Climate change: causes, consequences, and solutions

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Scientific background to the on-line platform Climate Quest

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Background document

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Further information on this study can be obtained from the contact person Rens Kortmann.

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Solutions for environment, economy and technology

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Foreword

Climate change is an urgent and complex problem of concern to people across the world. This report provides scientific background to Climate Quest, an on-line gaming portal for young people and teachers designed to raise awareness about climate change and promote solutions to the problem.

Climate Quest was commissioned by UNESCO, the United Nations Educational, Scientific and Cultural Organisation. The project was coordinated by Games Factory Online.

The following organisations participated in the development of Climate Quest (in alphabetical order):

- Alterra - Wageningen University and Research Centre.
- CE Delft.
- Games Factory Online.
- Goal 043.
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- Limburg Provincial Executive.
- RPS.
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Rens Kortmann
Edgar Peijnenborgh
Judith Harrewijn

Contents

Summary

Human activity is changing the Earth's climate. The good news, though, is that climate change can be effectively tackled without any serious threat to economic growth. The on-line gaming portal Climate Quest explains how this can be achieved. On this platform, young people can learn about climate change and what they themselves can do to limit it and adapt to a changing world. This report sets out the platform's scientific underpinnings.

Climate change
The United Nations' authoritative Intergovernmental Panel on Climate Change (IPCC), which brings together hundreds of scientists from all over the world, recently confirmed once again the relationship between human activity and climate change: human emissions of so-called greenhouse gases are reinforcing the Earth's natural greenhouse effect and causing atmospheric temperatures to rise. The main cause of climate change is the burning of fossil fuels, a process necessarily accompanied by release of the greenhouse gas carbon dioxide (CO_2). Other key greenhouse gases include methane (CH_4) and nitrous oxide (N_2O), deriving mainly from farming activities.

By the end of the 21st century the IPCC expects the planet's temperature to have risen by between 1 and over 6 degrees Celsius. Some parts of the Earth will face worse droughts than they do today, while elsewhere it is additional rainfall that is likely to be the problem. Sea levels may also rise by as much as half a metre or more. This will all have major consequences for the natural environment, the economy and human welfare. According to some researchers, the resultant costs may total as much as 20% of global income. If measures are taken to limit climate change, according to the IPCC global income will grow slightly less fast between now and 2030 than if nothing is done (by less than 3 percentage points). In ideal circumstances, this means the worst climate problems can be avoided by sacrificing just one year's economic growth.

Causes and mitigation solutions
Between 1970 and 2004 global emissions of greenhouse gases rose by 70%, mainly as a result of rising energy consumption. The CO_2 emissions of electrical power stations, factories, motor vehicles, homes, offices and other sources grew even greater: by 80%. Developed countries are responsible for half the world's CO_2 emissions. While the share of emerging economies like China and Latin America in global CO_2 emissions is rising, it is still far less than that of Europe and the United States taken together (both in absolute terms and per head of the population). If no action is taken, global CO_2 emissions are projected to rise by a further 45 to 110% between 2000 and 2030.

In many of the world's regions and countries governments have introduced policies to reduce emissions of CO_2 and other greenhouse gases. This is often referred to as mitigation policy. A case in point is the Kyoto Protocol, under which industrialised countries have committed themselves to a certain cut in emissions; this has not been ratified by Australia or the US, however. The European Union has an additional policy target of reducing its CO_2 emissions by twenty to thirty percent by the year 2020 relative to 1990. One of the key instruments for securing these targets is the European 'carbon emissions trading scheme'. At the national and local level, too, action is being taken by governments as well as environmental organisations. One example of the latter type of action is Green4sure, a green energy plan presented to the Dutch government in 2007 by the Netherlands' largest environmental and trades unions organisations.

Young people themselves can also take action to limit climate change. The first step is for them to realise that many everyday activities - computer gaming, showering, travel, and so on - consume energy and that energy is also required to produce food, clothing, cars, buildings and all kinds of other products. Everyone uses energy and every unit of energy consumed can further exacerbate climate change. It's therefore important to realise that all of us share some of the responsibility for climate change.

There are many tools for calculating one's own CO_2 emissions. Once these are known, one can start thinking about how to reduce them. There are three golden rules for cutting your personal CO_2 emissions:

1 Use as little energy as possible.
2 Try and ensure the energy you do use comes from renewable sources (wind, water, solar).
3 Compensate for any fossil energy you use by supporting energy efficiency projects or by other means (a variety of schemes are available).

When it comes to reducing emissions of the other main greenhouse gases - methane and nitrous oxide - the single best tip is to eat less meat and more organically grown food.

In this report we have broken down the issue of greenhouse gas emissions and climate change into manageable 'chunks' (four in all), which together explain the main causes of climate change and provide suggestions on how they can be addressed, both by government and by young people themselves.

Consequences and adaptation solutions

The consequences of climate change can be seen all over the world. Sea level rise, flooding, hotter summers and wetter winters are the picture of present and future. The key question is to what extent these changes will persist and how we should adapt to them.

Contrary to mitigating measures, adaptive solutions do not contribute to a reduction of the climatological problems. Instead, we reconcile ourselves to the changes and adapt ourselves as best we can to the consequences. This means that much infrastructural development will be needed: raising of dikes, improving

of sewer systems, making more space for water and similar measures. We must become conscious of the fact that we will not always be safe any more (from flooding), but we must adapt ourselves to the changes. In the cases a number of subjects have been further detailed. It concerns:

- Sea level rising/floods/water nuisance.
- Drought and desertification.
- Global heating and melting of the polar ice.

