Climate Change: Solution in Sight

A Dutch Perspective

Energy Policy Platform

Climate Policy Working Group

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This booklet is published by the Dutch Energy Policy Platform (*Bezinningsgroep Energiebeleid*), an informal think tank of Dutch energy specialists from science, business, government, commercial services, advisory bodies and politics founded in 1974 to voice concerns on energy and environmental decision-making in the Netherlands. It has since communicated its views at regular intervals.

It is the conviction of the Energy Policy Platform that global climate change will have a decisive impact on the world's energy supply, for the simple reason that fossil fuel combustion is one of the principal forces driving the problem. The Platform has therefore opted to actively engage in the political debate on appropriate strategies for controlling climate change. To this end a long-term vision on climate policy has been developed, with particular emphasis on long-term Dutch policy in the international context. That vision is elaborated in the present publication, the main aim of which is to generate wider support for a far more forward-looking Dutch position in the international climate negotiations. Although global commitments are now in place for the period until 2012, thereafter all options remain open.

Climate change calls for urgent action, and this means adopting a more radical and comprehensive strategy than has been the case to date. This publication shows that such a strategy is not only feasible, from both the technological and the policy angle, but that it is also affordable.

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The views expressed by the Energy Policy Platform are not necessarily endorsed in their entirety by all its members.

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Executive summary

Climate policy is a tricky business, for climate change presents society with a number of complex technological, economic and political challenges. In the first place there is scientific uncertainty about the consequences of the so-called enhanced greenhouse effect on the earth's climate, natural ecosystems and economy. There is still also a remarkable lack of public and political interest in the issue, given the potentially dramatic consequences of climate change. It is, moreover, a worldwide issue, although mechanisms for global decision-making are still in their infancy. Neither does there appear to be a straightforward and cheap solution at hand. When it comes to possible strategies and their associated cost, finally, the opinions voiced range all the way from 'solutions cost next to nothing'to 'controlling climate change will put us back in the Stone Age'.

This booklet examines the background to this important issue and reviews current policy efforts and alternative strategies that might be more effective. Is tougher climate policy necessary? Is it feasible? And is it affordable? The answers to these three crucial questions form the core message of this booklet and are summarised below.

Is tougher climate policy necessary?

After a short introduction, Chapter 2 reviews the latest scientific evidence regarding mankind's impact on global climate. In recent years evidence has accumulated that human activity is indeed altering the earth's climate. In particular, it is becoming increasingly clear that the atmospheric emissions of carbon dioxide resulting from combustion of fossil fuels are disrupting the energy balance of the earth, with a range of potential consequences. Although carbon dioxide is not the only greenhouse gas, this booklet focuses on energy-related carbon emissions, which are the hardest to tackle.

Since about 1880 the earth's average surface temperature has been gradually rising and in the past few decades the temperature rise has been particularly marked. Since the 1960s there has also been a surge in the material damage and human suffering caused by weather-related disasters, as extreme weather events become increasingly common. In and of themselves, however, these facts are still no proof that the changes are indeed induced by fossil fuels combustion. Complex computer models of the climate system have been created incorporating the impact not only of greenhouse gas concentrations but also of aerosols (minute airborne particles with a cooling effect) and variations in the amount of incoming solar radiation (the sunspot cycle). Scientists are now modelling the earth's climate system with ever greater accuracy and both empirical measurement and model calculations prompt but one conclusion: the balance of evidence suggests that human activity is already a significant cause of climate change.

While the consequences of climate change are difficult to predict in all their ramifications, they may evidently be dramatic. Indeed, in the absence of effective action the climate problem may well spiral out of control. As temperatures continue to rise, we shall see a major rise of sea level, the melting of glaciers and ice caps and increasingly volatile weather patterns. In many parts of the world there will be a change of climate, with a range of negative impacts on ecosystems, the economy and human health. Although the developing countries will undoubtedly be hit hard, Europe is also vulnerable, for climate change may cause the warm Gulf Stream to stagnate.

Although prevention is better and cheaper than cure, it is now too late for prevention in any absolute sense. The most we can do is to limit the foreseeable damage and do all we can to avoid a ‘runaway’ greenhouse effect. This means, in the first place, drastically reducing emissions of carbon dioxide and other greenhouse gases and stabilising them at a safe equilibrium level. Ultimately, the world’s carbon emissions will have to be reduced by about half, at which point they will once more be in balance with the natural carbon cycle. There is thus a global ‘carbon budget’ available to the world’s human population. Given projected growth in the developing countries, if this budget is to be shared equitably the industrialised world must reduce its carbon emissions by 80 per cent, i.e. to 20 per cent of present levels. The position of both the Dutch government and the European Union is that temperatures may rise by no more than 2 degrees Celsius. Using this figure a maximum permissible CO_2 concentration can be calculated. This is not a target that can be achieved overnight, but requires emissions to be cut back annually by 2 to 4 per cent.

In summary, climate change poses profound risks. With the policies currently in place, a runaway greenhouse effect appears unavoidable. A more rigorous policy response is therefore most definitely necessary.

Is tougher climate policy feasible?

Climate policy is already very much on the political agenda, both internationally and in the Netherlands. In June 1992 the UN Framework Convention on Climate Change was adopted. Under the Kyoto Protocol, five years later, quantified emissions targets were agreed to by western and East European countries and the former Soviet Union. Chapter 3 reviews the current status of climate negotiations and the issues on which no agreement has yet been reached. The most prominent voids in agreements to date are the absence of any emissions reduction targets for developing countries, and ditto for international sectors like aviation and shipping.

If the countries of the South are to be brought on board, the global carbon budget will have to be shared equitably. Ultimately, the only tenable principle for allocating carbon emissions would appear to be equal per capita entitlement for the global population. This implies a substantial transfer of funds from North to South, for the North would have to buy ‘emission rights’ from the South.

The next question is how the required emissions reductions can best be achieved, from both the technological and the policy perspective. This issue is addressed in Chapter 4. In most countries including the Netherlands policies have until now focused mainly on energy efficiency: aiming to use less energy to achieve the same or greater economic output. As this publication clearly shows, further energy efficiency improvements are in themselves an inadequate response to predicted climate change.

The main new policy strategy advocated by the Platform is accelerated introduction of clean energy, i.e. forms of energy causing lower or even zero carbon emissions. What we must do, it is argued, is make maximum use of the opportunities offered by these energy sources, starting today. There are essentially two kinds of 'carbon-free' energy: renewable energy like solar, wind and biomass and fossil energy whereby the carbon dioxide in the combustion gases is captured and subsequently isolated from the atmosphere in depleted gas or oil fields or aquifers. Given the current technological state of the art, the second of these approaches appears to be more cost-effective at present, although the perspective may obviously alter as new progress is made. Furthermore, the cost of avoiding a unit carbon dioxide emission is obviously not the sole criterion on which climate policy hinges.

There are a host of options at hand for tackling climate change, and quantitative analysis shows that in technological terms a solution is perfectly feasible. From the policy perspective, too, a number of useful leverage points can be identified, the most important of which is vigorous promotion of clean energy.

Is tougher climate policy affordable?

From neither the technological nor the policy angle, then, are there any obstacles to a more rigorous climate policy. The question now is what it costs. For the next few decades at any rate, clean energy will inevitably remain more expensive than their conventional, high-carbon counterparts. From the perspective of climate policy, however, this is in fact a blessing in disguise. Technology forcing and other measures to promote clean energy will push up energy costs, encouraging more efficient use of energy. Adopting clean energy thus also promotes energy conservation and improves energy-mindedness generally, reflecting in turn on purchasing behaviour. There may also be a degree of economic restructuring, leading to a slight decline in economic growth on the yardstick of Gross Domestic Product.

Effective climate policy is not as costly as might be assumed, however, especially when measured against the continued 3% growth in income projected for the foreseeable future. In this light, mitigation in fact comes at quite a modest price, even though the figures seem substantial in absolute terms. Fifty years from now in the Netherlands, for instance, about twenty billion US dollars more would be being spent on energy than if a blind eye were turned to the problem of climate change. Although that may sound a lot, initial impressions are in fact misleading. Expressed as a percentage of GDP, the energy supply is becoming steadily cheaper because of ongoing economic growth. At present about 12% of Dutch GDP is spent on energy (incl. duties and taxes). In the absence of additional climate policy, by the year 2050 this figure will have gradually declined to about 8% and under a tougher policy regime to about 10% of national income. In other words, a smaller percentage of income will be spent on energy than today, but more than if we were to leave the climate issue untackled. Crucially, though, we will recoup the additional investment: by averting undue climate change with all the risk and damage that entails.

Drawing up the balance: what route to take?

And so we must take stock. The threat of climate change is real and is today already unfolding. The potential damage to natural ecosystems, economies and human health is huge. Technological solutions are available, however, and cost need not be a prohibitive factor. Though the choice is thus abundantly clear, it is in the political arena that decisions are ultimately made, however. It is therefore time for a vigorous public debate on the issue of climate change. This booklet, written by design from a mainly economic and technological perspective, hopes to kick off such a debate in the Netherlands - in terms of substance, at any rate, for the actual form of the debate is still undecided.

The climate control strategy proposed has two main thrusts: pro-active policies to achieve accelerated deployment of clean energy in the Netherlands and parallel efforts to get other countries to adopt a similar strategy, with the ultimate aim of developing tougher policy at the global level. On their own, Dutch emissions reductions are obviously not enough. For climate change to be effectively tackled the same kind of tough policies must be adopted by a large part of the world.

Here in the Netherlands, finally, policy-makers should above all endeavour to mobilise greater support for tougher measures at the international policy level, with all the risks, measures, costs, benefits and deliberations that entails. An aggressive global policy on climate change is necessary, it is feasible and it is affordable. The question is no longer whether we should embark on such a course, but how we should go about it.

1 Climate change: an obstinate problem

When the Swedish physicist and chemist Svante Arrhenius first called attention to the specific risk of climate change posed by the use of fossil fuels, in 1896, he could not have foreseen that it would be almost a century before his insight moved onto the political agenda. With hindsight, though, it is not surprising his ideas came to be accepted so slowly, for climate change is a complex scientific issue that confronts society with a number of difficult economic and technological and administrative problems.

To start with, scientific uncertainties loom large. The existence of a 'greenhouse effect' as such is uncontested: without it, life as we know it would not be possible. The temperature of the planet is kept viable by a certain fraction of incoming solar energy being captured by 'greenhouse gases' present in the atmosphere. These include water vapour and carbon dioxide (CO_2), the second of which derives from a variety of sources, some of them anthropogenic like fossil fuel combustion. What is less unambiguous, however, is the actual response of the climate system to currently surging greenhouse gas emissions, even though the earth's atmosphere can be modelled with growing sophistication and accuracy. We know that global temperatures are rising and that weather patterns are changing and will continue to do so. What is far less clear, however, is the specific regional impact across the world. The potential consequences for natural ecosystems, the economy and human health are enormous, however.

Secondly, there is comparatively little public engagement with the issue of climate change. This is not that surprising when one considers that it is future generations that will be primarily affected by the impact of climate change. It will be some time before its effects are felt in day-to-day life and the main impact may generally be elsewhere, in particular in the developing countries of the South. 'The future' and 'elsewhere' are generally underrepresented in the political debate, which all too easily hovers around such topics as the local nuisance associated with airport expansion or motorway construction. The further an environmental problem is removed in time or space, the greater the tendency for the burden to be shifted into 'the future' or 'elsewhere', and the weaker public and political opposition tends to be.

Third, climate change is a global issue. The world must therefore collaborate on finding a solution, for there is little point in any one country going it alone. The actual response of individual countries has varied widely, however, for a host of reasons. There are gradations of historical responsibility for the problem, some countries stand to suffer more than others, there may be higher priority issues, or appropriate financial resources may be lacking. As yet, international organisations such as the United Nations lack the clout to coordinate effective climate policy and the same holds for regional institutions like the European Union.

Fourth, there does not appear to be any simple, quick, cheap solution - as was the case with ozone layer depletion, for example. To the contrary, for if climate change is to be effectively addressed, we shall have to intervene to alter the structure of our energy supply and the same may even hold for the economy itself. This will cause additional resistance. There are also differing views and perspectives on preferred solutions, in itself a further complicating factor. While some are convinced that technology will generally suffice to resolve the problem, others hold that nothing short of a complete change in our patterns of consumption and production or a far-reaching austerity programme will do. To make maters worse, the technological camp has various schools of thought, some championing nuclear power, others fossil fuels with carbon dioxide capture and storage, yet others deployment of renewable sources like solar power and biomass. To top it all, biomass as a potential energy resource is a highly controversial topic in its own right.

It should be clear that the debate on climate change and appropriate mitigation strategies is a complex one and one that could all too easily lead to a stalemate. Indeed, international climate policy is an area where progress is painfully slow.

This booklet seeks to shed light on the debate, examining the various aspects of the climate issue, considering the international dimension and proposing effective solutions. We start in the following chapter by summarising the basic issue: what do we know, and what not? We consider both the causes and the potential effects of climate change, reviewing the predicted consequences and considering the uncertainty factor in these predictions.
In Chapter 3 international climate negotiations are reviewed: what agreements are already in place for the period up to 2012, as per the Kyoto Protocol, what elements are still lacking and what should climate policy beyond that time horizon entail?
Chapter 4 examines the strategies available for controlling greenhouse gas emissions and looks at the question of cost. A low-emission strategy for the Netherlands is elaborated in greater detail. As part and parcel of this exercise we consider the policy options available for implementing such a strategy. The purpose of this chapter should be not misconstrued: we have no desire to present a blueprint for the future. Other strategies and scenarios may be equally feasible. The purpose of our Chapter 4, rather, is to explore one possible scenario, in order to gain an impression of the probable costs. For this factor is crucial if the choice facing society is to be brought into clear focus: given the risks and given the costs, are we going to seriously tackle climate change?
Chapter 5 goes on to review the policies the Netherlands would have to adopt to implement this scenario, bearing in mind the ecological backdrop, the international context, the policy leeway and the financial costs discussed in the previous chapters.
The booklet concludes with a critical epilogue by Jan Paul van Soest, who places the issue in a wider perspective and voices the question now facing Dutch society and the world at large.

We hope this booklet will catalyse the public debate on the interrelated issues of climate change and energy supply and on the preferred options for tackling the problem. This publication shows that there is a solution in sight, if we choose accordingly. We can prevent dramatic damage to the ecosystems, economies and people of this planet, and we can do so without any major impact on the economy.

2 Mankind and climate

The changing climate

The term 'greenhouse effect'has now been largely superseded by 'climate change', a more appropriate term given the consequences currently forecast by the scientific community. Beyond a general rise in global temperatures, we face the threat of multiple climatic disturbance and disruption, in the form of excessive rainfall, and elsewhere drought, and storms of growing intensity and frequency as the established pattern of cyclones and other weather systems comes to shift. In some areas and regions, temperatures may in fact fall rather than rise.

The underlying causes will by now be familiar: a number of atmospheric pollutants are altering the balance between incoming solar radiation and the infra-red radiation reflected back from earth, in turn affecting a series of processes and cycles that directly influence the planet's climate. It is this anthropogenic disturbance of climatic processes that is referred to as climate change. So how exactly is our climate changing? And how bad is that? What are we sure about and what is still uncertain?

Since the late 1800s average global temperatures have risen by approximately 0.8 degrees Celsius, with much of this increase having taken place over the past thirty years. This trend is shown in Figure 1 below. For comparison: the Ice Ages were marked by temperature changes of around 4 or 5 degrees.

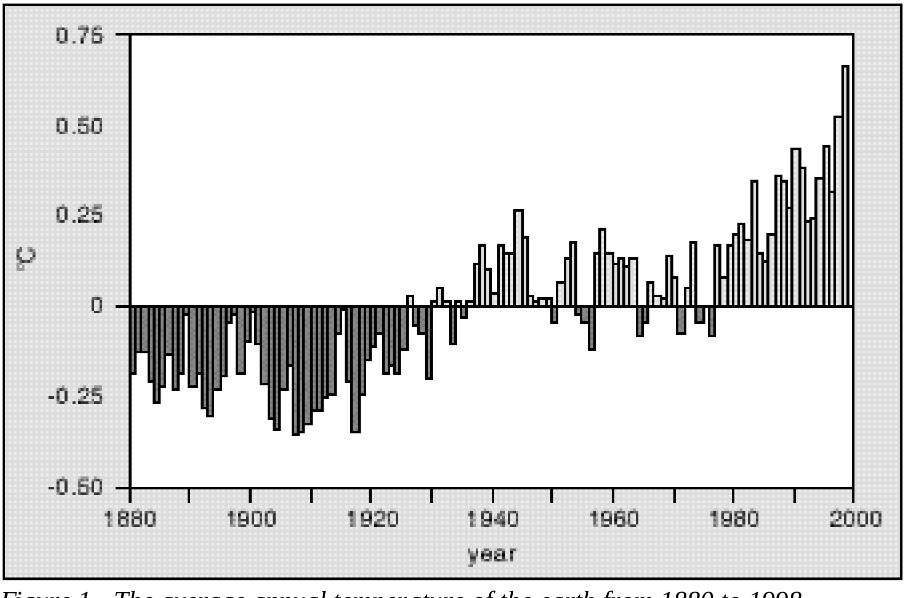


Figure 1 The average annual temperature of the earth from 1880 to 1998 compared with the average for the same period, showing the temperature rise, which is particularly pronounced in recent years. (Source: NOAA.)

In 1998 the earth's average surface temperature reached the highest level on record and 1999 was again far warmer than average. The ten warmest years since 1880 have all occurred since 1981. Average temperatures reveal only part of the picture, however. As measurements show, temperature changes vary geographically, the greatest warming having occurred in the high northern latitudes, between 40° and 70°N. In other areas a temperature decrease has in fact been recorded over the past few decades (Houghton et al., 1996).

