental improvement of processes through small modifications and developments, (Weyant (2000). There is considerable research which shows that technological breakthroughs have often occurred when several researchers have been experimenting with projects at the same time, The automobile, telephone and airplane being prominent examples, Pew Center (2001)

37 In most macro-economic models the most common method of modelling technological change in the energy sector has been to assume that there exists an Autonomous Energy Efficiency Improvement (AEEI).

38 Grubb & Koehler (forthcoming) cite various examples and empirical research, which demonstrate that technological developments bought about in response to market prices or government incentives, can reduce technology costs in the long run. One example cited is the macroeconomic response to the energy price shock of the 1970s and subsequent decline in energy prices in the 1980s. While energy consumption dropped markedly in response to the price increases it did not rise back to expected levels when the prices decreased. Dargay (1993, cited in Grubb & Koehler) identified the reason as being due to high energy prices inducing the development and application of energy efficient technologies that later remained economically optimal despite falling prices.

39 See Goulder & Schneider (1998), Grubb & Koehler (forthcoming), Weyant (2000)

40 As discussed by Goulder & Schneider (1998) a key conceptual and computational problem for economists has been dealing with increasing returns to scale associated with induced technological progress.

41 Grubb & Koehler, forthcoming

42 Flexner 1987, in IPCC (1996)

43 For example, some of the more common schools of thought on equity include: rights, basic needs, utilitarianism, Rawlsian justice, entitlement etc. For a detailed summary of different principles of equity see the chapter on "Equity and Social Considerations" in IPCC (1996)

44 IPCC (2001 a)

45 IPCC (2001 c)

46 A good reference is CICERO/ECN (2000)

47 IPCC (2001 c)

48 Claussen & McNeilly (1998)

49 CICERO/ECN (2001)

50 OECD/IEA (2001, in draft) "Evolution of Mitigation Commitments. Fixed targets versus more flexible architectures".

51 By dividing the total absorption capacity of each greenhouse gas in proportion to national population, they showed that the developing countries share of the global reabsoprtion of greenhouses gases exceeded their actual gross emissions (IPCC, 1996, Ch3 p9).

52 Clauseen & McNeilly (1998)

53 Cumulative emissions for various regions developed using this database are provided in the IPCC SAR, (1996)

54 Note these figures are calculated using purchasing power parity, Claussen & McNeilly (1998).

55 See Torvanger & Godal (1999)

56 See Torvanger & Godal (1999) for a description of this approach.

57 See CICERO/ECN (2001)

58 For further evaluation of these types of criteria, see also Torvanger and Ringius (forthcoming)

59 This citation is taken from an interview with Wolfgang Sachs, conducted by Eco-Equity in May, 2001. See www.ecoequity.org

60 Three publications are referred to extensively in this section. These are: Müller *et. al* (2001) Pizer, W.A. (1997) and Philibert (2001).

61 Reference cited in Grubb *et. al* (2001)

62 In March 20002 the Australian Environment Minister Dr David Kemp stated that the US policy programme appeals to Australia because it "clearly recognises the importance of taking action in a way that does not undermine the economies of countries like the US or Australia". Environmental News Service, March 2002. The Australian Government has since announced that it will not ratify Kyoto.

63 See Müller *et. al* (2001)

64 Philibert (2000).

65 See Philibert (2001 in draft) Pizer W. (2001) for a detailed analysis of the respective merits of price-based versus quantity-based approaches.

66 Economists preference for either a price based or a quantity based instrument depends on the slope of the marginal abatement costs curve and the marginal benefit function. If the marginal benefit curve is thought to be steeper than the

marginal cost curve then quantity instruments are preferred. However, this analysis is difficult to carry out because the shape of the benefit curve (environmental damage avoided is very uncertain), Müller *et. al* (2001).

67 Müller *et. al* (2001)

68 Müller *et. al* (2001)

69 Philibert & Pershing (2000)

70 Pew Center's analysis of President Bush's February 14th Climate Change Plan

71 Müller *et. al* (2001)

72 Müller *et. al* (2001)

73 If this method had been applied for the Kyoto Protocol the implied assigned amount for the Economies in Transition would be very different from that which was agreed to under the Kyoto negotiations.

74 Philibert and Pershing (2001) note that as far as they are indexed on actual economic growth, dynamic targets would entail less uncertainty on the likely difference between assigned amounts and actual emissions during the commitment period. This suggests that trading with dynamic targets would not be more difficult or complex than trading with fixed targets.

75 See Rozenzweig *et. al* (2002).

Kyoto and Beyond: Issues and Options in the Global Response to Climate Change.

With the Kyoto Protocol likely to enter into force in 2003 it is now timely to look at possible next steps for global action to mitigate the effect of global climate change. The Swedish Environment Protection Agency sets out many of these issues in its report, *Kyoto and Beyond: Issues and Options in the Global Response to Climate Change.*

Section 1 of this report presents an overview of the **current scientific opinion on climate change.**

Section 2 addresses the question: **What global targets?** What are the implications of stabilising atmospheric concentrations of greenhouse gases emissions at different levels? Is it meaningful to define long-term goals in this way? Are there alternatives? What types of short and medium-term interim goals are needed?

Section 3 looks at the question: **When to act?** Should emissions reductions be taken now or deferred until later date? What are the economic and environmental implications of early versus delayed action? How can we determine 'optimal' strategies in the face of uncertainty as to environmental impacts? What is the role of technological change in the debate on 'timing'?

Equity issues are at the very core of the climate change debate and these are discussed in **Section 4**. Who bears the greatest responsibility for climate change? Who is at greatest risk? Who is best able to act? What responsibility do we have to future generations? The section focuses on what sort of criteria can be used to assist policy makers in making decisions as to how to share the global effort to reduce emissions.

Section 5 takes this discussion a step further and looks at **possible frameworks for a future global agreement.** Does the Kyoto Protocol provide a viable framework for a future agreement? If not what are the alternatives? What may be needed to bring the US and developing countries into a global agreement?

The report is available in PDF version on the Swedish Environmental Protection Agency's website, www.naturvardsverket.se/english/climatechange. Alternatively printed reports can be requested from the Agency at the same address.

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