1 Introduction

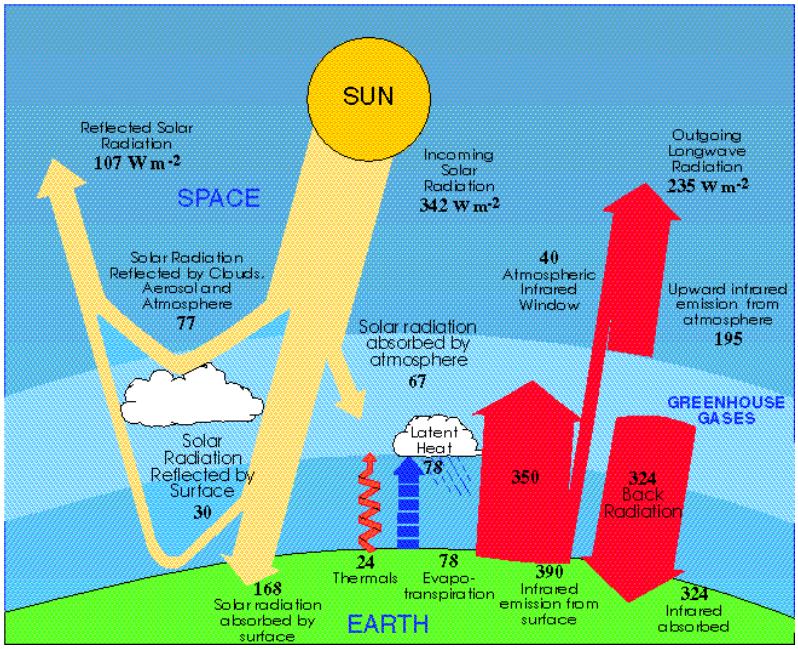
1.1 Climate Quest

A consortium of games developers, scientists and consultants is presently developing the on-line platform Climate Quest, which is to form the basis for a global community of young people around the theme of climate change and its likely impacts. Climate Quest provides a space to play on-line, casual games and develop and implement 'alternate reality quests'. This document sets out the scientific background to climate change: its causes and the consequences. The main focus is the quest for solutions, though, in other words government climate policy and what young people can themselves do about climate change and limiting its consequences.

1.2 Climate change

The world's climate is governed by a great many factors including the amount of incoming solar radiation and atmospheric conditions. One such condition is the concentration of so-called greenhouse gases in the atmosphere (see Figure 1).

Figure 1 The greenhouse effect: a schematic representation

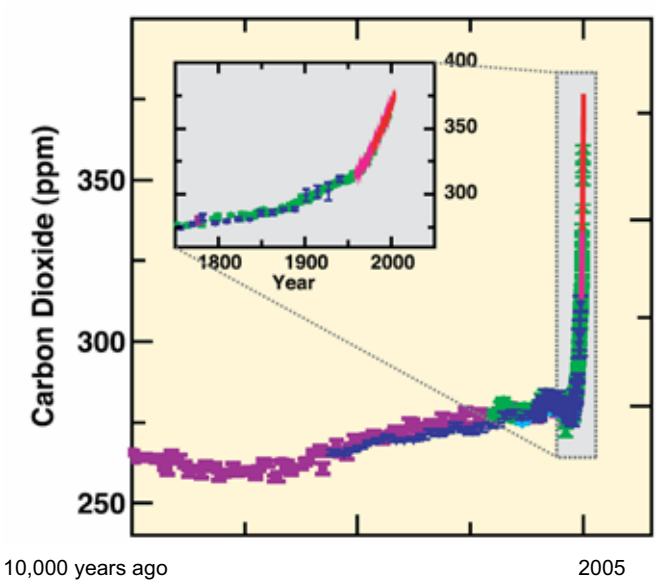


Source: University of Washington.

The IPCC's conclusions

In early 2007 the United Nations' Intergovernmental Panel on Climate Change (IPCC) concluded once again that human activity is causing the Earth's climate to change (IPCC, 2007a). The single most important cause is the rapid increase in the quantity of greenhouse gases in the atmosphere (see Figure 2). This increase is driven mainly by three kinds of activity: the burning of fossil fuels, agriculture and livestock production, and changes in land use like clearing forests. The elevated concentrations of greenhouse gases mean that heat is retained in the atmosphere for longer, causing it to heat up. This, the so-called 'enhanced greenhouse effect', is much more pronounced than can be expected from any of the other possible causes of global warming, like natural variations in solar radiation levels. The 2500 IPCC scientists therefore conclude that it is 'extremely likely' that climate change is being driven by human activity. This conclusion has been endorsed by all the countries affiliated to the IPCC (over 130).

Figure 2 Trend in atmospheric CO_2 concentration over the past 10,000 years, to 2005; trends in CH_4 and N_2O levels (not shown here) are similar

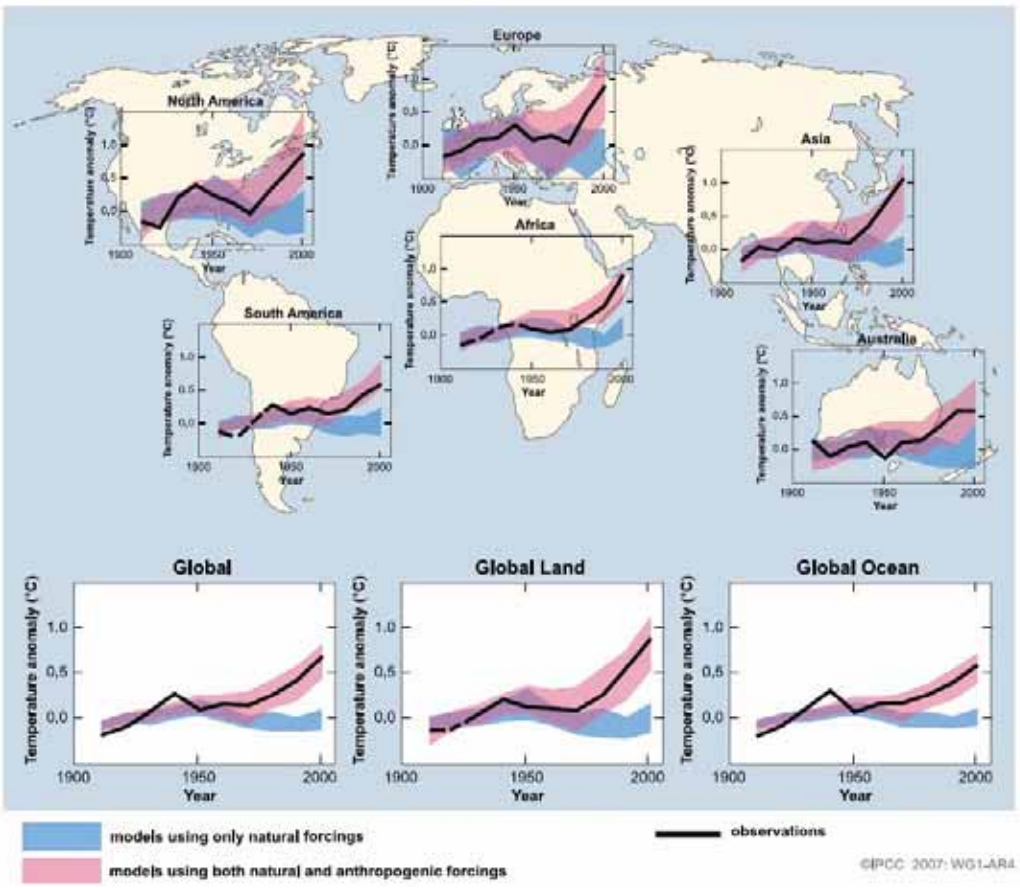


Source: IPCC, 2007a.