On a planetary scale, though, the earth is warming and this is affecting the dynamics of the weather. There is a close correlation between the world's climate, i.e. its characteristic weather patterns, and average temperature. Global warming leads to greater evaporation and thence to increased precipitation. Measurements show that average precipitation has increased throughout the southern hemisphere, as it has in the higher northern latitudes. Between 0° and 30°N, on the other hand, the weather has become drier. Science predicts that rising temperatures will act mainly to increase the intensity rather than the frequency of rainfall and snow. This has been confirmed repeatedly by analysis and observation (Karl et al., 1997).

In some parts of the world we are seeing an increased incidence of extreme weather events like storms, droughts and floods, as well as changes in their traditional patterns of occurrence (Francis and Hengeveld, 1998). There have been losses of human life. Worldwide economic losses from these natural disasters have also risen dramatically in recent decades. In percentage terms, these rising losses are outstripping the growth of gross global product. The calculated losses for 1960 to 1998 are shown below in Figure 2.

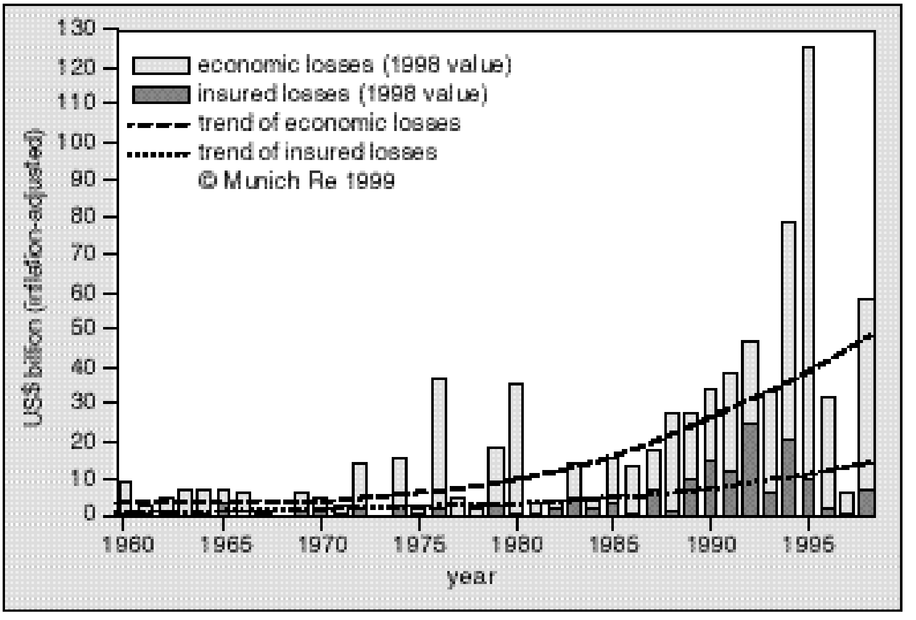


Figure 2 Global economic losses due to weather-related disasters have risen markedly since the 1960s. (Source: Munich Re, 1999.)

According to a survey by Munich Re (1999) this mounting rate of capital destruction cannot be ascribed entirely to the exposure of greater human numbers or more capital or other resources. Part of the trend indeed seems to be due to changes in the frequency and intensity of extreme weather events.

The impact of human activity

Elevated emissions of greenhouse gases and other substances have altered the composition and dynamics of the atmosphere. The atmosphere plays a crucial role in the earth's radiation balance, trapping some of the incoming solar radiation as it is reflected in the form of outgoing infra-red radiation, i.e. heat. The greenhouse gases occurring naturally in the atmosphere slow down the rate at which this radiation escapes, a process that has by analogy been dubbed the 'greenhouse effect'. If there were no greenhouse gases in the atmosphere the earth would be 33 °C cooler. Natural greenhouse gases such as water vapour, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and ozone (O_3) are therefore essential for life on earth.

Since the industrial revolution and particularly in the past 50 years the levels of natural greenhouse gases in the atmosphere have risen significantly. In addition, mankind has developed several novel greenhouse gases such as HFCs, PFCs and SF6. The 'enhanced' greenhouse effect we face today is due principally to an elevated concentration of CO_2, now over 25% above the level for 1850. There are two main causes: large-scale combustion of fossil fuels, by far the leading cause of higher CO_2 levels, and changes in land use such as large-scale deforestation.

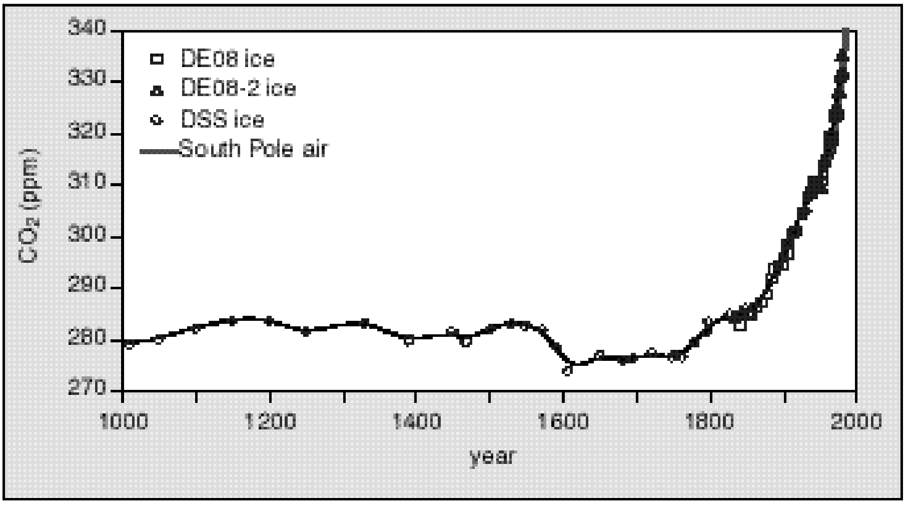


Figure 3 Carbon dioxide concentrations have surged in the last 200 years. (Source: Etheridge, 1999.)

While greenhouse gases warm up the atmosphere, some components of the atmosphere have an opposite, cooling effect. This is the case for certain aerosols, microscopic airborne particles in the form of naturally occurring sulphur dioxide (sulphate), soot and volcanic dust, for example. Sulphate aerosols, which are also formed when fossil fuels are burned, have a particularly pronounced cooling effect. Figure 4 shows the respective impact of the various greenhouse gases and aerosols on the earth's radiation balance.

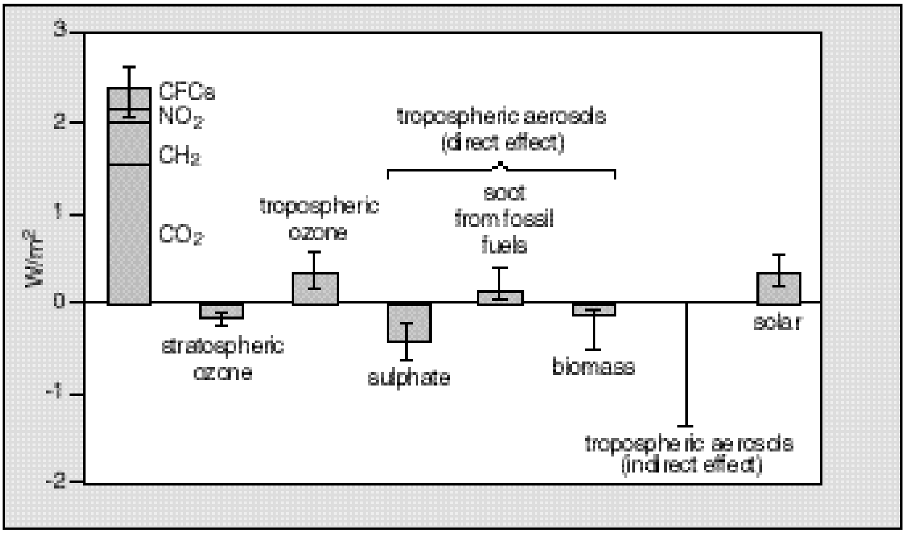
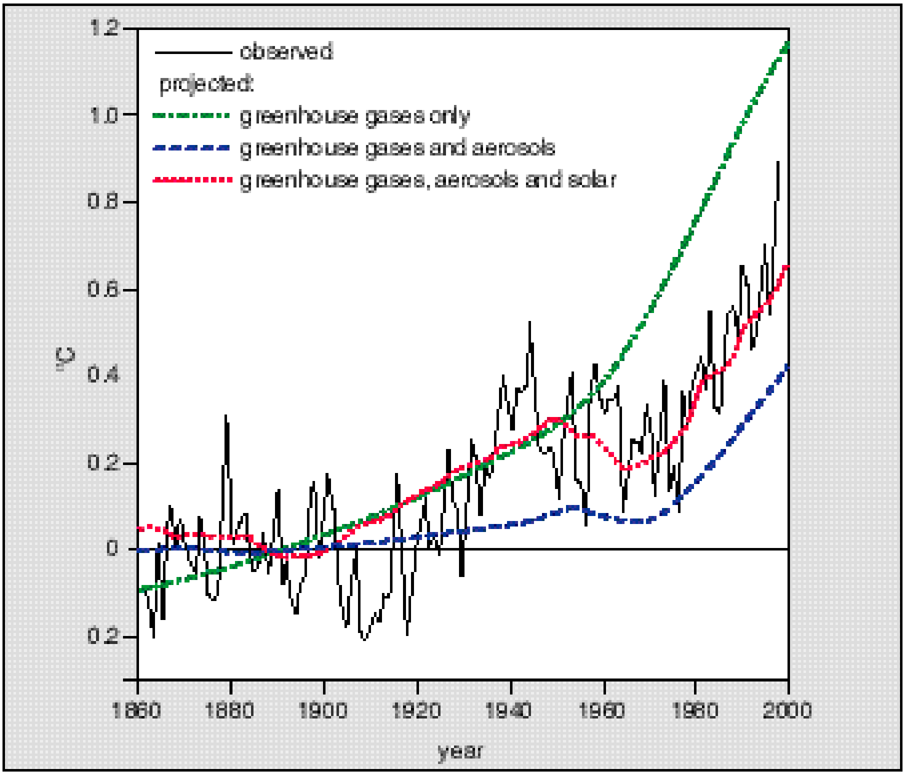


Figure 4 Individual greenhouse gas and aerosol emissions have altered the earth's radiation balance in different ways; the heating effect predominates (data 1850-1990). (Source: Houghton et al., 1996.)

It was not until a few years ago that the crucial importance of aerosols was appreciated. Their impact on the radiation balance has since been incorporated into climate models, and these have improved substantially as a result. There is yet another factor of influence on the earth's average temperature, however: variations in solar activity and the sunspot cycle and the associated changes in the amount of solar radiation striking the earth's atmosphere. This too has now been successfully factored into the equation. Figure 5 shows the correlation between average global surface temperature as recorded empirically and as calculated in successive computer models accounting for measured changes in greenhouse gas and aerosol concentrations and the observed natural variation in solar radiation.



factored in - greenhouse gases, aerosols and solar activity - computer projections of temperature change are becoming increasingly consistent with actual surface temperature measurements. (Source: Wigley, 1999.)

With today's sophisticated climate models we can both estimate and validate mankind's approximate contribution to rising global temperatures, apart from some small residual natural variations. Until about 1960 variations in incoming solar radiation were the main driving force behind variations in average global temperature. Since then human intervention has become increasingly dominant as a new factor disturbing the radiation balance (Figure 5; from Wigley, 1999).

Based in part on these and other model calculations, several years ago the prestigious Intergovernmental Panel on Climate Change (IPCC; see box) drew what was to become a historic conclusion. In the words of its Second Assessment Report: "The balance of evidence suggests a discernible human influence on global climate" (Houghton et al., 1996).

The IPCC

The Intergovernmental Panel on Climate Change, or IPCC, was established jointly by the World Meteorological Organisation (WMO) and the United Nations Environment Programme (UNEP) in 1988. Its remit is to analyse and assess the available scientific, technical, environmental, economic and social information regarding climate change and report on its findings in an extensive, open, transparent and politically unbiased manner. The IPCC's procedures allow hundreds of experts from many countries and organisations to participate in the reporting process. The Summaries for Policy-makers are submitted to the national delegations as well as to their research teams. These final summaries are approved line-by-line by IPCC working groups, in a process of consensus, with representatives of non-governmental organisations (NGOs) also being allowed to respond. Given the authority of the IPCC and the importance of these summaries in climate policy, it is evidently crucial that there be strict consistency with the overall substance of the report.

The threat of runaway climate change

Without a vigorous effort to curb climate change, global temperatures will continue to rise. Model calculations based on the IPCC's most recent emission scenarios indicate a temperature rise of 1.9 to 2.9°C between 1990 and the end of this century; this is on top of the 0.6°C increase prior to 1990 (Wigley, 1999). These figures are based on a 'climate sensitivity parameter' of 2.5°C, i.e. the average global temperature change that is estimated to result from a doubling of atmospheric CO_2 compared with pre-industrial levels. There is still considerable uncertainty regarding the value of this parameter, and the IPCC subsequently gives a range of 1.5° to 4.5 °C, with 2.5°C as a best estimate. The assumed temperature increase will cause sea levels to rise by about 46 to 58 centimetres, the combined result of thermal expansion of the world's oceans and freshwater influx from the melting of glaciers and polar ice caps.

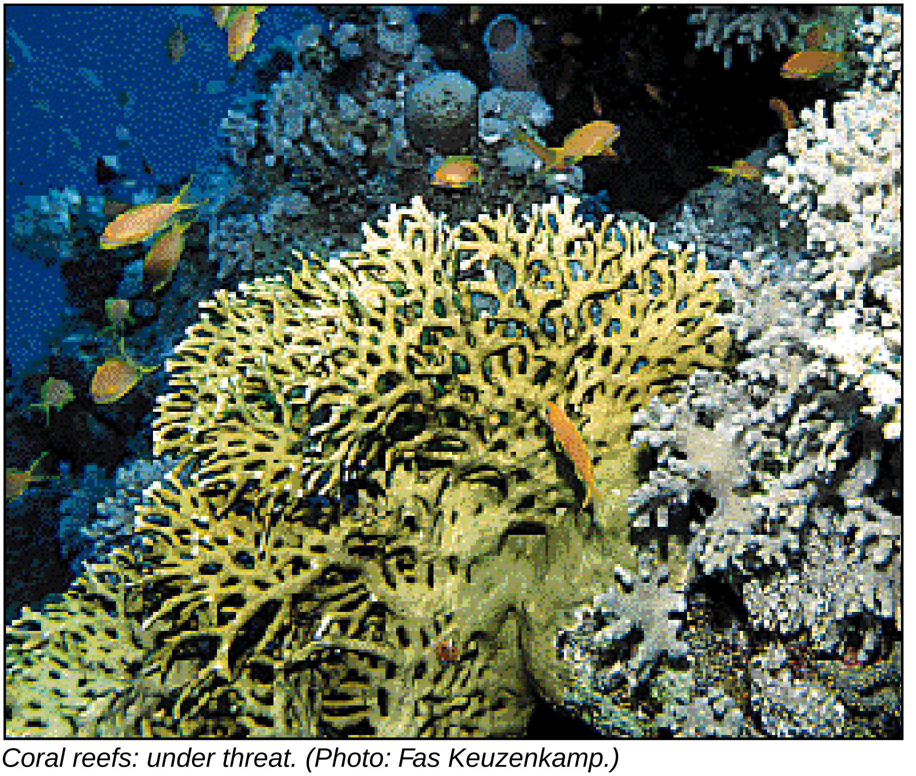
Rising temperatures will lead to further disruption of the climate. Patterns of precipitation will change and at the global level precipitation intensity will generally increase, atmospheric circulation patterns (i.e. wind systems) and ocean currents will shift and change, and there will be a higher incidence of extreme weather events (Vellinga and Van Verseveld, 1999b). These climate shifts will in turn lead to growing ecological disruption, human suffering and economic damage.

Climate change will have the greatest impact on the hydrological (i.e. water) cycle. In regions with rising temperatures and declining rainfall there will be an increased risk of drought, while in areas with additional rainfall it is the risk of floods that will increase. Rising temperatures will also cause less precipitation in the form of snow and more in the form of rain. Snow tends to be more persistent, acting as a buffer in the water cycle, while rain is carried off more or less instantly. Because some precipitation is still seasonally buffered as snow, the flow of rivers like the

Rhine is now far greater in summer than if all precipitation were in the form of rain. At a different scale level, unless drastic countermeasures are taken the rise in sea level will submerge coastal areas and cause a number of islands to permanently vanish.

Climate change may also have an impact on public health. During heat waves there will be increased morbidity and mortality due to cardiovascular and respiratory disease. As climate zones shift, so too will the natural distribution of such tropical diseases as malaria and yellow fever.

At the global level, climate change will probably have only a limited impact on agricultural output. That, at least, is the current understanding. Although some of the effects will certainly be unwelcome, there will also be benefits in the form of additional CO_2 fertilisation and a lengthening of the growing season. At the regional level, though, projections indicate that climate change will have a substantial impact, especially in the developing countries. The picture is compounded by the fact that little is currently known about pest and disease incidence under changing climatic conditions.



Coral reefs: under threat. (Photo: Fas Keuzenkamp.)

Coral bleaching

Of all the world's marine ecosystems, coral reefs are the most stunningly beautiful and the richest in biological diversity. Often an oasis in a nutrient-poor environment, they may be home to hundreds of thousands of different species. Beautiful as they are, coral reefs are also of major economic value to fisheries and tourism.They also harbour an extensive gene pool, and constitute a natural line of defence against coastal storms.

In the past few decades, however, the world's coral reefs come under increasing pressure from pollution episodes, changes in salinity, sedimentation, overfishing and various other human influences. Since the 1980s, moreover, a new occurrence has been observed with alarming frequency across the world. Coral reefs are host-symbiont partnerships of corals and single-celled algae and in recent years there has been a marked decline in the vitality of the latter as well as in the amount of pigment they produce. The outcome is a fading of the reef's rich colours, a phenomenon known as coral bleaching. Because of the vital symbiotic role played by these algae, their demise threatens the health of the coral itself. Although this process may sometimes lead to complete ecosystem collapse, in many cases the reef recovers within a few years. The coral bleaching events observed until now have generally been triggered by local sea water temperatures rising above a critical threshold. Since 1997 there have been six excessively warm periods attended by mass coral bleaching, most extensively in 1998 - the hottest year of the century.

Coral experts are concerned that coral bleaching will become more frequent if global temperatures continue to rise, becoming an annual event from about 2030 onwards. As it is often many years before stressed coral reefs regain their vitality, it remains very much to be seen whether they can survive under such circumstances. The scientific evidence seems to show that coral reefs are unable to adapt fast enough to changing climatic conditions. As a result, climate change could well herald the demise of the planet's richest marine ecosystem. (Source: Hoegh-Guldberg, 1999)

Ecosystems are of themselves dynamic and likewise exposed to climatic variation. However, the plant and animal populations making up a particular terrestrial ecosystem can only survive if the ambient temperature and water availability remain within certain bounds. If these are exceeded, some populations will be replaced by others. Species vary widely in their sensitivity to climatic variation and in their ability to adapt to changing ecological conditions. Climate change is therefore very likely to lead to disturbance and disruption of ecosystems around the world. At particular risk are the vulnerable northern boreal forests, the world's wetlands, alpine and coastal ecosystems and coral reefs (see box). In many cases ecosystem disruption will have a serious impact on biodiversity and on drinking water supply, as well as impacting upon agriculture, forestry, fisheries and tourism.

Climate change: a threat to polar bears

The most pronounced temperature rise is predicted in the highest latitudes, in the Arctic and on Antarctica.This poses a direct threat to the marine ecosystems of the polar regions, where biodiversity is typically low - in contrast to that of coral reefs, for example. These ecosystems are characterised by a high degree of species interdependence, and the demise of one species will frequently have a domino effect on others. Consider the case of the polar bears.

Over 90% of a polar bear’s diet consists of seals, which feed on cod, which in turn feed on plankton, which feed on algae that live on the subsurface of the sea ice. The algae-covered ice thus forms the basis of the entire food chain, the ecological motor where the sun’s energy is converted into food. As global warming melts ever greater expanses of ice, algal density will decline, affecting production throughout the food chain.This is not the only threat to the food supply of polar bears. Seals, their primary food source, will find it increasingly difficult to rear their young.As seal pups have only a thin layer of blubber at birth, they start out life in underground snow burrows. As the Arctic warms and suitable areas for such burrows become scarcer, seal populations will also be increasingly threatened.
Another consequence of global warming will be a shortening of the feeding season. Polar bears tend to stalk their prey on the pack ice, catching seals when they surface for air. When the floating pack ice thaws in the summer the bears retreat to the mainland ice cap, living off their fat reserves for a few months. As temperatures rise and the pack ice melts sooner and faster, the polar bear’s feeding season will be curtailed and its habitual fast extended. Recent studies in Hudson Bay, Canada, suggest that polar bears are already feeling the initial effects of global warming, with both birth rate and average weight now clearly in decline.

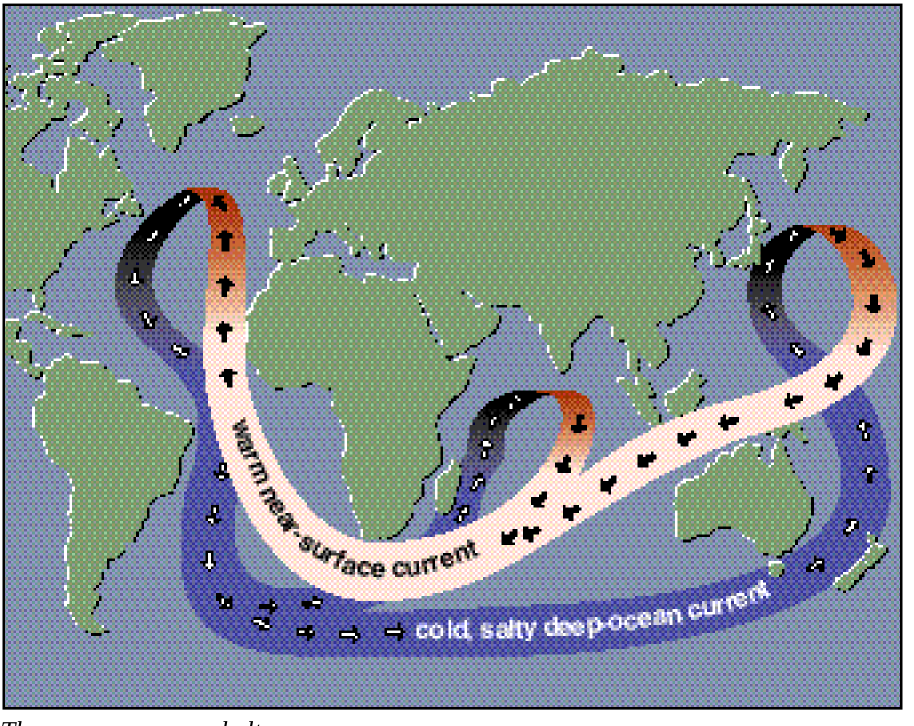
Climate change poses a major threat to the marine ecosystems of the Arctic, where snow and ice cover are quintessential.The disappearance or deterioration of these ice fields will be accompanied by a decline in all the species that depend on them.

(Source: Malcolm, 1996)

photo *“Don’t melt the North Pole… Use green energy!” A joint campaign by the World Wide Fund for Nature and Dutch energy companies. (Photo: World Wide Fund for Nature.)*

All in all, climate change will result in a general reshuffling of the costs and benefits associated with the weather. It seems likely that the developing South will be worst affected, for these countries generally lack the technological and financial resources for taking effective action - if such action is feasible at all.

Climate change has been considered until now as a gradual process, but there is also a risk of comparatively rapid climate destabilisation, triggered by some change within the enormous complexity of the world climate system. Although the risk of a ‘climate flip’is as yet unclear, the implications are enormous. A case in point is the possible stagnation of the Gulf Stream, a catastrophic event that would leave Europe with a climate more akin to that of Labrador or Siberia (see box: The next European Ice Age?). Another major threat is collapse of the West Antarctic ice shelf, an event which would cause sea levels to rise by up to six metres. Yet another threat is the potential release of huge quantities of greenhouse gases currently sequestered as hydrates in the ocean bed and in permafrost regions as well as the carbon dioxide immobilised in boreal soils and in the oceans.



The ocean conveyor belt.

The next European Ice Age?

Paradoxical as it may be, global warming may in fact trigger a new Ice Age in Europe, for changes in rainfall patterns and increased ice-melt could disrupt the ocean currents of the North Atlantic. At present the ‘ocean conveyor belt’ that pumps sea water around the world’s oceans (see figure) ensures a permanent influx of warm water from the southern Atlantic, giving Europe the temperate climate it currently enjoys. If this current were to weaken or stagnate altogether, temperatures in Europe would plummet.The conveyor belt is driven by differences in the density of sea water, which increases as the water gets colder or its salt content rises. The densest water forms near Antarctica, from where it branches into two deep-sea ‘rivers’to the Pacific and the Indian Oceans. Having been heated in the tropics, warm and relatively salty water is transported northwards by the so-called North Atlantic thermohaline circulation, or Nordic heat pump. In these higher latitudes the sea water loses its heat to the cold winds blowing across from Canada, and the cooler, denser water sinks to the ocean floor and flows south, eventually to heat up and resurface.
If global warming is allowed to continue rainfall is projected to increase sharply, particularly at higher latitudes. On top of this, the Arctic ice cap will thaw. Together this will result in a greater influx of fresh water to the North Atlantic, lowering ocean water salinity and thus density, in turn slowing the ocean conveyor belt, to the point where its northernmost loop could shut down completely. There are signs that a similar occurrence took place about 10,000 years ago, when meltwater from continental ice sheets is assumed to have caused the Nordic heat pump to stagnate. The record shows that temperatures in Europe plummet by some 10°C as a result.
Current climate models predict that a doubling of carbon dioxide levels will slow down this part of the ocean conveyor belt by between 10 and 30%; with a three- or fourfold increase it could grind to a halt altogether.

(Source: Stocker and Schmittner, 1997)

The need for drastic emissions reductions

To limit the damage due to climate change and minimise the risk of climate destabilisation, human interference in the earth’s radiation balance must be sharply reduced. There is only one way to avoid a runaway temperature increase and that is to stabilise atmospheric concentrations of greenhouse gases. The lower the level at which they are stabilised, the less severe the ensuing damage and the lower the risk of a climate flip.

In the present context we confine ourselves to the reduction of CO_2 emissions, as carbon dioxide is by far the greatest contributor to global warming. We hasten to add, though, that this does not in any way imply that reducing emissions of other greenhouse gases is less important and should not be given priority where cost-effective.

To stabilise atmospheric CO_2 levels means that global emissions must not be allowed to exceed the combined absorption capacity of the oceans and the biosphere. This implies that annual carbon emissions must ultimately be reduced from the 1990 level of 7.4 GtC to about 3.5 GtC (gigatonne, i.e. billion metric tons, of carbon). The timetable for achieving the required stabilisation is a political issue and will involve wise reconciliation of ecological, economic and social considerations. At heart, though, there are two choices before us: what level of stabilisation - and by implication what maximum temperature rise - is to be deemed acceptable, and how soon is it to be reached?

The most radical approach would be to immediately reduce global CO_2 emissions to the equilibrium level of 3.5 GtC per year. Even then temperatures would continue to rise for several decades, owing mainly to the long atmospheric residence time of CO_2: between 50 and 200 years. There is also a delayed response, or 'overshoot'. Because of the slowness of ocean warming, it would be several decades before the equilibrium temperature associated with a given greenhouse gas concentration were reached.

In socio-economic terms this radical strategy would be an irresponsible gesture, however. It would mean cutting our consumption of fossil fuels by about half at one stroke. Given the pivotal role of these fuels in industrial society and the time and funds required for a shift to benign alternatives, this is simply not a viable option. In practice some midway course will have to be steered between the risks to global ecology and those to the global economy.

Both the Dutch government and the European Union have opted to take a maximum temperature rise of 2°C above pre-industrial levels as the point of departure for climate policy. This temperature ceiling is intended to reduce the risk of climatic destabilisation as far as possible. It should be noted, though, that even an average global temperature rise of just 1°C will lead to an appreciable impoverishment of alpine ecosystems, oak forests, mangrove swamps, coastal wetlands and other ecosystems.

The rate at which greenhouse gas emissions can be reduced is subject to a variety of social and economic constraints. One such constraint is the need to limit the capital resources sacrificed in switching to alternative energy systems. Technological progress is another key factor. The maximum rate of emission reduction to be achieved without resorting to capital destruction (i.e. premature retirement of plant and equipment) is estimated at 2 to 4% per annum, a point discussed in more detail in Chapter 4 (Van der Sluijs and Turkenburg, 1998).

An important question is how a maximum acceptable temperature rise of 2°C translates into an equilibrium level for the CO_2 concentration. This depends on the assumptions one makes about the contributions of the other greenhouse gases and the value taken for the climate sensitivity parameter, i.e. the average global temperature resulting from a doubling of atmospheric CO_2 levels. As already mentioned, this parameter is associated with major uncertainties. The IPCC gives a range of between 1.5 and 4.5°C, with 2.5°C as their best estimate. Proceeding from this middle estimate, it can be calculated that the combined concentration of all greenhouse gases should be kept below about 500 ppmv, expressed in CO_2-equivalents.

These terms require a little explanation. To express the concentrations of the various greenhouse gases as a single figure, the concept of CO_2-equivalence has been introduced, with the capacity of one kilogram of a given gas to contribute to the enhanced greenhouse effect being expressed in terms of the quantity of CO_2 that would have an equivalent impact. The abbreviation ppmv stands for parts per million volume: 1 ppmv is thus one litre of CO_2 per million litres of air. Allowing for the contribution of greenhouse gases other than CO_2, then, the maximum CO_2-equivalent concentration can be calculated to be about 450 ppmv. This is illustrated in Figure 6, which shows a possible reversal of the CO_2 emission trend with which to accomplish stabilisation at this level.

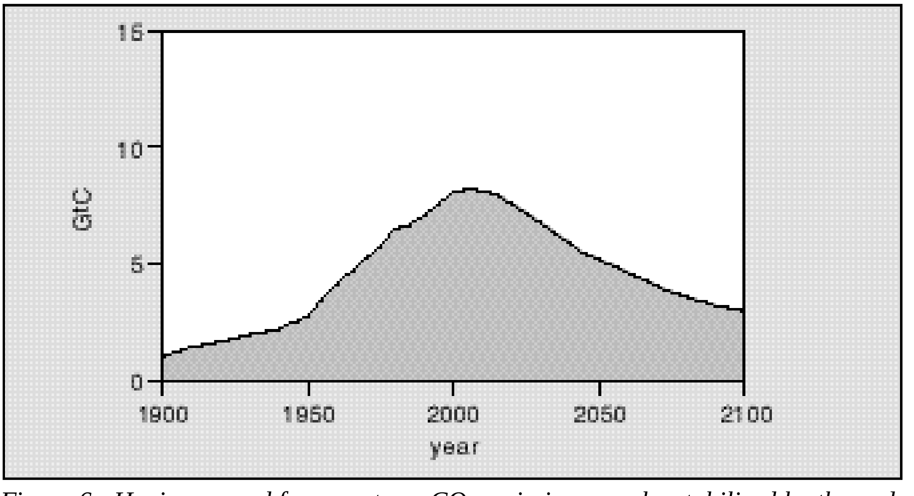


Figure 6 Having surged for a century, CO_2 emissions can be stabilised by the end of the twenty-first if we seriously aim for a maximum level of 450 ppmv. (Source: Houghton et al., 1995.)

If a higher value of 4°C is taken for the climate sensitivity parameter, or a lower value of 1°C for the maximum permitted temperature rise, the atmospheric concentration to be targeted would drop further to 400 or 350 ppmv CO_2-equivalents, respectively.

How, then, are current Dutch and European stabilisation targets to be judged? The most striking fact is that they have no margins reflecting all the remaining uncertainties. This appears to contradict the Precautionary Principle, which has been adopted as a policy cornerstone by both the Netherlands and the European Union (Van der Sluijs and Turkenburg, 1998). In this light the 'stabilisation targets' are better viewed as 'ultimate limits'. Given the current state of affairs and the time required to curb emissions, in all likelihood the 450 ppmv ceiling implies no more than a reduction of the risk of climate destabilisation to acceptable proportions. This risk is predicted to rise sharply as CO_2 concentrations approach about 650 ppmv.

3 International policy in the 21st century

Current climate policy: just the first step

The United Nations Climate Convention, signed at the Rio de Janeiro environmental summit in 1992, forms the basic framework for current global climate policy. At the end of 1997, following extensive negotiation, this treaty was elaborated into a binding Protocol in Kyoto, Japan. This chapter begins with a discussion of the obligations embodied in the Climate Convention and the Kyoto Protocol, including their shortcomings. We then outline the contours of a global, long-term climate policy to follow on where the Kyoto Protocol leaves off.

The UN Climate Convention of 1992 marks the first move by the international community to address the issue of climate change. As Article 2 of the treaty states: “The ultimate objective of this Convention … is to achieve … stabilization of greenhouse gas concentrations in the atmosphere 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.”

The Climate Convention contains no quantitative provisions regarding either the level at which greenhouse gases are to be stabilised or the timetables by which the required emissions reductions are ultimately to be achieved. The treaty merely obliges signatory parties to seek reduction of their greenhouse emissions and covers arrangements regarding monitoring, scheduled reporting of emissions and mitigation action, and suchlike.

Because of the historical contribution of the industrialised nations to climate change and their more substantial financial resources, it was agreed that these countries should take the lead in tackling the problem. This is reflected in the additional responsibilities of the so-called ‘Annex I countries’of the Climate Convention: the OECD nations, Eastern Europe and the former Soviet Union. For these countries quantitative emissions reduction targets were set: to 1990 levels by the end of 2000. With the exception of the so-called economies in transition, i.e. the countries of Eastern Europe, Annex I countries are to transfer funds to the non-industrialised nations to enable the latter to fulfil their treaty commitments, to fund technology transfer and to compensate for the impact of climate change and climate policy.

The 1992 agreement was merely a first tentative step on the road to tackling climate change and the Kyoto Protocol of 1997 establishes concrete - and binding - emissions reduction targets for the industrialised nations. No additional obligations were imposed on the non-industrialised world. The Kyoto Protocol is still to be ratified by the majority of countries, including the United States, a key player in the arena of climate policy. The Protocol will not formally enter into effect until it has been officially endorsed by the leading nations of the world.

For the industrialised world an average aggregate emissions ceiling, or ‘budget’, has been set entailing a 5.2% reduction of these countries’carbon emissions from (aggregate) 1990 levels by the period 2008-2012. Individual nations or groups of nations have thereby been assigned quota of ‘tradable emissions permits’, representing a certain percentage of 1990 ‘baseline’emissions. These range from 92% for the EU as a whole to 110% for Iceland. This burden-sharing among the industrialised nations is not based on any formal allocation principle, but was dictated by considerations of political feasibility, in a political settlement based largely on technological and economic feasibility.