Figure 3, shows the temperature changes that have occurred over the past century, per continent and worldwide. The individual graphs show three temperature curves: in black the temperature actually observed, in blue the temperature predicted by computer models that include only natural influences, and in pink predictions when both natural and human influences are included. As is clear, the temperature rises actually recorded are best described by models that allow for the influence of human activity on climate.

It is not only the earth's atmosphere that is warming, but also the oceans. This has led to changes in precipitation levels (rain and snow), snow and ice cover and sea level. These changes will vary widely from region to region, with some parts of the world becoming far wetter, for example, and others far drier. Today we are already seeing these consequences, and that will remain so for many centuries to come, even if measures are taken to stabilise greenhouse gas concentrations. If no measures are taken, though, the consequences will be far more drastic

Figure 3 Temperature changes per continent and worldwide



Source: IPCC, 2007a.

Causes and consequences

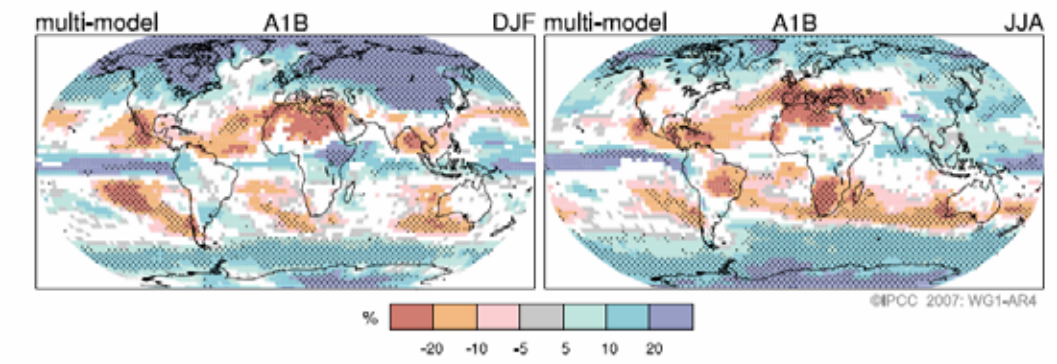
The principal greenhouse gases and their main sources are as follows:

- Carbon dioxide, CO_2 (fossil fuel combustion and land use changes).
- Methane, CH_4 (arable farming and livestock production).
- Nitrous oxide, N_2O (arable farming and livestock production).

The IPCC predicts that climate change will become apparent in the following main ways:

- By around 2100 global temperatures will have risen by between 1.1 and 6.4°C. The exact increase depends on future emissions of greenhouse gases and other pollutants and on the combined action of physical and chemical processes in the atmosphere.
- Some parts of the world will receive more precipitation, with others becoming drier (see also Figure 4).
- In the course of the present century sea levels will rise by between 18 and 59 centimetres. This is because warmer water occupies more space than cold water and because of the retreat of glaciers and polar ice sheets. Our understanding of the melting of the Greenland and Antarctic ice sheets is still incomplete. This, together with the fact that there may be large regional variations in sea level rise, means that in some parts of the world the consequences may be even more dramatic than predicted by IPCC.
- The Gulf Stream, which transports relatively warm water from the Caribbean to Europe, is expected to decline in strength, causing temperatures in north-west Europe to rise less markedly than elsewhere. Standard climate models, however, make no allowance for an *abrupt* change in the Gulf Stream.

Figure 4 Projected changes in global precipitation patterns (left: December-February; right: June-August)



Source: IPCC, 2007a.

Economic consequences

These changes in the Earth's climate will have enormous consequences for living nature as well as the economy. Even a small rise in mean annual temperature can have a major impact on a region's ecology and biological diversity (Pounds & Puschendorf, 2004). Biodiversity is of crucial importance for the stability of ecosystems as well as for human health (Harvard, 2002). The economic impact of drought, floods and other climate change effects will become quite substantial. Some researchers estimate that these costs are set to rise to between 5 and 20% of global income (Stern, 2006). The IPCC has not yet managed to provide a rock-solid cost estimate of the consequences of climate change. It has estimated the cost of limiting further change, though. If such action is taken, global income will grow by only slightly less than if nothing is done: overall economic growth up to the year 2030 would then be 3 percentage points lower (57% instead of 60%, for example).

Avoiding extreme climate change is also important if the 'Millennium Development Goals' are to be achieved, formulated by the United Nations as follows:

- Eradicate extreme poverty and hunger.
- Achieve universal primary education.
- Promote gender equality and empower women.
- Reduce child mortality.
- Improve maternal health.
- Combat HIV/AIDS, malaria and other diseases.
- Ensure environmental sustainability.
- Develop a global partnership for development.

That climate policy and the Millennium Goals go hand in hand is readily illustrated. In regions where climate change leads to more severe drought, for example, poverty and hunger will be exacerbated rather than eradicated. Climate change will mean that malaria spreads further round the globe rather than being effectively combated. The multiple impacts of climate change on biodiversity will mean less environmental sustainability, not more. The message is clear: if climate change is not halted, the Millennium Goals will simply not be achieved.