Under the terms of the Kyoto Protocol the industrialised nations have four options for meeting their obligations, the latter three of which are known as ‘flexible mechanisms’ or ‘Kyoto mechanisms’:
- cut domestic greenhouse emissions and possibly also sequester atmospheric CO_2 in forest ‘sinks’through domestic afforestation/reforestation programmes and/or projects to control deforestation;
- trade in emissions reduction with other industrialised nations;
- invest in emissions reduction schemes in other industrialised nations, referred to as ‘Joint Implementation’;
- invest in emissions reduction schemes in non-industrialised nations, referred to as the ‘Clean Development Mechanism’.

In practice, a decision has been made in favour of tradable emissions permits, in tandem with a credits system for carbon-cutting investment projects implemented in other countries. The extent to which such trade will be entirely ‘free’is still the subject of negotiation. In this context the Kyoto Protocol stipulates that overseas mitigation measures must be additional to domestic efforts. The EU would like to see this translated into an agreement that at least half a country’s mitigation efforts are implemented at home. Even though this implies that emissions reduction would not necessarily be achieved at least cost, it is held that this would improve the credibility of the industrialised nations. In addition, it might limit the trade in ’hot air’ (see box).

Hot air

‘Hot air’ refers to the scenario of nations selling their ‘surplus’ emissions permits, i.e. the unused portion of their apportioned emissions budget, a situation not inconceivable in Russia and the Ukraine. Because of the economic crisis prevailing in these countries, national emissions in the initial budget period (until 2012) will be significantly lower than the entitlements assigned under the terms of the Kyoto Protocol.This means that these nations could sell some of their entitlements without these having to be offset by any concrete emissions reduction at home. It should be noted that such a modus operandi is fully in accordance with the Kyoto agreements.

In summary then, the Kyoto Protocol is merely a first step towards a global strategy for addressing climate change. It is still flawed by two voids in particular. First, no cap has in fact yet been set on *global* emissions: no emissions restrictions or reductions have been agreed for the non-industrialised countries of the South, and the same holds for international aviation and shipping (Figure 7). Second, no agreement has been reached on further reduction of global emissions.

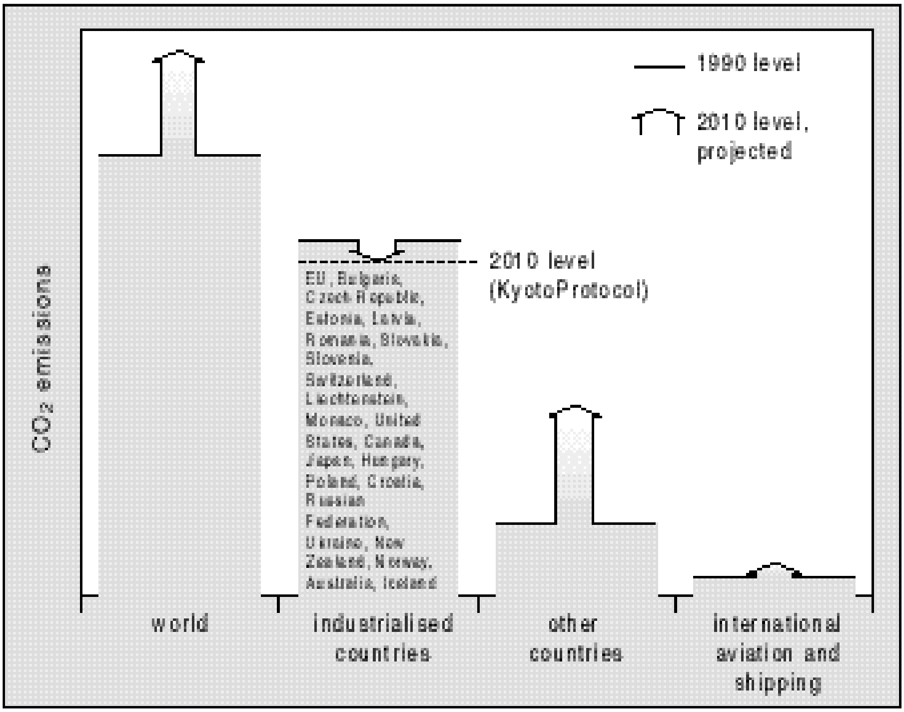


Figure 7 For certain countries and economic activities (aviation and shipping) the Kyoto Protocol sets no binding reduction targets.

In addition to these two fundamental shortcomings, the Protocol leaves open a number of ‘grey areas’ where crucial issues remain unresolved:

- How is a secure system of emissions registration to be established?
- How are the Kyoto mechanisms (Joint Implementation, Clean Development Mechanism, emissions trading) to be implemented in practice?
- How is a significant transfer of technology from North to South to be initiated and funded?
- What sanctions are to be introduced for non-compliance?

An issue in its own right is the value to be assigned to natural carbon ‘sinks’such as forest biomass and the oceans, where a certain amount of atmospheric carbon dioxide is absorbed and immobilised. Although the so-called sequestration capacity of these sinks needs to be quantified for inclusion in carbon inventories, it is an area that remains fraught with uncertainty. Consensus is likewise lacking on how afforestation, reforestation and projects to control deforestation are to be credited in this context. The option has also been left open to include other categories such as wetlands, agricultural land-use changes and forestry project at some future date. Given the thorniness of these issues, the standing targets for the initial commitment period up to 2012 may very well have to be renegotiated. The unfinished debate on the creditable value of carbon sinks forms the Achilles heel of the Kyoto Protocol.

SO_2 trade in the United States compared with trade under the Climate Convention

An important motive for opting for a system of tradable emissions permits under the Climate Convention is the success of a similar trading scheme for sulphur dioxide emissions in the United States. There the system is administered by the Environment Protection Agency (EPA), which sets a ceiling on aggregate annual emissions and defines the means by which the available permits are to be distributed, measured and reported.The bulk of the permits are apportioned on a ‘grandfathered’ basis, i.e. according to historical emissions, with a small portion being auctioned.Companies exceeding their assigned quota are fined a sum ten times the market value of their additional emissions and obliged to reduce their emissions by the same amount the next year.
The Climate Convention has no regulatory body with powers similar to those of the EPA. In the present case emissions budget allocation, reporting method, possible new categories of projects qualifying for inclusion (e.g. forests) and enforcement regime are all left up to the participating countries themselves. This difference goes a long way to explaining the slow progress of the climate negotiations, as every discussion on what initially appear to be technical issues essentially reopens the debate on the scope of the agreements under the Kyoto Protocol and the extent to which they are binding.

A further weakness is the uncertainty surrounding ratification of the Protocol by national governments. Although the Kyoto Protocol has currently been signed by 84 countries, it has been ratified by only two. Ratification by the United States is particularly crucial to the Protocol’s future success. However, it remains very much to be seen whether the support of the US Congress and Senate will be forthcoming.

Meanwhile a growing number of international companies are formulating their own emissions targets. The oil company Shell, for example, has stated its intention to reduce its CO_2 emissions by 10% worldwide by the year 2002 compared with 1990. BP Amoco and DuPont have likewise committed themselves to targets going beyond those of the Kyoto Protocol. Exactly how corporate objectives such as these are to be reconciled with the Kyoto targets is an issue for further negotiation, but the Protocol certainly offers due scope for such initiatives.

Beyond Kyoto

Although a fair amount of negotiation and detailing are still required before the Kyoto Protocol can be finalised in all its ramifications, it is worth looking beyond Kyoto already. What kind of climate policy is required beyond the Kyoto horizon of 2012? The principal aim should at any rate be to fill in the various ‘voids’of the Kyoto Protocol. More specifically, a follow-up protocol should cover *all* the world’s greenhouse gas emissions, i.e. including those of the international aviation and shipping sectors as well as those of the non-industrialised nations. Before a political accord can be reached on the latter point parties will have to come to equitable arrangements for allocating emissions quota.

Agreement is still furthermore to be reached on an ultimate stabilisation target and on a timetable for accomplishing the implied emissions reductions in the course of the 21st century, i.e. the annual global emissions budget.

Global emissions budget

Economic and ecological considerations dictate the permissible levels of greenhouse gases in the atmosphere. Calculating back, appropriate timetables can then be drawn up for emissions reduction. We refer once more to Figure 6, which shows a possible scenario in line with the basic premises of Dutch policy.

Let us assume for the sake of argument that Dutch policy premises are adopted worldwide, thus implying that global carbon levels are to be stabilised at 450 ppmv CO_2-equivalents as an ultimate target. In that case global carbon emissions may rise only fractionally over the next 20 years and must be cut back to about 3.5 GtC by the year 2100. Cumulative carbon emissions from 1990 through to 2100 may not exceed more than 550-750 GtC (Houghton et al., 1996), equivalent to average annual global emissions of 5-6.8 GtC throughout the period. This compares with a global emissions figure of 7.4 GtC for the year 1990.

Fair allocation

Very substantial emissions reductions are required if the risks of climate change are to be limited. By implication, the ‘right’to release carbon emissions will be a scarce commodity. The crucial question thus arises of how such rights are to be allocated: crucial, because the allocation rules adopted will dictate how the financial burden of climate stabilisation is to be shared. Worldwide agreement will therefore have to be reached on an allocation principle acceptable to all parties - and this obviously includes the South if these countries too are to be brought on board.

There are a number of conceivable principles for allocation (cf. Gupta, 1998 and Ringius et al., 1998):

Egalitarianism	Emissions budget allocated on an equal per capita basis, i.e. equal rights for every world citizen.
Grandfathering	Emissions budget allocated proportionally to historical emissions levels ('historical rights').
Solidarity	Financial burden shared according to (financial) resources, and emissions 'rights' according to this burden.
Utilitarianism	Emissions 'rights' allocated so as to maximise utility.
Contingent on local conditions	Allocation determined by factors governing magnitude of burden (e.g. climate, economic structure, population growth).

Ultimately, the choice of allocation principle is a normative, political decision. In the long run, though, egalitarianism would appear to be most tenable basis for sharing out 'emissions rights', following as it does from the ethical principle that every individual should have maximum freedom in shaping his or her life, to the extent this does not infringe upon the similar freedom of others (cf. Davidson, 1995).

Adoption of the principle of egalitarianism is justified for two main reasons. In the first place, every human being needs access to the world's natural resources to shape their life. Equal rights to these resources is the only allocation principle acceptable all round, for every alternative embodies preferential regimes that will be rejected by disadvantaged parties. Secondly, an egalitarian approach paves the way for tougher global emissions reduction commitments. The industrialised nations can thus demonstrate their good intentions while bringing the South on board with the potential revenue to be earned from emissions trading.

A number of developing countries are in fact unlikely to cooperate on emissions mitigation unless national quota are allocated on an equitable, i.e. per capita basis. In part, this is because these countries do not consider themselves responsible for the problem of climate change. In addition though, they have other priorities such as combating poverty and local environmental degradation. These countries are concerned that greenhouse gas abatement commitments will retard their economic development, given the historical correlation between economic growth, energy consumption and carbon emissions. Per capita allocation of tradable emissions permits would form an incentive for virtually all countries to accede to the Climate Convention: those not yet making full use of the emissions quota to which they are entitled as well as those able to reduce their emissions at relatively low cost.

In political terms, however, per capita allocation is not at present a feasible option.

The movement of capital between groups of nations implied by such a step is politically off limits, for the time being at any rate. It is important, nonetheless, that a dialogue already be started on possible routes towards sharing emissions rights on an equal per capita basis by, say, the turn of the century. In doing so, a balance must be struck between political feasibility and equity.

By way of illustration, Figure 8 depicts a hypothetical scenario. It is based on 'hybrid rights': a weighted average of 'historical'and equal rights, with the former progressively dispriveleged until equal per capita allocation is finally achieved in the year 2100. The scenario is based on the projections of population growth and Gross Regional Products employed in the new B1 Scenario developed by the IPCC for its Third Assessment Report (see box: A sustainable scenario).

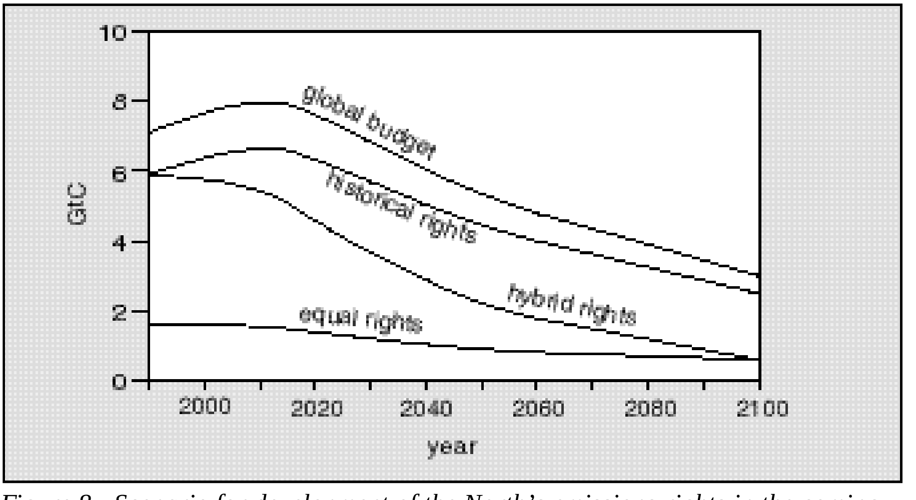


Figure 8 Scenario for development of the North's emissions rights in the coming century. Assigned quota vary substantially depending on the allocation principle employed: grandfathering ('historical rights'), equal rights or a hybrid approach.

This scenario embodies just one of the many possible weighting strategies for moving from grandfathered to equal emissions rights. Ultimately, an appropriate transitional period will have to be agreed upon in a process of due negotiation among the nations of the North and South.

A sustainable scenario

The B1 Scenario is one of the latest generation of IPCC scenarios and has been used here to calculate the North-South cash flows that would potentially ensue under a global emissions trading regime. This particular scenario has been selected because it constitutes the best overall match for the energy path advocated in this booklet.
This scenario is based on assumed worldwide pursuit of sustainable development, with society collectively opting for a service economy in which social equity and a clean environment are both held to be important values. Although there is popular interest in a cleaner environment, this is not specifically the case for climate change. The global population peaks at 9 billion by 2050, subsequently falling to 7 billion by 2100. There is solid economic growth, similar to that enjoyed over the past 50 years, with the bulk of this growth occurring in the less industrialised countries. Thanks to a combination of 'dematerialisation', technology transfer and high-tech innovation there is a progressive delinkage of economic growth and energy consumption. Having doubled in 2050 compared with present levels, primary energy use goes on to decline by the end of the century to 40% above today's levels. From 2050 onwards there is a downward trend in carbon emissions, leading to a greenhouse gas concentration of 600 ppmv CO_2-equivalents in the year 2100. This does not mean that the concentration has been stabilised, however.
What this scenario underscores is that even if developments are exceptionally favourable in social, economic, ecological and technological terms, a most rigorous climate policy will still be called for.

(Source: Vries et al., 2000)

By opting for a system of internationally tradable emissions permits, greater support can be fostered for further greenhouse gas reduction commitments, for a permit regime represents a potential source of revenue for developing countries. To gain an idea of the potential North-South cash flow implied we ran a series of calculations using the IPCC's B1 Scenario (see box) and assuming a permit trading price of US$ 150 per tonne of CO_2 throughout the period. These calculations are only very approximate, it should be noted, and are intended to be merely illustrative. They furthermore assume that global trading will not start until 2010.

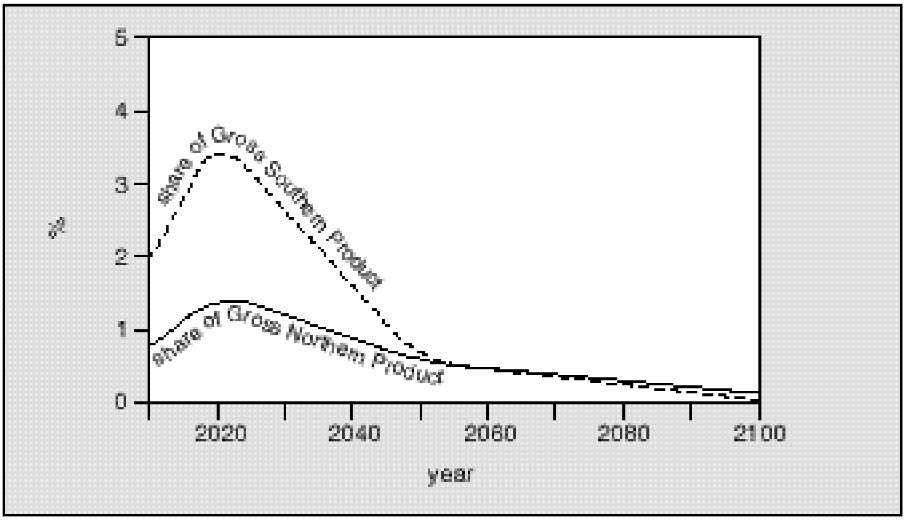


Figure 9 North-South cash flows as a percentage of Gross Northern Product and Gross Southern Product, based on allocation according to 'hybrid' rights (see Figure 8).

Even if emissions 'rights' were not initially equally allocated, a substantial cash flow to the South would soon materialise as these countries began to sell emissions permits to the North.

Emissions budget for aviation and navigation

Although emissions by international aviation and shipping are not yet covered by the Kyoto Protocol, its terms stipulate that the International Civil Aviation Organisation (ICAO) and the International Maritime Organisation (IMO) are to develop policies to reduce the emissions of their respective sectors. Until now the two organisations have focused primarily on elaborating mitigation options and scenarios for burden-sharing (cf. Wit, 1996; United Nations, 1996). We propose a new strategy for tackling the emissions of international aviation and shipping, a strategy in line with the philosophy developed above.

In the transitional period until such time as general emissions rights are distributed equally on a per capita basis, a transitional regime should also be created for the international aviation and maritime transport sectors. The proposal is then to allocate emissions permits to these sectors as if they held country status, with initial allocation based on the grandfathering principle, or 'historical rights'. With time these inherited rights would be gradually retracted down to zero, moving international aviation and shipping to either implement sectoral mitigation measures or procure emissions permits elsewhere, just like every other market player. By the year 2100 the only remaining emissions entitlements would then be those equitably distributed among the world's citizens on an equal per capita basis.

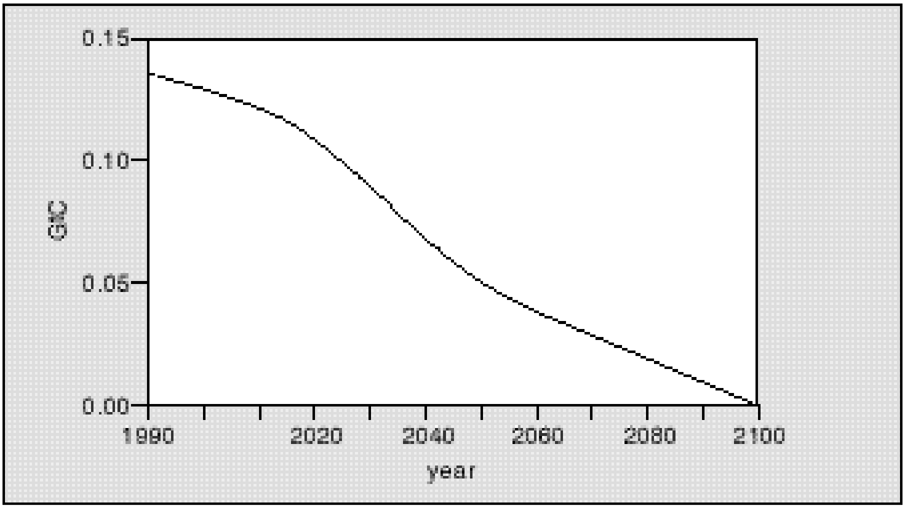


Figure 10 The historical CO_2 emissions 'rights'of international aviation will have to be reduced to zero in the coming decades to bring it in line with other sectors.

Multi-track international policy

We have outlined a post-Kyoto policy that takes as its point of departure standing agreements. In principle this strategy provides sufficient scope for a climate policy that is both effective and efficient. For a variety of reasons, however, it would be imprudent to gear efforts entirely to this one scenario.

The greatest risk is from sluggish progress - or in a worst-case scenario, failure - of international negotiations on the proposed strategy and objectives and the policy mechanisms to be employed. It is very much to be seen whether national governments have sufficient leadership to come to binding agreements on a global greenhouse gas emissions budget and establish a system of equitably allocated emissions permits. The distribution issue is particularly sensitive. The notion of equal, per capita allocation is not new and has already been tabled several times at negotiations by India and China but has invariably met with opposition, from the United States in particular. The US Pew Center on Global Change considers that per capita allocation would bring about "perverse incentives for population growth" (Claussen and McNeilly, 1998). As this stance already signals, a debate on the population issue is unavoidable. The industrialised countries of the North remain anything but comfortable with the notion of tradable emissions permits based on equal rights, moreover, with the substantial initial North-South cash flow they imply. According to Grubb and Sebenius (1992) "these large transfers would be politically unfeasible". This objection is addressed in recommendations made by the Dutch Council for Housing, Spatial Planning and Environment (VROM Council, 1998). The Council argues, however, that "there is essentially no difference between importing consumption goods from a country and buying emissions capacity in that country".

Other problematic aspects of the Kyoto Protocol concern its concrete elaboration and practical enforcement. It is only recently that these issues have been tabled for detailed debate at the periodic negotiations among parties to the treaty and the record shows that these issues remain far from resolved (as already discussed under 'Current climate policy: just the first step').

The environmental movement is generally critical of emissions trading, furthermore. It is concerned that western countries will simply 'buy off' their carbon emissions reduction commitments instead of effectuating concrete reductions at home. This problem is particularly acute in the case of trade in 'hot air': surplus emission permits bought from other countries without this having to be offset by genuine emission reductions at home (see box, Hot air). This argument is first and foremost an objection to the current Kyoto arrangements rather than a principled objection to tradable emissions permits as a policy instrument. If trading enables aggregate emissions to be kept within the collective global emissions budget, it is all to the good. It is immensely important for the further debate that a critique of emissions trading *per se* be divorced from critical discussion of how individual emissions budgets are to assigned to specific countries or regions.

Given the many questions still unanswered and the inertia of the political process, it would be naive to reckon on tougher national commitments emerging exclusively from the international forum around the UN Climate Convention. The process will probably be more dynamic, with advances in international climate negotiations likely to hinge on progress made in other areas, such as global agreement on efficiency standards, regional experimentation with emissions trading, or vigorous action by multinational companies prompted by non-governmental organisations and consumers (cf. the Science Plan of the Industrial Transformation programme (Vellinga and Herb, 2000)). It would be a gamble of the highest order if mitigation of climate change were to be left to success or failure at the negotiating table. A multi-tracked global policy is therefore essential. The principal policy objective at present should be to tighten existing agreements under the Kyoto Protocol, particularly in respect of implementation and enforcement. The second aim should be to fill in the voids of the Kyoto Protocol as it now stands (essentially a follow-up exercise). As a third and final policy goal, it is crucial that international agreement be reached on a number of other issues, in fora other than 'Kyoto'. These issues include:

- introduction (or augmentation) of a national or supranational carbon-based energy levy;
- international arrangements on energy efficiency standards for equipment, aircraft and other vehicles;
- incentives for development and deployment of innovative technologies. A coherent approach in collaboration with other forward-looking countries is the preferred option: for example, a joint procurement campaign by government, industry and NGOs to deploy a million cars doing 35 kilometres to the litre;
- technology transfer from industrialised to developing countries.

Alternatives to the Kyoto scheme

Global agreements on carbon intensity

The current Kyoto scheme is geared to reducing fossil carbon dioxide emissions. One means of achieving this aim, from the policy angle, is to pursue reduction of the carbon intensity of the energy supply, i.e. the average carbon content per unit primary energy. In the following chapter we argue that carbon intensity should indeed form the principal leverage point for climate policy and that global efforts should consequently be geared more to reducing the carbon intensity of the world's energy supply. One way to operationalise this strategy would be to set national caps on carbon intensity rather than on carbon dioxide emissions, with lower ceilings for the North than for the South, for example.

Agreements on carbon intensity are relevant only for carbon emissions due to fossil energy use; they make no allowance for the emissions associated with changes in land use and land cover. Specific arrangements would still need to be made for the latter category of emissions as well as for emissions of other greenhouse gases.

Fossil fuel levies

Under the Kyoto Protocol a system of tradable emissions permits has *de facto* been adopted. An alternative or complementary approach would be to introduce a world-wide levy on crude fossil fuels. A system of levies on fossil carbon would be significantly less susceptible to fraud than a permit system requiring monitoring of invisible CO_2 emissions. The production of solid, liquid or gaseous fossil fuels is, after all, far easier to monitor and verify than the volume or mass of atmospheric emissions, implying a far simpler implementation and enforcement regime, in particular.

A carbon levy would raise the price of fossil fuels, thus creating an incentive to improve energy efficiency or reduce carbon intensity, or both. If the levy is set at an appropriate level, it should in theory be just as effective and efficient as a tradable permit market. Under a system of levies the equity issue would arise once again, as it does in the context of emissions 'rights'. The distribution principle adopted (cf. Fair allocation, above) dictates how levies would be imposed and how the ensuing revenues would be redistributed both nationally and internationally.

It is conceivable that the issues presently frustrating further elaboration of the Climate Convention along with growing public anxiety will create renewed global interest in the use of levies as an alternative policy option.

4 Mitigation measures and costs

In the previous chapter the main concern was to establish a figure for a worldwide carbon emissions budget and examine how rights to that budget might be equitably shared among the nations of the world. We now turn to consider the strategies available for realising the agreed emissions targets. Our main focus will be on the industrialised world, for that is where the greatest reductions must be achieved. In the latter part of the chapter we estimate the overall cost of carbon abatement policies in the Netherlands.

Energy-related emissions

There are essentially three options for achieving the substantial emissions reductions envisaged. The first is to increase the biosphere's capacity to take up carbon dioxide, planting forests and other vegetation to augment the global carbon sink. The second option is to isolate some fraction of CO_2 emissions underground. The third is to reduce the amount of CO_2 generated by human activity. All three forms of control are rewarded by the Kyoto Protocol.

The first option, carbon absorption by the biosphere, has major potential as a short to medium term strategy. According to IPCC estimates (Houghton et al., 1996) over the next half century as much as 60 to 90 Gigatonnes of carbon (GtC) can be sequestered in forestry alone. This is 8 to 12 times the average annual global carbon emissions of the 1990s. Once a forest has matured, however, its carbon uptake dwindles to near zero. Useful as this option may be in the short to medium run, then, it fails to address the climate change problem in a structural manner.

The second strategy is to physically capture the carbon dioxide generated in processes involving fossil fuel combustion and sequester it in depleted oil and gas reservoirs or deep aquifers. For the present century, at least, this is an appealing option, for storage is underground, where the fossil fuels once originated.

The third strategy is to implement at-source measures to cut back the carbon emissions associated with fossil fuel combustion and land use. Abatement strategies relating to land use are beyond our present scope and are left aside here. With respect to fuel and energy use, a broad range of options are available: reducing energy demand, increasing resource efficiency (both materials and energy), a further shift from high- to low-carbon energy sources (substituting coal by natural gas, for example) and deployment of zero-carbon energy sources: wind, solar and other renewables, and nuclear. In the long run, the third strategy has greatest potential for achieving the drastic emission reductions required.

Given the major contribution of energy use to the enhanced greenhouse effect and the specific expertise of the authors, this chapter is concerned exclusively with strategies for controlling energy-related emissions, i.e. policies geared to improving energy efficiency and reducing carbon emissions per unit energy. The first of the strategies above – augmenting the global carbon sink with forests and other vegetation – is thus left aside here, valuable though it may be in tackling climate change in the near to medium term. It should be noted, though, that as an energy source that can replace fossil fuels in many applications, biomass from sustainably managed production forests also has a part to play in reducing carbon emissions.

Policy leverage

The overall carbon emission associated with the energy use of a given country is the product of four factors: population, per capita income, energy intensity (average primary energy use per unit of Gross Domestic Product, GDP) and the carbon intensity of the energy supply (average carbon content per unit of primary energy). As a formula:

$$C = P \times \left(\frac{GDP}{P}\right) \times \left(\frac{E}{GDP}\right) \times \left(\frac{C}{E}\right)$$

where:

C	= CO_2 emission (in GtC)
P	= population
GDP	= Gross Domestic Product
GDP/P	= per capita income
E	= primary energy consumption
E/GDP	= energy intensity
C/E	= carbon intensity of energy supply

There are, thus, essentially four routes available for reducing national CO_2 emissions: by decreasing carbon intensity, energy intensity, per capita income and/or population. It is these four factors that constitute the leverage points for climate policy action.

We focus here on the leverage offered by energy intensity and carbon intensity. Although population density is obviously of influence on the environmental burden of a country, it is beyond our present scope to discuss the ramifications of population politics. It would be unwise, though, to overestimate the scope for curbing population growth. Besides, in many regions population growth is in fact declining for a variety of other reasons. Rising economic prosperity appears to correlate with declining population growth and the additional revenue to be earned from trading in carbon emissions permits (as outlined in the previous chapter) may therefore well contribute indirectly to reducing population growth in the South.

In the present context we also leave aside per capita income, i.e. GDP divided by population, for the main reason that it is not the obvious rudder for steering through climate change. Curbing economic growth would be a most ineffective and unnecessarily expensive way of reducing carbon emissions, and GDP can therefore be ruled out as a potential leverage point. At the same time, though, GDP may well be affected both structurally and quantitatively by focusing on one of the other leverage points. Whatever the case, for the present at least there is a policy scenario conceivable whereby cleaner energy systems are vigorously implemented without any significant decline in economic growth.

The basic thrust of such a scenario is to reduce both the energy intensity of the economy and the carbon intensity of the energy supply, by pro-actively supporting clean energy resources, here taken to mean resources causing minimal carbon emissions. Besides solar, wind, biomass and other renewables, fossil energy can also be included in this category, provided the carbon dioxide is stripped from flue gases and isolated from the atmosphere, in depleted oil or gas fields or deep aquifers, for example. Because a reduction of carbon intensity involves additional cost, energy intensity would also decline. With clean energy more expensive, the use of more efficient appliances, plant and equipment would be encouraged and consumers and producers induced to adopt more energy-conscious behaviour generally. The additional costs associated with clean energy would also lead to a slight decline in GDP growth, as discussed later in this chapter.

With the above mathematical formula an analysis can be made of the quantitative changes required to achieve the envisaged emissions reduction. Our primary focus here will be on abatement efforts in the industrialised nations, for it is here that the greatest reductions must be accomplished. In the following discussion the pivotal target is a 75% cut-back of global carbon emissions in the next 50 years, an average reduction of 2.7% per year. For the sake of convenience, we assume that the global population remains stable over this period as does economic growth, at 3% per annum. It can then be calculated that the product of energy intensity and carbon intensity must be reduced by about 5.5% annually in order to achieve emissions targets. The record shows that an average reduction of about 1.5% is the best that has been achieved in the past at the global level. A mere continuation of this trend would obviously not suffice to achieve the required reductions. New policies are therefore required to reduce both energy intensity and carbon intensity. The prime aim of these policy efforts should be accelerated deployment of clean, i.e. low-carbon, energy resources (cf. Rooijers et al., 1996, others).

Energy intensity: conservation and structural change

The energy intensity of an economy is defined as the average quantity of primary energy employed in producing a single unit of GDP. More precisely, it is the product of two quantities: energy efficiency and a parameter representing economic structure, the configuration of goods and services produced in a given economy. Improving energy efficiency means providing the same basic ‘energy services’ (heating, cooling, motive power and so on) using less energy, through technological innovation or by improving production and conversion technologies: fuel cells, heat pumps and combined-cycle gas-turbine (CCGT) power generation, for example. Energy efficiency improvement often goes under the more humble name of energy conservation. The second way to change energy intensity, through economic restructuring, involves altering consumption and production patterns in such a way as to effect a change in the average energy service requirements per unit product. This may be the case in moving away from a resource-intensive economy to an information and services economy, for example.

In the 1970s, in the wake of the first oil crisis and in light of the ‘Limits to Growth’ debate, the first policies to reduce energy intensity were implemented, mainly in the west. At that time the main focus was on improving energy efficiency, with the key impetus coming from the notion that fossil fuels would soon be scarce, along with a desire for continued economic growth. The outcome was a series of policies designed to steer economic growth away from over-dependence on energy, with preference given to measures offering a reasonably quick return on investment.

Between 1986 and 1995 energy efficiency in the Netherlands rose on average by 1% a year (CPB, 1997). With an all-out effort, the industrialised nations might be able to boost energy efficiency by an estimated 2% annually (Van der Sluijs and Turkenburg, 1998). Over the ten-year period cited, structural changes in the Dutch economy in fact led to increased national energy demand, due in particular to the rising share of energy-intensive activities in GDP. This structural effect was 0.3% per annum between 1986 and 1990 and 0.2% from 1990 to 1995 (CPB, 1997).

For the past century global energy intensity has been growing at a rate of about 1% a year. During the economic recession that followed the first oil crisis, when fossil fuel prices were relatively high, the Netherlands managed briefly to achieve a record decrease in energy intensity: 4.6% per annum (Figure 11).

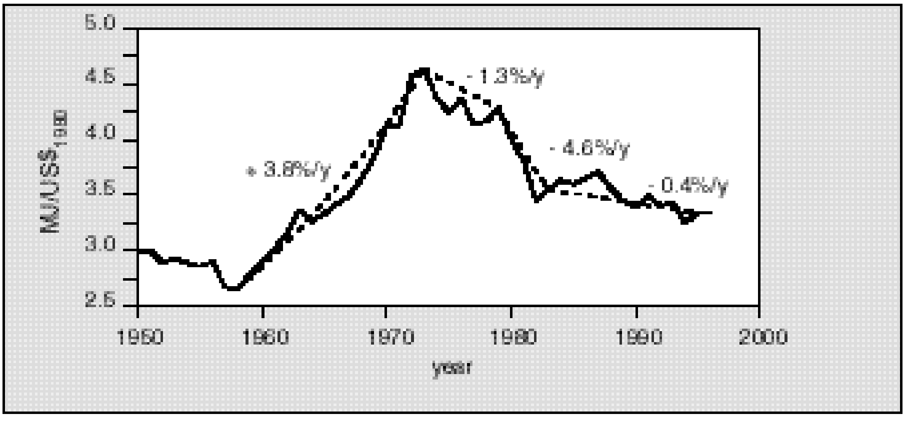


Figure 11 Dutch energy intensity initially increased between 1950 and 1973, but began to decline after the first oil crisis of 1973. (Source: Van der Sluijs and Turkenburg, 1998.)

Many improvements in energy efficiency are endogenous, new technologies generally being more efficient than the ones they replace. On the whole, then, equipment and appliance substitution will lead to greater energy efficiency. Further improvements can be induced by means of price signals and efficiency standards. Price signals, in the form of suitably high energy prices or taxes, act to improve energy efficiency by accelerating returns on investments in high-efficiency plant and equipment.

When adopting efficiency improvement as a strategy for carbon emissions reduction, due account must be taken of the fact that the resultant efficiency gains will to some degree be offset by the 'rebound effect'. As a result of energy efficiency improvement the cost price of energy services will fall, because energy consumption will decline and so too will the associated costs. Lower energy costs in turn encourage consumption, however, and efficiency improvement therefore creates a feedback loop causing a (slight) rise in energy consumption. This rebound effect is estimated to cancel out some 10% of anticipated efficiency improvements (Swigchem et al., 2000). At the policy level this can be addressed by means of a further increase in the price of energy services or energy. The latter price correction can be effectuated either by taxing energy or by deploying clean energy resources, which generally have a higher price tag than fossil alternatives.