1.3 Reading guide

In this document we have broken down the issue of climate change into three elements, according to the organisational structure of the IPCC in three working groups. The first of these is concerned with the climate system itself and the (meteorological) consequences of increased levels of greenhouse gas. The other two working groups focus respectively on addressing the causes of climate change and adapting to its consequences. In Chapter 2 we set out the principal causes of climate change, breaking down the discussion into four recognisable 'chunks'. In each, we describe the causal factors involved and how governments and individual citizens can take action to address them. In Chapter 3 we describe some serious consequences of climate change and possible solutions to adapt to the changes. In Chapter 4, finally, we consider how the issues discussed in the previous chapters can be translated into concrete 'quests' in the on-line platform Climate Quest.

2 Causes and mitigation solutions

The enhanced greenhouse effect, as it is known scientifically, is caused by elevated concentrations of several gases in the Earth's atmosphere, the most important of which are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O, also called laughing gas). The historical rise in atmospheric CO_2 levels is due mainly to the burning of fossil fuels and, to a lesser degree, changes in land use such as deforestation. The prime causes of rises in the levels of the other main greenhouse gases, methane and nitrous oxide, are arable farming and livestock production. This chapter first considers these greenhouse gas emissions in a little more depth. We then go on to explain what steps can be taken to reduce these emissions by both governments and individual citizens. Finally, we summarise the main causes and solutions, thereby organising the discussion under four easily recognisable headings.

2.1 Greenhouse gas emissions and mitigation potential

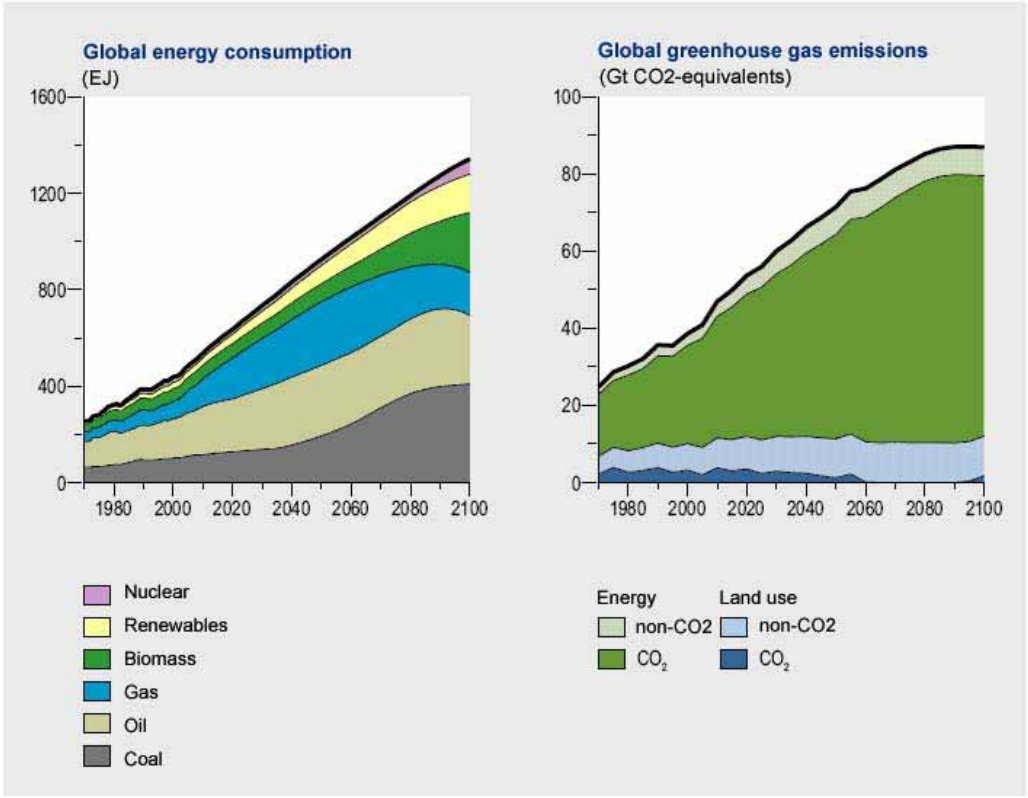
Between 1970 and 2004 the world's greenhouse gas emissions rose by 70% and in recent years many countries have introduced policies to reduce them. Despite these so-called 'mitigation policies', though, emissions are predicted to be 45-110% higher in 2030 than they were in 2000 (IPCC, 2007c), a result of projected trends in economic growth, consumer and business behaviour, and the number of people living on the planet.

Although the mitigation policies currently in place are by no means effective in stabilising emissions, then, there is certainly a huge variety of measures that can be taken to avoid the severest effects of climate change. The UN Intergovernmental Panel on Climate Change (IPCC) projects that the impact of climate change will stay within manageable proportions if temperature rise is restricted to no more than 2 to 3 degrees Celsius. It has recently been calculated that it is indeed technically feasible to limit the rise to 3°C and that this would lead to about 0.6% less overall economic growth in the period up to 2030. Limiting the temperature rise to 2°C is also technically feasible and would mean an estimated 3% less growth over this period (for instance, by 57% rather than 60%). In ideal circumstances, this means the worst climate problems can be avoided by sacrificing just one year's economic growth.

2.1.1 Trends and projections

The Netherlands Environmental Assessment Agency (MNP), a key partner of the IPCC, has plotted recent trends in worldwide energy consumption and global greenhouse gas emissions and projections for the coming century. This so-called Basic Scenario is shown in Figure 5.

Figure 5 Global energy consumption and greenhouse gas emissions: recent trends and projections according to the Basic Scenario



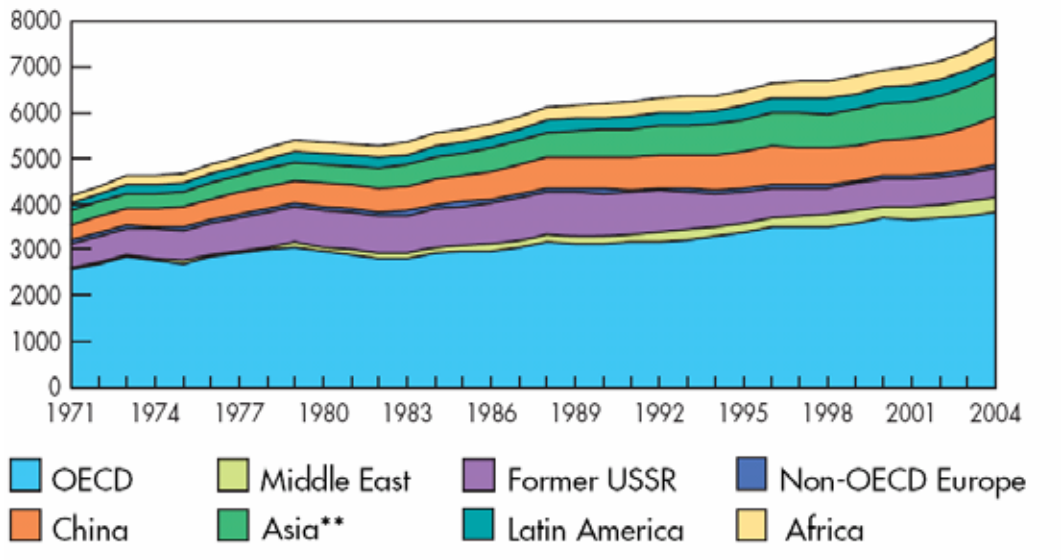
Source: MNP, 2006.

The MNP's Basic Scenario assumes the world's population will continue to grow, as will the global economy. In addition, it assumes there will be no further progress on climate policy beyond the measures currently in place, in other words 'Business as usual'. As the figure shows, without additional policy there will be a massive increase in both energy consumption and greenhouse gas emissions. The figure also shows that without new policies the consumption of fossil fuels will increase steeply as well.

2.1.2 Regional differences

The International Energy Agency keeps records of the amount of energy consumed in the various regions of the world. As can be seen from Figure 6, it is the industrialised world (the so-called OECD countries) that uses most energy, although its share has gradually declined from 60% in 1973 to 50% in 2004. In absolute terms, though, the energy demand of OECD still grew over this 30-year period. The publication *Energy, powering your world* (FOM, 2002) provides an illuminating explanation of global energy consumption past, present and future.

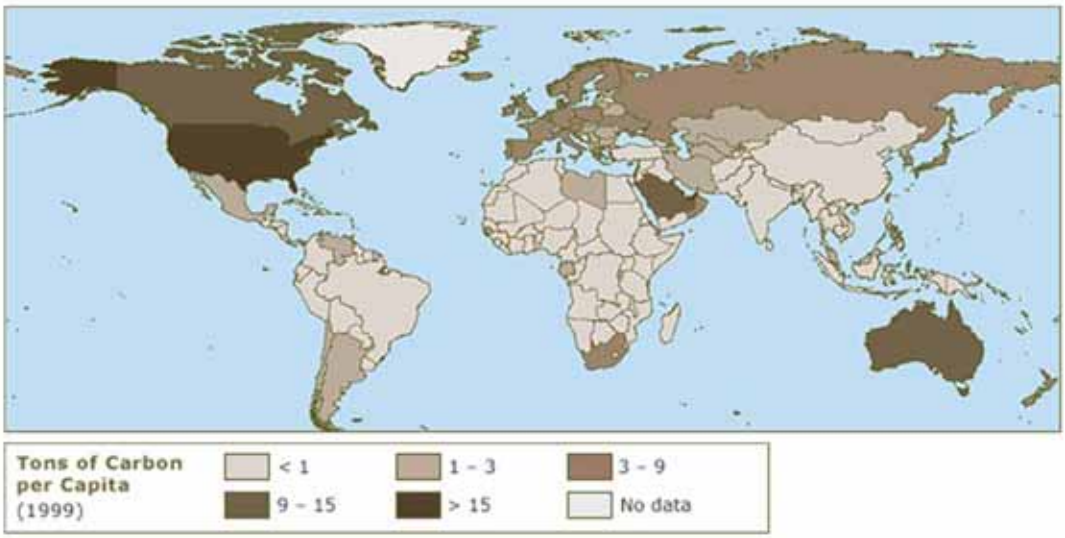
Figure 6 Global energy consumption: regional shares



Source: IEA, 2006.
** Asia excludes China.

Figure 7 shows the greenhouse gas emissions of the world's countries, but now expressed per head of the population, i.e. 'per capita'. As can be seen, citizens in industrialised countries emit far more greenhouse gases than people in other countries.

Figure 7 Greenhouse gas emissions, per ountry, per capita (1999)

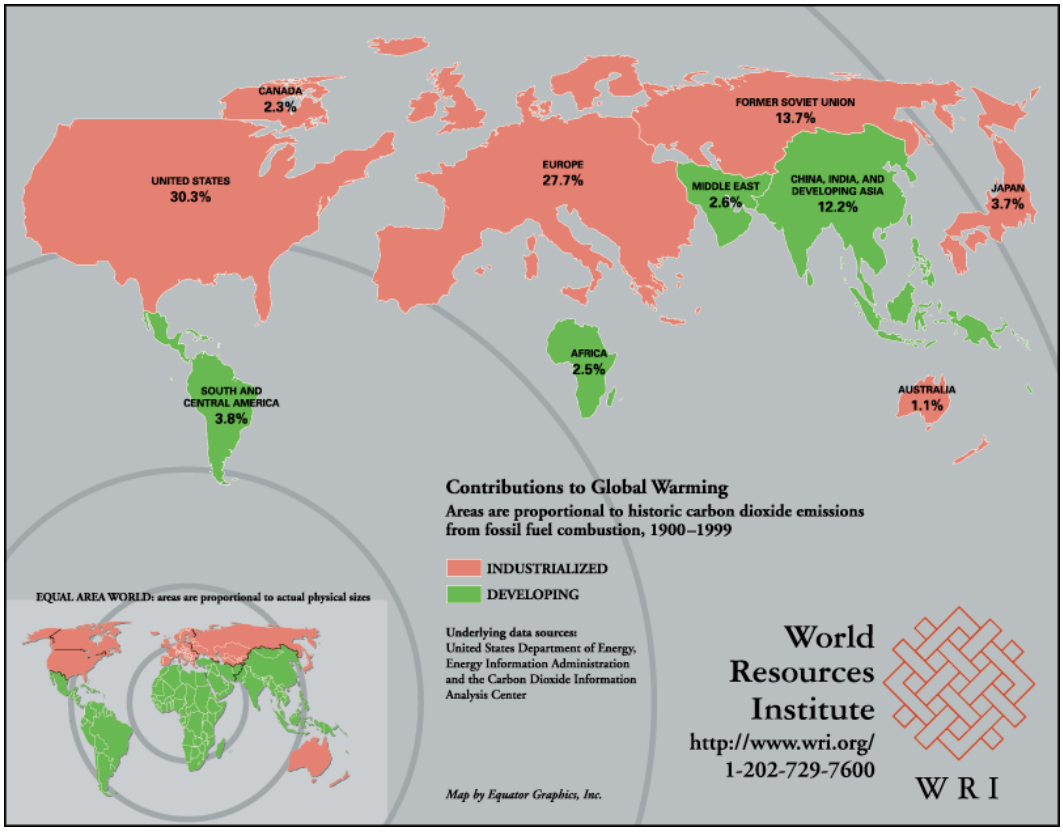


Source: World Resources Institute (Earthtrends website).