Although energy efficiency policy was originally conceived as a response to the 'impending scarcity' of fossil fuels, it has also made a contribution to tackling climate change. The obvious question, then, is whether a more rigorous efficiency policy would not suffice to meet standing Kyoto commitments as well as the tougher emissions criteria that are likely to follow. Unfortunately this is not the case. As long as efficiency policy is constrained by conventional rates of return on investment, any gains in energy efficiency will be outstripped by continued growth of energy demand. Given the historical record, an unprecedented policy effort would be required to achieve the necessary leap in energy efficiency. Given the premature retirement of plant and equipment this implies, considerable destruction of capital would inevitably be involved. Once the rate of efficiency improvement has increased beyond a certain level, other options become more cost-effective.

One such option, already mentioned, is to increase the contribution of clean energy, as a means of reducing the overall carbon intensity of the energy supply. This strategy will be discussed in more detail in the next section. A second option involves prudent restructuring of the economy. The record shows that governments are generally unwilling to intervene directly in the economy and are indeed not always able to do so, given the intimate relationship between economic structure and the nature of modern society with all its consumer preferences. Governments do have a number of indirect tools at their disposal, however. One of these is taxation, which to date has been targeted mainly on labour and much less on energy or other material resources. Price signals are now being used increasingly to exert indirect policy leverage. A case in point is the energy tax introduced in the Netherlands as part of an effort to 'green'the national tax system. The aim of the tax is twofold: to encourage production and consumption of less energy-intensive goods and services, on the one hand, and secure price-induced efficiency improvements, on the other. A second example of indirect structural intervention - having the opposite effect - is govern-

ment expenditure on traffic and transport, which acts precisely to encourage energy-intensive transportation.
In weighing up the various policy options, cost-effectiveness and the availability of both energy resources and energy technologies are thus criteria to be carefully considered, along with a variety of other political considerations. In actual practice, then, the optimum strategy will consist of a mix of efficiency policies, structural policies and policies to reduce carbon intensity. These will be considered in further detail below.

Clean energy

The carbon intensity of the energy supply is defined as the average quantity of carbon released in converting a single unit of primary energy. Reducing carbon intensity, or 'decarbonisation', is therefore the most direct means of cleaning up the energy system, from the climate angle at any rate. Of all the carbonaceous fuels wood has the highest carbon intensity, followed by coal, oil and natural gas. Wood and other biomass resources are renewable, however, as long as the amount of biomass used for energy conversion is balanced by equivalent new biomass production, in the form of afforestation, for example. On balance, this would constitute a 'zero-carbon' energy conversion system.

A second strategy is to artificially lower the (net) carbon intensity of fossil energy systems, designing conversion systems in such a way that the carbon dioxide is physically prevented from entering the atmosphere. There are two options: elimination of the CO_2 from the flue gases once it has formed, or prior chemical conversion of conventional fossil fuels into hydrogen fuel and CO_2, with separation of the latter. The CO_2 captured in either of these processes can then be sequestered in depleted oil or gas fields or aquifers (cf. Vellinga and Van Verseveld, 1999a, among others). The 'energy carriers' yielded by these processes - hydrogen, electricity and hot water, for example - are themselves now carbon-free. Because of the minimal CO_2 emissions associated with their production, these will be subsequently referred to as 'clean energy carriers'.

Clean fossil energy

‘Clean fossil energy’is here taken to mean fossil energy accompanied by effectively zero CO_2 emissions to the atmosphere. If the CO_2 is stripped from flue gases, or conventional fuels first chemically converted to hydrogen fuel and CO_2, and the carbon dioxide injected into underground reservoirs, fossil fuels can in fact be deployed on a ‘low-carbon’ basis.

The potential for generating clean energy from fossil resources is determined by resource availability on the one hand and potential carbon storage capacity on the other. For the medium term at any rate, both appear to be ample.

Contrary to what until recently was conventional wisdom, it will be some time before fossil fuels are scarce. New reserves are constantly being discovered and technological progress means that known reserves can be exploited ever more efficiently (cf. Lako and De Vries (1999) and Lenstra (1999)). According to recent estimates by Nakićenović (1998), economically recoverable resources are more than adequate for meeting energy requirements for the rest of the century, even if demand were to surge.

Current assessments of the potential for underground CO_2 sequestration are still fairly crude. Hendriks (1994) estimates the overall capacity of depleted oil and gas fields at about 500 GtC CO_2. Additional capacity could be provided by aquifers: water-carrying rock formations deep underground. Depending on the structural geological criteria set, the total potential for sequestering carbon in aquifers is estimated at between 50 and 14,000 GtC (Hendriks, 1994). By way of comparison, the worst-case IIASA/WEC scenario assumes cumulative CO_2 emissions of 1,490 GtC between 1990 and 2100 (Nakićenović, 1998).

Underground CO_2 sequestration may thus have a substantial part to play in tackling climate change.

Non-fossil energy resources such as solar, wind, hydroelectric and nuclear contain no carbon and deployment thereof is consequently a very effective means of lowering the carbon intensity of the energy supply. With the exception of nuclear power, all these forms of energy derive ultimately from the sun, for it is solar energy that drives the climate system and wind and rainfall patterns (whence hydro-power). These sources of energy will probably come to predominate in future energy systems. Solar power in combination with efficient transmission and storage represent a particularly attractive option, from both the technical and the ecological angle. Whether technological development will be rapid enough for this option to emerge within the required time span remains to be seen, however. Underground sequestration may therefore provide a welcome breathing space in moving to a renewable energy future.

Decarbonisation of the energy supply involves a shift in fuel mix in favour of low- and zero-carbon energy sources. The switch from coal to natural gas is a familiar example. The historical record already shows a clear endogenous trend of declining carbon intensity, as Figure 12 shows. The basic motor behind this trend is the ever-growing demand for high-quality energy services, now measured increasingly in terms of convenience, efficiency and low ecological impact (Nakićenović, 1998).

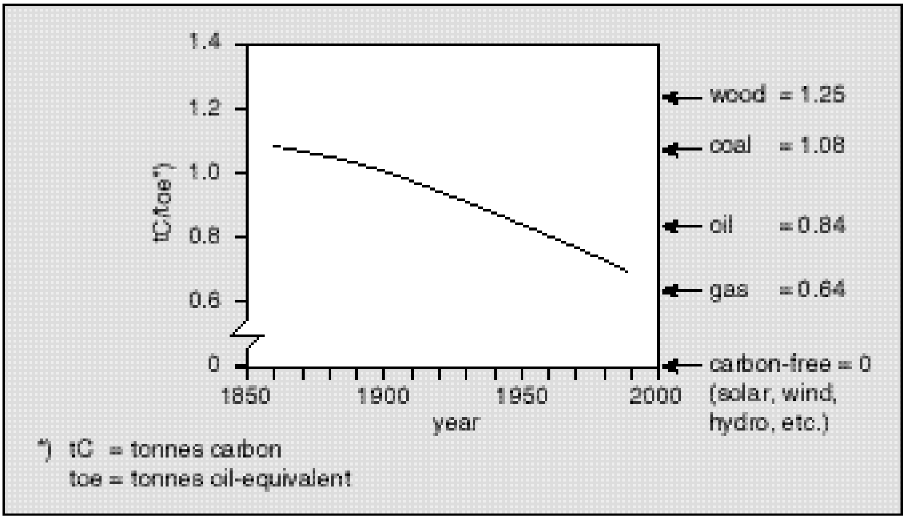


Figure 12 The carbon intensity of the world's energy supply, including non-CO_2-neutral use of biomass, has fallen on average by 0.5% a year for the past century and a half. (Source: Nakićenović, 1998.)

Clean energy, efficiency and behaviour

Once deployed, clean energy systems also contribute indirectly to improving energy efficiency and 'energy-mindedness' among both consumers and industry. As low-carbon energy is more expensive than its high-carbon counterpart, contrary to the case of energy efficiency improvement, the price mechanism now means that wider use of clean energy has knock-on benefits on the demand side. There are, in fact, three forms of positive feedback. First, the higher price of clean energy will encourage a switch to higher-efficiency plant, equipment and appliances. Second, energy users will change their patterns of purchase and usage somewhat. Consumers will cut back on purchases of energy-intensive products, for example, and spend more on services low on energy. Third, consumers will have less to spend on other goods, leading to less overall growth of consumption volume than would otherwise be the case. There is of course a second option for improving energy efficiency and energy-mindedness: by making 'dirty' energy more expensive, through taxation, for example.

Because of the positive feedback mechanisms involved, increased use of clean energy provides interesting leverage for climate policy. Besides the first-order effect of lower CO_2 emissions per unit energy, i.e. decarbonisation, clean energy also pushes up prices, encouraging efficiency measures as well as adoption of less energy-intensive consumption and production patterns generally (see box:Clean energy, efficiency and behaviour). Clean energy therefore clearly deserves a place of prominence as an instrument of climate policy. Further on in this chapter we explore the potential impact of this kind of policy, which is geared primarily towards reducing the carbon intensity of the energy supply. First, though, let us consider the physical potential for efficiency improvement and decarbonisation.

Efficiency and clean energy: what is the potential?

When it comes to improving energy efficiency and reducing carbon intensity there is no shortage of options. Based on a number of global scenario studies, Turkenburg (in Zwerver and Kok, 1999) has estimated the potential contribution of some of these up the end of the present century. For the sake of completeness, we also include the estimated potential of reforestation. It should be noted that these estimates do not indicate maximum feasible potential but are ranges within which the various measures are deployed in the different scenarios.

Table 1 There is vast potential for reducing global CO_2 emissions (relative to 'business as usual' scenarios), as illustrated here for the period 1990 to 2100 for selected options. (Source: Zwerver and Kok, 1999; updated by Turkenburg, 2000.)

Measure	CO_2 emission reduction [GtC]
Improved resource efficiency (energy and materials)	200 - 600
Reduced carbon intensity	
- renewable energy sources	200 - 600
- nuclear fission	100 - 300
- shift from coal to natural gas	0 - 200
- CO_2 capture and sequestration	100 - ≥ 300 *)
Reforestation	50 - 100

* This option may in fact offer even greater potential: 550 GtC for sealed storage in depleted oil and gas reservoirs and over 14,000 GtC if storage in unsealed aquifers is also included (Hendriks, 1994).

In the IPCC's 'business as usual' scenarios, i.e. with no additional climate policy assumed, cumulative CO_2 emissions for the period 1991 to 2100 lie between 770 and 2,190 GtC. To achieve the 450 ppmv stabilisation target, cumulative emissions over this period must not exceed 650 GtC (Houghton, 1996). Table 1 confirms that in the worst-case emissions scenario virtually all the available options will need to be employed. If emissions transpire to be lower, there will be greater freedom of choice. All the options have their benefits and drawbacks, as briefly reviewed in Table 2.

Table 2 Main benefits and drawbacks of strategies to reduce energy and carbon intensities.

Measure		Main benefits and drawbacks
Energy and materials efficiency	+	cleanest form of CO_2 emissions reduction; also reduces other impacts of energy and materials production (materials flows with attendant emission and waste problems)
	+	numerous cost-effective options
	-	customised approach often required
	-	return on investment is generally slow
	-	high 'consumer' transaction costs (compiling information, etc.)
	-	generally low priority for end users; other aspects deemed more important
Renewable energy sources	+	potentially structural solution
	+	wide public appeal (notions of sustainable, equitable future)
	+	secondary benefits (synergy), e.g. acidification control
	-	higher-priced than fossil energy (at present)
	-	new, high-potential technologies still under-developed (solar photovoltaic, biomass gasification, biofuels, etc.)
	-	land use conflicts: biomass cultivation and wind turbines
Nuclear fission	+	secondary benefits, e.g. acidification control
	-	energy intensity of uranium mining
	-	proliferation (nuclear arms)
	-	operational reliability
	-	security of waste storage
Shift from coal to natural gas	+	secondary benefits, e.g. acidification control
	+	lower investment in power plant
	-	requires gas infrastructure (still lacking in many regions, especially in Asia)
CO_2 capture and sequestration	+	relatively cost-effective, especially with fossil fuel prices low
	+	deployable relatively soon, providing 'breathing space'
	+	eases transition to renewable sources
	+	accelerates development of infrastructure for clean energy carriers (e.g. hot water, hydrogen)
	+	sometimes secondary benefits, e.g. control of acidification and gas field soil subsidence
	-	requires additional energy
	-	security of storage (e.g. risk of leakage due to fissures), requiring monitoring
	-	lacks universal appeal; seen by some as an 'end-of-pipe' measure that will hamper development of a renewables-intensive energy supply

As matters currently stand, we reject only one of these options as a strategy for addressing climate change: nuclear fission. Whether this option will merit consideration at some future date hinges largely on the solutions proposed for the problems of safety, waste storage and proliferation. Existing reactor concepts are not intrinsically safe, although there has been some progress on new technologies such as the High Temperature Reactor. There are still problems surrounding nuclear waste and proliferation for which no solutions are yet in sight. Nuclear power requires long-term social stability. Experience in Russia shows that sweeping social changes may have disastrous consequences where nuclear energy is concerned. Intrinsically safe systems that produce only short-lived isotopes are therefore a minimum requirement. As long as such systems remain unavailable or relatively expensive, deployment of nuclear power will remain politically unacceptable.

At the end of the day the basket of measures implemented will depend on their potential impact in the near to middle term, as well as on the political support they enjoy. In the more immediate future, the greatest contribution at the global level is likely to come from proven forms of renewable energy (wind, hydro, solar and biomass for power production), a switch from coal to natural gas and CO_2 capture and sequestration. From 2020 onwards new forms of renewable energy such as solar photovoltaics and new biomass technologies could well become more prominent (see respective boxes). Support for the respective options will depend on their cost, the associated environmental burden and their appeal to consumers. Today the cost factor appears to be declining in importance, with prosperous consumers increasingly willing to pay a higher price for products that are more environmentally benign or hold other appeal, with wind and solar energy in particular growing in popularity.

Biomass

Biomass plays a prominent role in global energy scenarios that rely heavily on renewables, along with solar power (Shell, 1996, IIASA and WEC (Nakićenović 1998)). Biomass can serve as a fossil fuel substitute in just about every application. It can be used to produce biodiesel, bioethanol, biomethanol, biogas, syngas, electricity, hot water and steam.When it comes to liquid fuels there are virtually no alternative renewable sources, and biomass is therefore especially important for the transport sector, particularly as it can also be readily blended with other vehicle fuels.

Today, biomass is generally used for direct power and heat generation. A concerted effort is under way to develop gasification technologies, which are more efficient as well as less polluting. In the longer term liquid biofuels emerge as an option, although in Germany, Austria and France there is already a market today.

If biomass is to play a role of substance at the global level, energy crops will have to be cultivated on a vast scale, exerting additional pressure on land use. This may be particularly problematical in developing countries, where populations are projected to rise for some time to come. Competing land claims between energy and food crop production are therefore inevitable. In Western Europe, there appear to be no spatial constraints on biomass production (or on other renewable energy sources for that matter) for the next hundred years or so (Nakićenović 1998).

Solar power

Energy scenarios that assume vigorous policy support for renewables show steady growth in the share of solar (photovoltaic) power from 2020 onwards (Shell, 1996, IIASA and WEC (Nakićenović, 1998)).This contribution reaches the 10% mark by 2050 and may be as great as 40% by the end of the century As solar photovoltaic systems (‘solar panels’) can generally be integrated in buildings and structures, they imply no additional land requirements. If all Dutch rooftops and wallswere to be fitted with solar panels, some 85 to 105 TWh of photovoltaic power could be generated by 2010, depending on technological progress. Based on optimistic assumptions of cost and efficiency, 60 TWh could be generated for less than US$ 0.13 per kWh (Bergsma et al., 1997). With the forecast for Dutch electricity demand standing at some 120 TWh in 2010 (Sep, 1996), between 70 and almost 90% of demand could then therefore be supplied by solar photovoltaics, representing about 10% of overall Dutch energy use. Given the variability of incident solar radiation, generation of solar power on this scale would require co-development of extensive energy storage facilities.

Before it can become a factor of significance, solar photovoltaics must progress along a number of learning curves. Before the technology is implemented on any major scale prices must fall substantially, which can in turn only be achieved through large-scale manufacture of solar panels. In the absence of a market, large-scale production will not be taken to hand, however. Pro-active government policy, in the form of subsidies, can play a key part in creating such a market, giving serial production the kick-start it needs. According to a recent survey by McKinsey consultants, the price of solar power would drop from about US$ 0.60 to 0.15 per kWh if production were scaled up to 500 MW peak capacity. Once learning curves start to pay off, after about six years, subsidies could be withdrawn (McKinsey, 1999).These figures do not include the cost of power storage, required if fluctuations in incident solar radiation are to be balanced out.Without such storage, power supply would temporarily have to be taken over by grid facilities using conventional or biofuels.

A low-carbon energy supply for the Netherlands

In this section we examine the potential impact of a strategy geared primarily towards reducing carbon intensity that at the same time achieves a significant reduction of energy intensity. We do so with reference to the Netherlands, examining how the energy system of this country might evolve if carbon emissions had to be reduced by about 75% over the next 50 years. In developing this scenario, for simplicity’s sake we assume that other Western countries adopt similar targets, timetables and strategies. Clearly, there are many paths to a low-carbon energy supply, depending on a wide variety of factors, some of them endogenous, others to be decided on in the political process. It is not, therefore, our intention to lay down some sort of blueprint for an ideal energy supply. Our main aim, rather, is to provide a thumbnail sketch of a possible strategy, as an aid to calculating the cost of switching to a low-carbon energy supply. A proper understanding of cost issues is essential if the right decisions are to be made when it comes to the key question: given the risks associated with climate change, are we prepared to accept the cost of a clean energy supply?