In the media and in political circles one often hears that it is developing economies like China that should bear (more) responsibility for effectively addressing climate change. Although China is indeed one of the world's largest emitters of greenhouse gases, the data of Figure 7 give no support to this

position. Both in absolute terms and per head of their population, it is the industrialised countries that are responsible for by far the largest greenhouse gas emissions, and the massive increase in atmospheric levels of these gases over the past hundred years is due overwhelmingly to the activities of the industrialised world (Figure 8).

Figure 8 Regional contributions to climate change since 1900



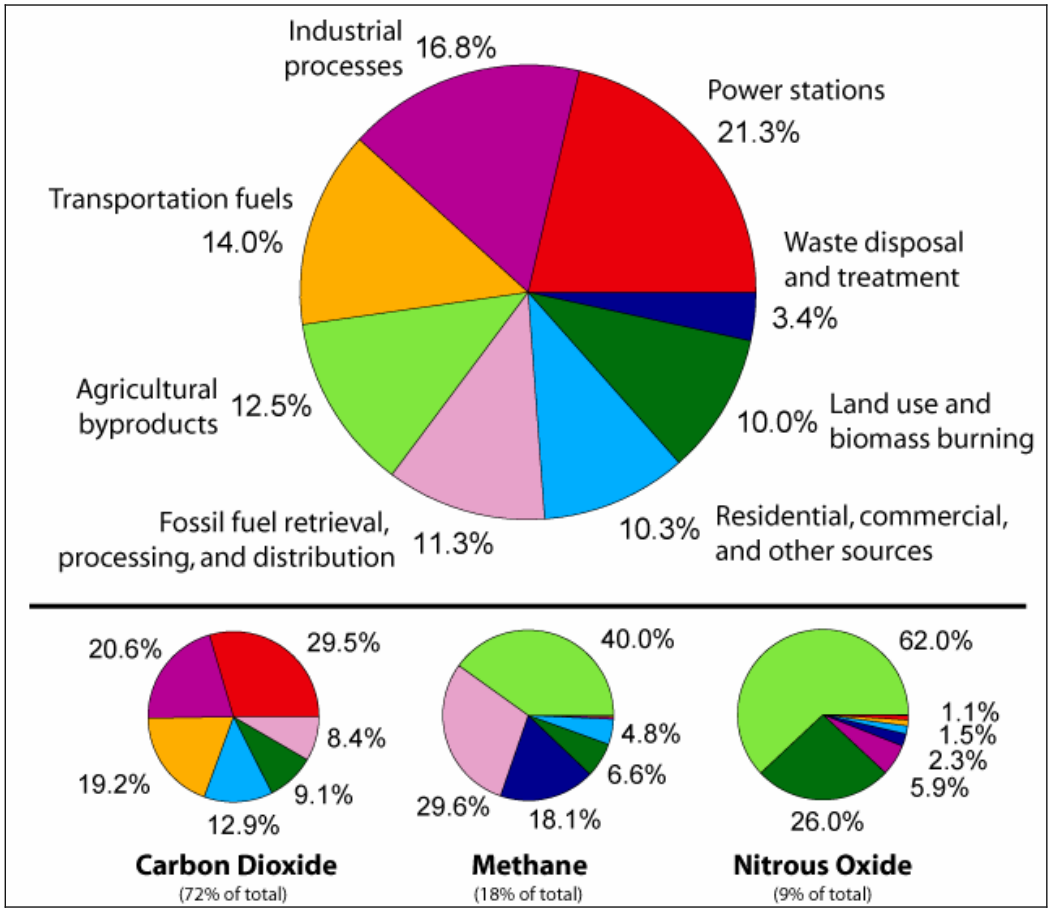
Source: World Resources Institute.

There is, in short, every reason to hold the industrialised countries accountable for having brought about climate change and for them to now bear prime responsibility for resolving the problem.

2.1.3 Emissions per economic sector

Figure 9 shows the share of various sectors of the economy, such as transportation and industry, in greenhouse gas emissions. It is based on the year 2000.

Figure 9 Shares of economic sectors in global greenhouse gas emissions in 2000



Source: Global Warming Art, based on data from the Emissions Database for Global Atmospheric Research (EDGAR3.2, Olivier and Berdowski, 2001).

As can be seen, it is power stations, industrial processes and transportation that contribute most to emissions. Even so, almost half are due to other sectors like agriculture, homes and offices, and fossil fuel production.

As mentioned above, between 1970 and 2004 there was a 70% increase in global greenhouse gas emissions. It is interesting to look at the emissions growth of individual sectors over this same period (see Table 1).

Table 1 Rise in direct greenhouse gas emissions by individual sectors (excluding electricity consumption) between 1970 and 2004

Energy supply	145%
Transportation	120%
Industry	65%
Land use, land use changes & forestry	40%
Agriculture	27% (between 1970 and 1990)
Buildings	26% (between 1970 and 1990, subsequently stable). (NB: growth including electricity consumption is 75%)

Source: IPCC, 2007c.

We see that the energy sector (i.e. power stations) contributed most to the global rise in emissions. The share of the transport sector also rose faster than the average. Note that the data in the table are for growth in *direct* emissions, i.e. excluding emissions associated with the electricity used in buildings, agriculture and industry and those occurring during production of transport fuels. However, the electricity produced in power stations is consumed in houses, industry, etcetera. Therefore, the growth of greenhouse gas emissions by the energy supply sector is mainly due to other sectors indirectly.

2.1.4 Mitigation potential

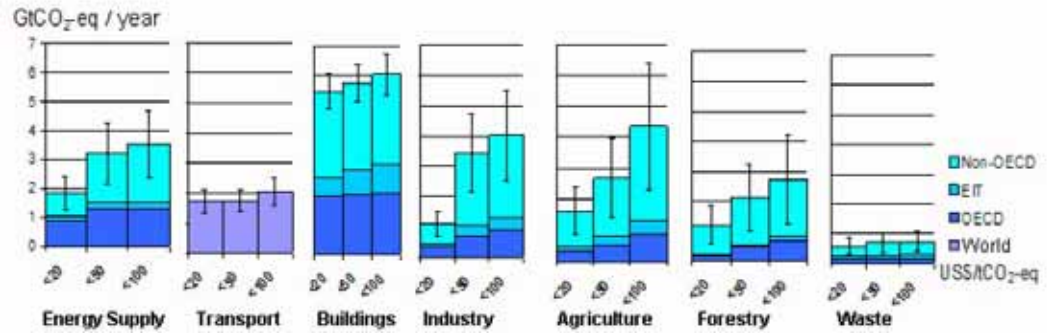
There are a whole range of measures that can be taken to mitigate emissions of greenhouse gases. To select the best measures means considering not only their potential effect (how many tonnes of emissions are avoided?) but also their cost. This gives us a more comprehensive idea of the technical and economic potential available in practice: what can be done and what is prohibitively expensive?

The IPCC has examined the following measures:

- Energy conservation in buildings.
- Renewable energy (water, wind, solar, etc.).
- Energy conservation in other sectors (transport, industry, etc.).
- Alternative transport systems.
- Nuclear energy.
- CO_2 capture and underground storage.
- Emissions reduction in agriculture and forestry.
- CO_2 storage in agricultural soils or forest trees.
- Measures relating to waste treatment.

Figure 10 summarises the potential of a number of measures. As can be seen, there is plenty of scope for action, particularly in buildings. There are also opportunities in industry, agriculture and the energy supply, but these measures are generally more expensive to implement. The transport and forestry sectors have only a modest contribution to make. Measures in the waste processing sector, finally, are the least effective of the measures considered below.

Figure 10 Potential for emissions reduction in economic sectors as a function of CO_2 price



Source: IPCC, 2007c.

From the above IPCC concludes that there are certainly plenty of ways to approach the problem of climate change. There are even sufficient measures to ensure that the problems will remain within manageable bounds. On a global scale, energy conservation in homes and offices offers the greatest potential for reducing greenhouse gas emissions at least cost.

2.2 Government mitigation policy

Governments at all levels have committed themselves to implementing policies to reduce greenhouse gas emissions. Under the auspices of the United Nations, 167 countries plus the European Union have signed and ratified the Kyoto Protocol (UN, 1998). Under this treaty the participating industrialised countries have committed themselves to reducing their greenhouse gas emissions either directly, in their own country, or by taking action to reduce emissions elsewhere, as provided for under several mechanisms. One popular measure in this context is the destruction of the strong greenhouse gases released during production of fridges in China (PEW, 2007). Under these mechanisms the country making the investments can add the emission cuts achieved abroad to those secured at home in pursuit of its declared commitment. Two major industrialised countries have not ratified the Kyoto Protocol: the United States and Australia. The protocol does not look beyond the horizon of 2012 but negotiations are already underway for a follow-up treaty. At the 2007 summit of the world's eight largest industrialised countries (G8), for instance, world leaders have committed themselves to setting up a new treaty by the end of 2009.

Climate protection programmes are also being elaborated by governments at the regional level. The European Union, for example, has set itself the target of achieving a 20% cut in CO_2 emissions by 2020 (compared with 1990). If other industrialised countries follow suit, the EU is even prepared to reduce its emissions by 30%. To secure these targets the European Commission usually draws up directives, to be transposed into appropriate legislation by member state governments. Under one of these directives in 2005 a Europe-wide market has been created in which the largest energy industrial users can trade in so-called CO_2 'emission allowances'[1]. Under this carbon emissions trading scheme, as it is known, companies emitting less CO_2 than foreseen can sell their surplus 'credits' to companies with too few to cover their current emissions. With each new phase of the scheme, the total number of emission allowances allocated to all companies is progressively reduced, thus compelling the companies as a whole to keep on reducing emissions. This system of emissions trading encourages that the best measures are implemented at least cost.

Governments are implementing climate policies at the national and local level, too. Among the most effective measures are the following:

- Subsidy schemes for renewable energy and energy conservation.
- A requirement for new housing to consume less energy.
- Energy-saving agreements with industry.

[1] See http://ec.europa.eu/environment/climat/emission.htm.

- ‘Green’ tax measures to encourage use of fuel-efficient cars, homes, electrical appliances and so on.
- Research budgets for new technologies, including:
  - Separation and underground storage of CO_2 from industrial flue gases.
  - New fuels from biomass that are more ‘climate-efficient’ and require less land (today’s biofuels are not ‘climate-neutral’ and require too much cropland for large-scale introduction).
- Information campaigns on energy conservation, ‘green’ electricity, etc.

To a large extent, government climate policy is fed by plans and initiatives launched by non-governmental organisations. A case in point is ‘Green4sure: a Green Energy Plan’, recently put forward by the Netherlands’ largest environmental and trades union organisations (CE Delft, 2007). The aim of the plan is to halve Dutch CO_2 emissions by 2030 relative to 1990 levels. The main means of achieving this end is to extend the current European CO_2 emissions trading scheme. At the heart of the plan is a cleverly designed and comprehensive package of government measures to induce businesses and individual citizens to make more energy-efficient and environment-friendly choices in their everyday activities. Green4sure was officially presented to the Dutch minister of environmental affairs in June 2007.

If you want to find out more about what the government of your region or country is doing to cut greenhouse gas emissions, get in touch with your environment or energy ministry, or regional or local council, or go to their website.

2.3 What can *you* do?

What you yourself can do to tackle climate change depends very much on your personal situation. It therefore makes sense to first work out how high your greenhouse gas emissions are, for example by going to one of the following websites:

- www.carbonfootprint.com.
- www.climateneutralgroup.com.
- www.carbonneutral.com.
- www.co2meter.nl.