The scenario explored here is based on several key assumptions. The first is that all cuts in carbon emissions are achieved in the Netherlands rather than abroad. This is because we are interested in the long-term picture. Ultimately, all western countries will have to achieve the same 75% cut-back in emissions, even though a major proportion may be internationally traded in the near to medium term, as discussed in Chapter 3. As a result, emissions reduction may prove less expensive than the estimate below indicates.

In the second place, we have opted for a 'hybrid'scenario combining energy efficiency improvement, fossil energy with carbon sequestration ('clean fossil'), renewable energy and behavioural change. We have selected emission abatement strategies mainly on the basis of current cost-effectiveness, i.e. seeking maximum impact at lowest possible cost. As a result, the price tag associated with the scenario described here can be regarded as a lower limit to the cost of securing the emissions reduction sought. According to present understanding, that is, for if priority were given to criteria other than cost-effectiveness, the bill might well prove higher. Given technological progress, however, the actual cost is almost certain to prove lower.

Third, and last, the principal focus here is on supply-side changes in the energy market, and more specifically on decarbonisation of the energy supply. Indirectly, however, there will also be an impact on the demand side, in the form of price-induced efficiency improvements and ditto structural change (lifestyle/purchasing behaviour).

Of these assumptions, the criterion of cost-effectiveness is perhaps the most controversial, the fear being that expenditure might become the sole yardstick for a low-carbon energy supply. Of course this is not the case. A whole range of other factors are also involved, not least of which are public acceptance and appeal. Solar power, for example, appeals to a basic instinct that sooner or later we shall have to adopt energy systems based entirely on renewables. Such mechanisms are not captured by the notion of cost-effectiveness, which if taken as the sole criterion would mean simply implementing the cheapest options – as currently understood – regardless of any other perceived benefits or drawbacks. We refer once more to Table 2. It is not our wish, however, to launch an in-depth debate on the pros and cons of the various individual options. Our prime aim here is to arrive at an approximate estimate of the overall cost to society of rising to the challenge of climate change, and for that task the criterion of cost-effectiveness is eminently suited. It is not the sole criterion, though, and it should be borne in mind that the low-carbon energy scenario presented below is not the only conceivable strategy.

Our scenario embodies a phased transition to a clean energy supply, i.e. one based on carbon-free end-use energy carriers produced with low-to-zero CO_2 emissions, such as to ultimately reduce carbon emissions to about one-quarter of current levels. In concrete terms the envisaged supply system is based on the following final energy carriers: electricity, hot water, steam, hydrogen, biogas and biofuels like biomethanol, bioethanol and biodiesel (biogas and biofuels 'carbon-neutral'in production). These can be produced by many alternative routes, creating a system flexible enough to bootstrap substantial CO_2 reductions in the short run and give a major initial impulse to the transition to a low-carbon energy supply.

From the perspective of climate control, the necessity of switching to carbon-free energy carriers derives from the fact that current CO_2 emissions emanate largely from a multitude of diffuse sources like motor vehicles and buildings (see, for example, Rooijers et al., 1996). In the Netherlands electricity, natural gas, petrol, diesel and, to a limited degree, hot water and steam are the main energy carriers currently used. For final users, the transition to a low-carbon energy supply will primarily entail a phase-out of natural gas, petrol and diesel fuels. The first of these can be readily replaced by other gaseous fuels such as hydrogen and biogas, and in some cases services currently provided by gas can be taken over by other fuels. Space heating and hot water production, for example, can already be taken over by electrical heat pumps. In the case of petrol and diesel vehicle fuels, biomethanol and biodiesel are proven substitutes, while for electromotive traction, biofuel- or hydrogen-charged fuel cells are also a practicable option.

We now flesh out the basic thrust of our scenario. Proceeding from the Dutch energy supply as it now stands, the selected measures are introduced in three phases; see Table 3. The actual development path may obviously prove very different, depending on emerging social preferences and technological and economic trends. It may well be the case, for instance, that more expensive options such as solar are deployed sooner than expected, anticipating the major cost reductions to be achieved in the medium term.

Table 3 Phased introduction of a low-carbon energy supply in the Netherlands through to 2050 (baseline: 2000).

Period	Additional measures
2000-2010	investments up to US$ 50 per tonne of CO_2:
	- energy efficiency - wind energy - district heat - CO_2 storage at hydrogen production plant
2010-2020	investments up to US$ 100 per tonne of CO_2:
	- energy efficiency - wind energy - district heat - cogeneration, part biomass-fired - CO_2 sequestration at fossil fuel facilities (power stations, hydrogen/methanol plant)
2020-2050	investments up to US$ 150 per tonne of CO_2:
	- energy efficiency - biomass-based fuel production - substitution of natural gas by electricity and hydrogen for small-scale users

In line with most global energy scenarios, it is not before about 2020 that renewable sources start to make a sizable contribution. Their subsequent contribution will be largely in the form of modern biomass-fired cogeneration plant (i.e. combined heat and power generation) and biofuels. Because of the prominence given to the criterion of cost-effectiveness, solar photovoltaics play a negligible part in our scenario. If other criteria were given greater priority, the picture would probably be different. With time, moreover, solar technologies will benefit from learning curves, increasing their cost-effectiveness. Among large corporations Shell, for one, is convinced of the case and is already investing in solar cell production capacity. However, even if the cost price plummets to US$ 0.15 per kWh - not unfeasible in the near future according to McKinsey consultants (1999) - solar power remains a relatively expensive means of controlling carbon emissions: about US$ 400 per tonne of CO_2 avoided.

The costs of clean energy carriers and energy efficiency improvements have been calculated from the supply cost curves shown in Figure 13, adapted from Beeldman et al. (1998) and Williams et al. (1995). All calculations are based on an oil price of US$ 20 per barrel.

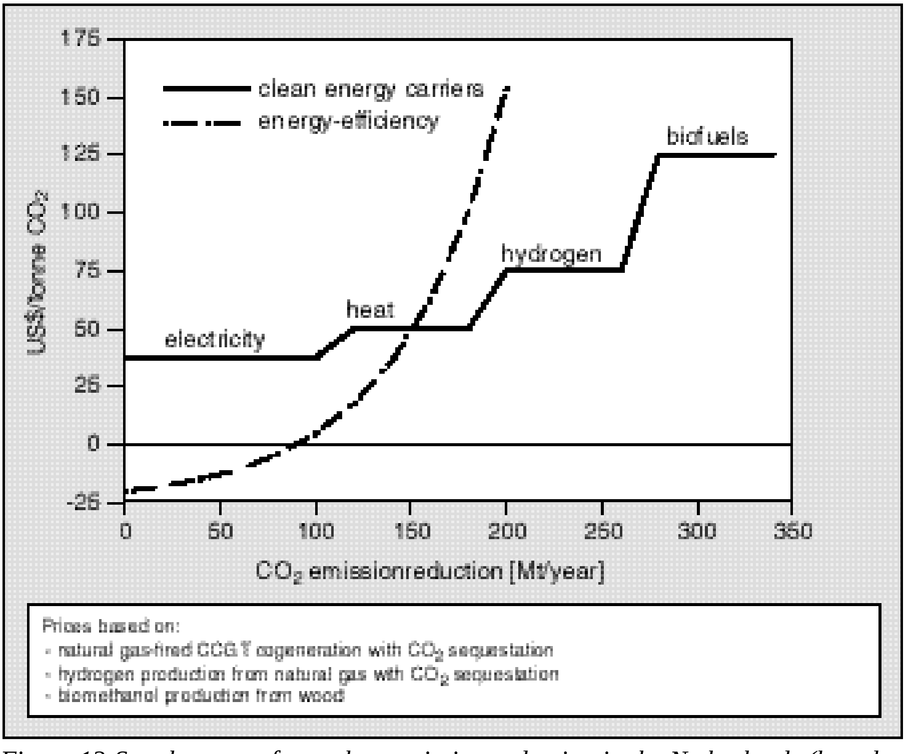


Figure 13 Supply curves for carbon emission reduction in the Netherlands (based on an oil price of US$ 20 per barrel) show that above about US$ 75 per tonne CO_2 avoided, clean energy carriers are more cost-effective than further efficiency improvement. (Source: Beeldman et al., 1998; Williams et al., 1995.)

All costs are assumed to remain constant throughout. No consideration is given to measures costing over US$ 150 per tonne of CO_2 avoided. The costs assigned to the various measures are based on current understanding, with no allowance made for learning curves. As a result, actual costs may ultimately prove to be 30 to 50% lower. Abatement costs are highly indexed to prevailing fossil fuel prices, moreover. If the oil price rises above US$ 20 per barrel, the figure assumed here, efficiency measures and renewable sources will become relatively cheaper. If prices fall, on the other hand, so too will those of clean fossil energy carriers.

In the early phases of the scenario, with emerging technologies still immature, the cost estimate presented here can certainly serve as a useful guideline. Further into the future, though, it will probably be on the pessimistic side. With time, moreover, other options currently assumed to be prohibitively expensive - in particular solar power - will also come into their own.

We have thus calculated the cumulative cost of a 75% cut-back in Dutch carbon emissions, to be achieved in phases by the year 2050 (relative to 2000 levels), thereby assuming implementation of 'post-Kyoto policy'starting in 2015. There are two basic cost categories: the immediate expenditure associated with production of clean energy carriers and the cost of endogenous and price-induced efficiency measures. Figure 14 shows the share of the various policy strands as well as that of price-induced and endogenous structural change. We hereby assume 3% economic growth through to 2050, 0.5% endogenous energy efficiency improvement and 0.5% endogenous structural change (all per annum), and energy efficiency and structural change elasticities of minus 20% and minus 10%, respectively. (The elasticity of a given quantity is the amount by which it changes relative to a change in another quantity such as price.)

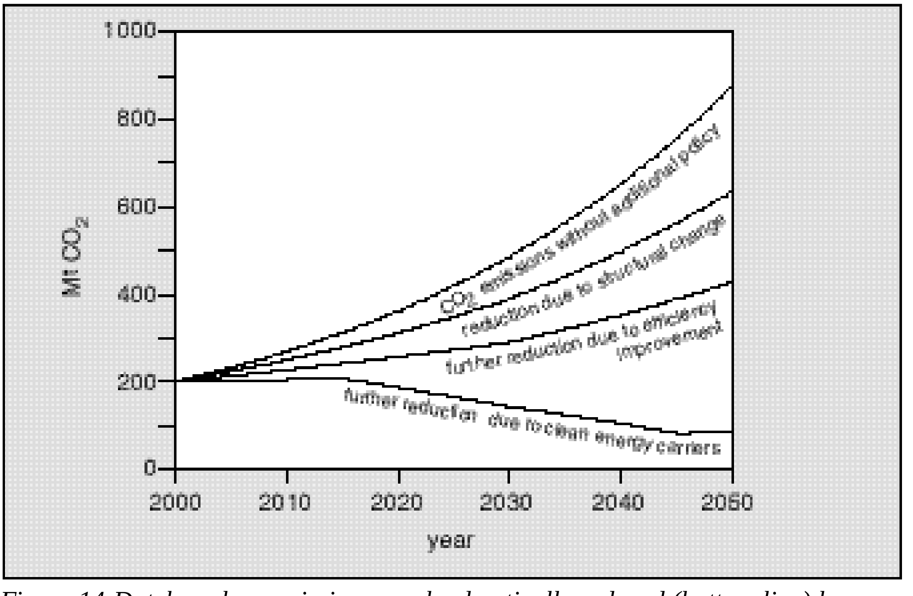


Figure 14 Dutch carbon emissions can be drastically reduced (bottom line) by a combination of means: efficiency improvement, structural change and clean energy.

As Figure 14 shows, the emissions avoided by reducing carbon intensity are virtually equalled by those due to a reduction of energy intensity (structural change plus improved efficiency). Structural change as well as the bulk of efficiency improvement are price-induced, the result of deploying more expensive clean energy sources. Using the cost curves and the carbon emissions trend of Figure 14, we can now calculate both the absolute and relative cost of the envisaged reduction in carbon emissions. The absolute costs are shown in Figure 15.

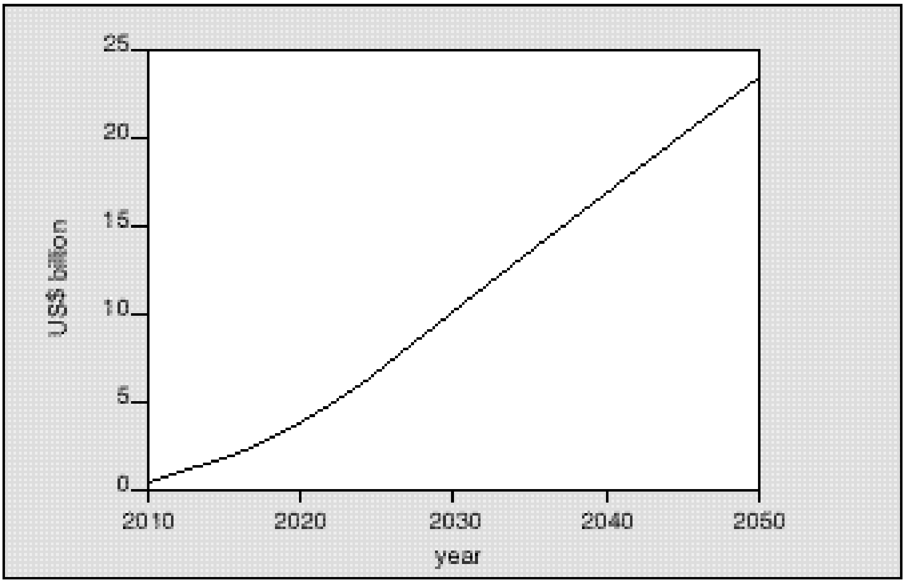


Figure 15 The estimated annual cost of achieving a 75% reduction in Dutch carbon emissions gradually increases (time horizon: 2050). All reductions are implemented domestically.

It should be noted that although the cost of CO_2 abatement indeed rises significantly over the years, this increase is only modest in terms of relative expenditure. Assuming 3% annual growth of GDP, by the year 2050 Dutch national income will have risen to 340% of the present figure. In terms of the relative share of national income, then, the additional cost of limiting carbon emissions to a quarter of present levels will be less than 2% of GDP. It should also be noted once again that our cost estimates are on the conservative side, so that a figure of between 1 and 2% of GDP is a more reasonable projection. By way of comparison, in 1997 final energy expenditure in the Netherlands (incl. refining, transport, distribution, levies, duties, VAT, etc.) stood at about US$ 35 billion (CBS, 1998). This is approximately 12% of the Gross Domestic Product.

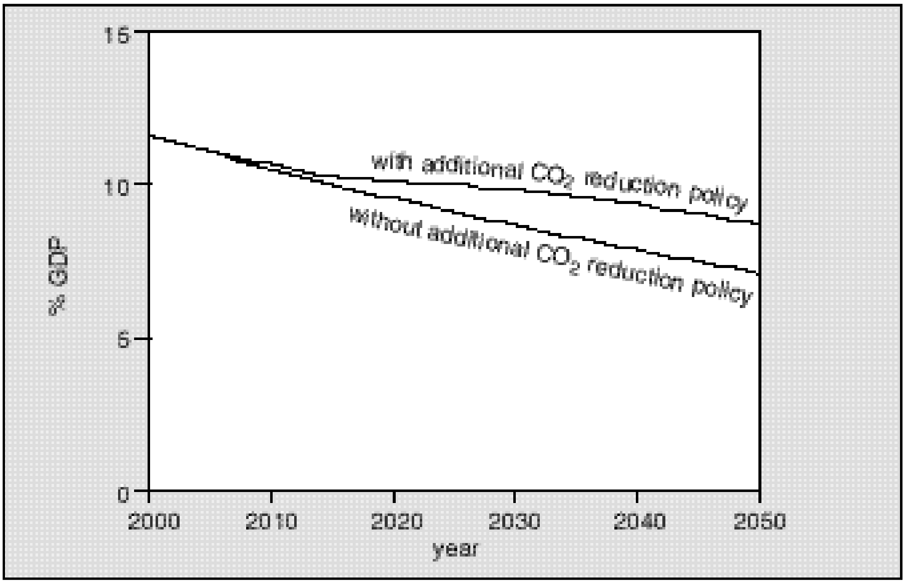
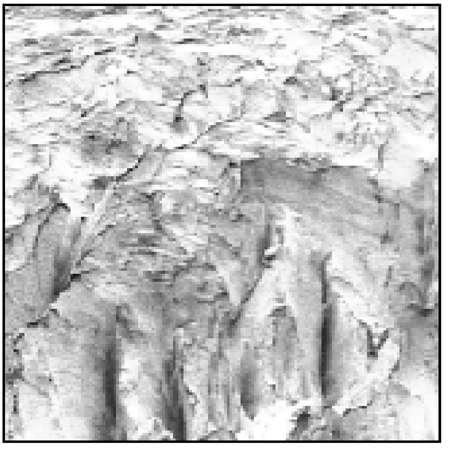


Figure 16 Estimated Dutch energy costs (incl. transport, distribution and taxes), with and without additional climate policy (relative to 1990) as a percentage of GDP in 1997 market prices.

If the full cost of CO_2 abatement is passed on to users, end user prices will rise by about 20%. As a percentage of GDP, however, energy costs will continue to decline, since GDP growth outstrips the growth of energy consumption.

The essential message of the scenario described here is that far-reaching, integrated climate policy is feasible at only limited additional cost relative to rising GDP. By means of a phased restructuring of the national energy supply, energy-related CO_2 emissions can be reduced dramatically. The transition to clean energy systems will not proceed of its own accord, however. Society will have to come to a decision on how to tackle the climate issue and then shoulder the consequences: a rise in energy prices, which will influence production and consumption patterns and reduce income *growth* slightly relative to ‘business as usual’.

Our scenario exercise shows that effective progress on climate policy calls for decisive choices to be made. The key question is whether we are now willing to embark on a large-scale transition to a low-carbon energy supply and shoulder the attendant costs - which, given the task at hand, are in our view rather modest.



5 Dutch climate policy

Dutch climate policy in an international context

The previous chapters examined the kind of global action required to address climate change, arguing the case purely 'on principle'. However, the strategy embodied in our low-carbon scenario will only succeed if adopted by a majority of the world's countries. Does that therefore mean that the Netherlands should simply sit and wait until such time as an international policy on climate change emerges? Not at all, for the Netherlands can play an active role in the international arena. Given the long haul ahead in combating global climate change, this final chapter outlines what we consider to be the best strategy for Dutch industry, consumers and government.

On its own, the Netherlands will clearly not be able to achieve the sort of sweeping overhaul of its energy system envisaged in the previous chapter. In this respect technological progress on the demand side constitutes one of the main constraints. Our scenario presupposes further maturation of hydrogen technology, for example, as well as development of appliances and vehicles that are considerably more energy-efficient than today. If these technologies are to be successfully deployed, a dedicated international R&D effort must be initiated and global markets created. International collaboration will also be needed when it comes to practical implementation of energy and materials efficiency programmes and renewable energy technologies.

The Netherlands obviously cannot go it alone and even if we could our country's contribution would be a mere drop in the ocean. With a share of just under 1% in global carbon emissions, even if the Netherlands were to adopt a carbon-free energy supply tomorrow it would make little difference. If climate change is to be effectively tackled, energy systems must be transformed at the international level. This is practically feasible, as we have demonstrated. There will be regional variations, of course, reflected mainly in the choice of primary energy sources. In South America, for example, greater use will be made of renewable resources like biomass and hydro-power, although the same final energy carriers will largely be used as here in the Netherlands. Rural areas with no connection to the electricity grid, by contrast, will benefit most from application of stand-alone solar photovoltaics. These and similar developments are in line with the energy future charted by IIASA and WEC (Nakićenović, 1998), independent of any climate policy: convergence towards a limited number of clean and convenient final energy carriers and use of a broader range of primary energy sources.

It is also conceivable that certain regions will develop into exporters of 'clean' fuels: biofuels from Latin America, for example, or hydrogen from Russia, Norway and other countries endowed with natural gas. In the second case, the carbon dioxide stripped at hydrogen production facilities could be stored directly in the underlying gas reservoirs as they are depleted.

If the process of overhauling energy systems is taken to hand on an international scale the overall cost of transformation will be considerably lower than the estimate given in Chapter 4, for two main reasons. Economies of scale will lower the cost of manufacturing technologies for efficient equipment and appliances as well as the price of clean energy carriers. Secondly, the possibility of international carbon emissions trading will enable more cost-effective solutions to be adopted, as discussed in Chapter 3.

Effective climate policy thus requires a coordinated global strategy. On the one hand, more vigorous commitments must be made on emissions reductions by all parties, although responsibilities will differ from country to country. On the other hand, there is a need to collaborate internationally on the development and deployment of appropriate technologies. The best way the Netherlands can contribute to global climate policy is therefore to make an all-out diplomatic effort to ensure that tougher and more comprehensive international arrangements are adopted.

What then should be the scope and substance of such arrangements? And how is a national strategy to be fleshed out that encourages public acceptance of tougher climate policy while at the same time satisfying criteria of effectiveness and cost-efficiency?

Taking the lead in international negotiations

If climate change is to be effectively addressed existing international agreements must be elaborated and strengthened. The most valuable contribution the Netherlands can make, preferably in collaboration with the European partners, is to make vigorous efforts to secure a more stringent and comprehensive international climate accord. More specifically, the Netherlands should seek to fill in the various Kyoto 'voids', actively champion a multi-track global climate policy and lead by example in the realms of technology and policy development.

Leading by example will have little or no direct impact on the actual process of climate change, it is true. However, what the Netherlands can do by putting policies into practice is demonstrate that carbon emissions can be drastically reduced at fairly modest cost (as shown in Chapter 4). By pursuing such a path, the Netherlands would help create a platform for tougher international agreements, in turn increasing the credibility of a strong, forward-looking Dutch position in the international climate negotiations. It might also move other countries to come down off the fence, especially when Dutch industry is seen to be reaping the first-mover rewards. Indirectly, then, the Netherlands can contribute very tangibly to securing tougher emissions reduction targets for the period following 2012, when the terms of the current Kyoto Protocol elapse.

Another way in which the Netherlands might help improve the effectiveness of international carbon abatement policy is by exploring and elaborating the trade-related aspects.

Public support

Public acceptance of tougher climate policy implies a need for a broad public debate. This is especially true in industrialised countries like the Netherlands, where the most drastic emissions cuts are required. Such a debate should seek clarification of two basic issues. First, the risks involved in climate change are anything but negligible. Second, these risks are manageable and the overall cost to society is relatively modest. Both positions have been plausibly argued here.

Technology provides the most tangible leverage point for cutting carbon emissions: technology policies are effective and provide an indirect means of influencing consumer behaviour. Clean energy, being more expensive, provides an indirect incentive for more energy-efficient patterns of consumption. While the price effect thus leads to less energy being used, the income effect will cause a slight decline in the growth of disposable income, and thus to reduced growth of final energy demand. This loss of disposable income would amount to 1 or 2% of Gross Domestic Product, with GDP itself scheduled to increase by nearly 340% over the next 50 years.

To widen public support for tougher climate policy, this message will have to be spelled out frankly and clearly. These are simply the costs that will have to be incurred to safeguard present and future generations from the risks of climate change. With policy efforts geared mainly to technology rather than directly to consumer lifestyles, the Netherlands' principal contribution to combating climate change will consist in the willingness of Dutch citizens to pay this extra price. Provided the envisaged transition is pursued in properly balanced fashion, there will be no justification for the sour taste of pecuniary conscience-salving.

National carbon abatement: the policy leverage of clean energy

An international climate strategy anchored in the Kyoto scheme implies allocation of emission rights at country level. How these are to be used is a matter for national discretion. Given an international system of tradable emission permits, economic considerations dictate that the international trading price be taken as the main guiding principle of Dutch climate policy. This should be more than just the short-term trading price, however. The future price trend anticipated is just as important, as is a need to minimise overall economic risk. In terms of risk management, climate policy will be very similar to the energy policy pursued in the wake of the oil crisis, the key question being: what share of emissions reductions is the Netherlands to implement at home and what share is to be procured abroad by means of permits trading?

Let us assume that a stringent emissions budget has been enforced in the Netherlands, as well as elsewhere. What, then, should be the principal contours of Dutch national policy?

It would comprise elements both old and new, the main innovation being solid incentives for wide-scale introduction of clean energy. Not only would this effectuate a 'decarbonisation' of the energy supply. Because of the attendant rise in energy prices it would also boost resource efficiency and set the country on a course of socio-economic development that is less energy-intensive. With time the materials- and energy-hungry consumption patterns of today might be superseded by lifestyles geared more to the consumption of services. Other scenarios are also possible.

Government policy for achieving the set targets should be restricted to setting the terms of a level playing field, using the policy instruments available for that purpose. The actual strategies employed for securing these targets can then be left to the creativity of the market, thereby encouraging both cost-effectiveness and innovation. There is an array of policy tools available for this purpose, and to these we shall now turn.

Progressive product standards

As a policy instrument, standards are particularly effective in situations involving low price elasticity, high transaction and information costs and a latent demand for environmentally friendly products that is not reflected on the supply side. In the present context product standards can be usefully employed to improve both the energy and the carbon efficiency of consumer goods, and the same holds for energy carriers too. Standards could be introduced for dwellings, domestic appliances, passenger cars and freight vehicles, for example, and if these were progressively tightened it would allow industry to anticipate the market. With respect to energy carriers like electricity, heat and vehicle fuels, there are two alternative criteria for benchmarking: maximum carbon content (average carbonemission per kWh, for example) and minimum embodied renewable energy content. If so desired, provisions could also be introduced allowing compliance with standards to be secured by means of tradable 'eco-certificates' or carbon emission permits. Consideration might also later be given to introducing materials standards in order to achieve a progressive decline in materials consumption per unit product.

Tradable carbon emission permits or taxes

Economic instruments like tradable emissions permits and taxes are appropriate in situations involving bulk consumers who are adequately informed with regard to alternative options. One way of limiting the emissions associated with overall Dutch energy consumption would be to introduce a national scheme of tradable carbon emission permits for the entire energy sector, with producers and importers being required to secure emissions permits for the fossil carbon content of the fuels they market. This kind of carbon trading scheme has already been introduced at the corporate level by several large companies including Shell and BP Amoco.

Some consumers are prepared to pay more for cleaner products of their own accord, one example being 'green power', i.e. electricity generated from renewable sources. A recent survey conducted at the request of the Dutch environment ministry (Weenig et al., 1998) moreover indicates that some consumers would likewise be willing to purchase 'climate-compensated'products (see box below). As with green electricity, then, there is also a potential market for environment-friendlier consumer goods. Climate-compensated products are virtually unavailable at present, however, and manufacturers therefore need an incentive to kick-start the process. The same kind of policy instruments could be employed for this purpose as for renewable energy technologies: investment tax credits and other fiscal incentives such as (part–) exemption from carbon/energy taxes ('ecotax') and environmental accreditation and labelling schemes.

The market for 'climate-compensated' products

A survey was recently commissioned by the Dutch environment ministry to assess the extent to which consumers are willing to pay more for 'climate-compensated' products, i.e. products with embodied carbon emissions that have been offset by emissions reductions purchased elsewhere.
A representative sample of respondents were asked to indicate the maximum extra price they would be prepared to pay for climate-compensated petrol, gas and electricity. The results are shown below in US dollar cents.

Climate-compensated product	Average maximum acceptable price rise (US dollars)
Petrol	14 cents per litre
Gas	6 cents per m^3
Electricity	4 cents per kWh

The survey also revealed that 30% of consumers declared themselves willing to pay at least the equivalent of 9 dollar cents more for a litre of climate-compensated petrol. In terms of the implied cost per tonne of compensated carbon emissions, acceptable price rises for natural gas and electricity were found to be similar. This means that an estimated 30% of consumers are effectively willing to pay US$ 25-50 towards a tonne of carbon dioxide abated and that there is consequently a potential market for climate-compensated products.

Green tax reform

Environment-based taxes are an effective incentive to reduce emissions. One example is the carbon/energy tax, or ecotax, recently introduced in the Netherlands for domestic users and small businesses. If set sufficiently high, this kind of tax can make clean energy carriers competitive with fossil alternatives. The Dutch government should therefore increase the rate of this carbon/energy tax and extend it to cover all sectors, i.e. including industry. Imposition of an ecotax on export industries would require international collaboration.

…

The Netherlands should pursue introduction of these policies at the European level, too. Given the emerging liberalised European energy market, implementation of product standards certainly requires legislation at the European Union level. At present the Netherlands can only set quality standards for energy supplied to energy users connected to a Dutch electricity or gas grid (a certain percentage of renewable energy, for example). A system of product standards allowing requirements to be set at the product level (biomass sourced in sustainable production forests, for example) and the carbon content level would be the best approach.

A final plank in an effective climate policy should be to eliminate all standing policies that encourage energy-intensive practices and lifestyles. There exist a broad range of government subsidies that are environmentally damaging in one way or another. As a recent inventory of ‘climate-unfriendly’ subsidies in the Netherlands shows (Bleijenberg et al., 1998), many of these subsidies are indirect, in the form of tax exemptions or reduced tax rates, as exemplified by the VAT exemption for air tickets and the ecotax exemption for bulk energy users.

Arrhenius vindicated: a postscript

Jan Paul van Soest

At the end of 1999 a storm of unprecedented ferocity carved a path of destruction across France. Two-thirds of the country was declared a disaster area. Over the past decade the incidence of extreme weather events has risen sharply and so too has the ensuing damage. The final decades of the twentieth century were the warmest of the millennium. Although these signs may not be irrefutable proof of the enhanced greenhouse effect, they all certainly point in that direction. Scientists are increasingly convinced that mankind is at least partly to blame for the changes currently occurring in the planet's climate, with patterns of energy use making a major contribution. These changes bring with them a growing risk of grave and irreversible disruptions of economies, ecosystems and communities. The Swedish physicist and chemist Svante Arrhenius first drew attention to this issue at the end of the 19th century. A hundred years on his concerns have proven all too justified.

With the knowledge and understanding we have today there are numerous reasons to be concerned about what we are doing to the planet and thus to ourselves and our children and grandchildren. What is perhaps even more disturbing, though, is the fact that climate change is at present scarcely a debating issue among politicians or the public at large. We have, of course, come a long way since 1896. A conference is now held every few years and such was indeed the case in Kyoto in 1997, but even the agreements-on-principle reached on that occasion are proving extremely hard to implement. To my mind the chances of our actually securing the Kyoto targets are in fact fairly slim. Learned debates and symposia on climate change are also organised with reassuring regularity, in the Netherlands as elsewhere. These are generally attended by a relatively select circle, though, and are therefore far removed from the world of ordinary citizens. I truly wonder whether the community at large is sufficiently aware of the risks we are presently running. These are risks we would rather not face up to. At the same time we certainly cannot afford to wait another hundred years before finally intervening.

Although we can only speculate as to why we continue to ignore these risks, it probably derives from a fear that if we decide to really tackle the problem we shall have to forfeit a significant measure of our current prosperity. In terms of human psychology there is nothing easier than ignoring a problem if you are uneasy about its solution.

This booklet spells it out it terms loud and clear. Additional climate policy is absolutely necessary, it is feasible in both technological and policy terms, and the projected cost is quite reasonable. The risks of climate change can be mitigated, but there is a price. To effectively address the problem will require earmarking one or at most two per cent of national income for the purpose. A sizeable sum of money, to be sure, but not exactly the return to the Stone Age some people seem to dread.

Here we have the crux of the matter. Given the risks embodied in climate change, are we prepared to devote this sort of annual budget to resolving the problem, or do we conclude that the medicine is worse than the complaint? This is the key question that must be addressed in the public and political debate we so urgently need.

With minds thus focused, there are several additional questions to be considered. The first concerns the power of technology. Technologies have enormous potential, it is true, but the required technological advances will only be made if there are policy incentives for doing so. Are we willing to implement such policies? And are we then also willing to accept the knock-on effects: certain economic consequences and lifestyle changes due to the higher price tag on clean energy? From the perspective of climate policy these effects will be purely beneficial, it may be added. There is a second question concerning technology. Every technology has its side-effects, and these are frequently unanticipated. As we are now aware, technologies can impact upon social relations, cultural patterns, the natural environment, attitudes and views and a lot else besides. In his book ‘Why things bite back’ Edward Tenner describes many superb, sad and surprising examples. The potential side-effects of underground carbon dioxide sequestration and large-scale use of biomass have still been insufficiently examined, for example. And unexpected consequences are by definition unamenable to study. Should apprehension about the foreseeable and unforeseeable side-effects of energy sources like biomass and decarbonised fossil fuels prompt us to adopt a cautious attitude and seek policy leverage elsewhere? And what then is the alternative?

This brings us at once to a second cluster of issues: the availability of alternative areas for policy leverage, in particular population (growth) and the structure and volume of the economy, as reflected in Gross Domestic Product. These issues have purposely been left aside in this booklet, and for good reason. Debates on population growth can go on indefinitely, without offering any perspective for action, and frequently deteriorate into useless bickering. Discussions about GDP unfortunately exhibit a similar tendency, all too often ending in such banalities as “You can’t stop progress” or “A desire for rising income is simply human nature” or “The only way to save the planet is through moderation”. And such discussions indeed help us little further.

Issues like these can be approached and discussed in other ways, however, and one possibility is the analytical line taken by the Energy Policy Platform in this booklet. My personal view is that the political and public debate would gain impetus from a broad discussion of such issues. I also think it would put the general thrust of the proposed technological solution in a clearer perspective. Pursuit of an overall shift in economic structure might well be a more effective strategy, for example - and I stress the word ‘might’, for I have no idea in advance whether it would be - which is more in line with social preferences and that thus proves ‘cheaper’than technological measures that might ultimately cost say US$ 150 for every tonne of carbon emissions avoided.

The third issue is arguably the most fundamental of all. It is the environmental damage, in the widest sense, that is being inflicted by our ever-expanding economy.

Energy is the driving force of the economy. It is energy that enables us to pump such enormous and ever-growing quantities of materials round the economy, with all the various impacts implied along the product chain. Is this a sustainable development path, or is there a point at which the process must be halted?

Perhaps the final issue is the role of emotions and in particular the desire of individual citizens, groups and businesses to help shape solutions. In the vision set out in this booklet, the problem is resolved on behalf of, rather than by, the population, by providing alternative forms of energy. Is this indeed the best way to proceed, or should there be more scope for personal involvement and individual perspectives for action?

To my mind these issues should be brought up for debate and the Energy Policy Platform would perhaps do their Dutch name true justice if besides 'reflection on energy policy'they encouraged greater reflection on demographic, economic and emotional issues as well. I would therefore very much like to see a sequel to this booklet in which these and similar issues are addressed.

Let me hasten to add, though, that the above remarks in no way detract from the enormous value of this publication as a catalyst for debate. I offer them merely by way of 'instructions for use'. This booklet provides an excellent springboard for the public debate proposed by the Platform and although the ins and outs of such a process are still unclear, there can be no doubt about its necessity. And the question could not be voiced more clearly. Which is worse: climate change or the remedy, considering all the risks and the ultimate cost of managing them? It is this question that must be give absolute priority on social and political agendas. Unlike Arrhenius before us, we cannot afford to wait another hundred years before recognition of the problem is finally translated into a willingness to act.

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