These sites will then point you to ways of reducing your emissions.

There are three golden rules for cutting your greenhouse gas emissions:

1 Use as little energy as possible.
2 Try and ensure the energy you do use comes from renewable sources (wind, water, solar).
3 Compensate for any fossil energy you use by supporting climate-friendly projects.

Let us now look at each of these rules in turn.

2.3.1 Energy conservation

There are many ways to cut down on how much energy you use. This will not only reduce your CO_2 emissions, but also save you money. There are three things to focus on here: what you need, what you buy and how you use it:

1 **Needs**: Before going out to buy a new electrical appliance or use some service, first consider whether you really need it. Ask yourself the following kinds of questions: Do I need a tumble dryer for my laundry, or can I just as well hang it out to dry? Do I really need to spend my holidays in some far-away land, or is there some alternative nearer home?
2 **Purchases**: When you do decide to buy a particular appliance, vehicle or service, go for the most energy-efficient model or arrangement available.
3 **Usage**: When using appliances and vehicles, do so as efficiently as you can.

The following examples give some idea of the wide range of choices to be made. If you're a child and don't have a home or car of your own, some of the measures below may be difficult to implement. However, you could instead try and persuade your parents to implement them or think of them when you're an adult.

- Home energy consumption:
  - Stop using inefficient appliances, or replace them with more efficient models; don't leave equipment on unnecessarily (NB: many kinds of appliances use power even when they are on stand-by!).
  - Replace incandescent light bulbs by compact fluorescent ones; don't leave lights on unnecessarily.
  - Make sure you heat your home wisely (e.g. high-efficiency boiler, loft insulation, double-glazing); turn down your thermostat.
  - Instead of air-conditioning, cool your home in other ways when it's hot.
  - Use a more efficient shower-head; take shorter showers.
- Travel:
  - Travel less often and less far by car; use a fuel-efficient vehicle; adopt a more efficient driving style.
  - Travel less often and less far by air.
  - Travel more often by bike or on foot, or use public transport.
- Indirect energy consumption:
  - Buy more of your food locally; buy food that is in season.
  - Eat less meat and greenhouse vegetables.
  - Make less use of energy-intensive products (e.g. aluminium foil).
  - Buy second-hand goods instead of new ones (recycling!).
  - Switch to a 'green' savings account or investment portfolio.

By reducing the amount of energy you use you can already achieve substantial cuts in your greenhouse gas emissions. The above tips are very concise, but will be treated at length in section 2.4. For more information you can also get in touch with the organisations listed below under the heading 'Climate initiatives and links'.

2.3.2 Renewable energy

It always makes sense to conserve energy. Of the energy you still use you should now try and ensure that as much as possible comes from sustainable, renewable sources. Many electricity suppliers deliver 'green electricity' in various forms and some have even made it their speciality, supplying nothing but renewable energy. In many countries there is 'green gas', too. It is usually very straightforward to switch to renewable energy. When it comes to the car you drive, you can consider using biofuels. But bear in mind that although biofuels can help address climate change, they may at the same time well cause other problems, as discussed in section 2.4.3 below.

2.3.3 Compensation

Finally, you can opt to have the non-renewable energy you do use compensated for in some way. But be on your guard and critical at all times: the market in so-called carbon offsets is growing by the day, but is still largely unregulated. Some compensation schemes are better than others, and some have damaging side-effects. A recent investigation of the UK Parliament encouraged the UK government to set out clear criteria which offsets ought to meet (EAC, 2007). While these criteria have not yet been set, be careful in selecting an offset project to compensate your CO_2 emissions.

Carbon emissions can be offset in a variety of ways:
1 By supporting energy conservation projects.
2 By supporting renewable energy projects.
3 By avoiding deforestation and tree-planting.

There are a range of professional organisations that will calculate the climate impact of your energy use and implement the appropriate level of compensation. A number of these organisations can be found on the EcoBusinessLinks website[2]. Some credit cards automatically compensate for the greenhouse gas emissions of products and services purchased on the card.

Carbon offsets should only really be considered when you're convinced you can reduce your energy consumption no further, nor increase the amount of renewable energy you use. And if you do go down this road, convince yourself that the organisation implementing the offsets is truly *bona fide*.

[2] http://www.ecobusinesslinks.com/carbon_offset_wind_credits_carbon_reduction.htm.

2.3.4 Climate initiatives and links

The above tips have been kept very concise, as we shall be examining them more closely in the next section. For more information you can also get in touch with environmental organisations or government agencies in your particular region or country. Alternatively, you can go to the websites of international organisations like:

- Greenpeace: www.greenpeace.org (see especially the 12 steps to cut your emissions[3]).
- Friends of the Earth: www.foe.org.
- WWF (formerly Worldwide Fund for Nature): www.wwf.org.
- Climate Crisis Coalition: www.climatecrisiscoalition.org/.
- Clinton Climate Initiative: www.clintonfoundation.org (see especially the 10 steps to living the green life[4]).
- Grist 'Environmental news and commentary': www.grist.org.
- World Resources Institute (Earthtrends database): earthtrends.wri.org.
- Intergovernmental Panel on Climate Change (IPCC): www.ipcc.ch.
- United Nations Environment Programme (UNEP): www.unep.org.
- Treehugger: www.treehugger.com (info on a modern, green way of life).

There are many other sources of information on climate change besides these websites of course. So go out and get involved!

2.4 Breaking down the issue

The issues involved in greenhouse gas emissions and climate change sometimes seem like a vast, confusing jigsaw puzzle, with too many pieces to grasp. To make it easier to get to grips with, we have broken down the discussion into four bite-sized 'chunks' with easily recognisable headings. Together, these cover all the main issues focused on in Dutch, European and global climate policy and by IPCC Working Group III, dealing with mitigation (IPCC, 2007c). Where possible, we have also tried to tie in with current public information campaigns and other climate change initiatives. In addition, we adopted the following criteria:

- Each of the 'chunks' should illustrate at least one key factor driving climate change.
- The factors identified should be the subject of government policy.
- There should be scope for young people to tackle the issues involved, through personal or collective action.

To frame the basis discussion, consider Figure 11, which shows the amount of energy expended by a typical Dutch household on different types of activity.

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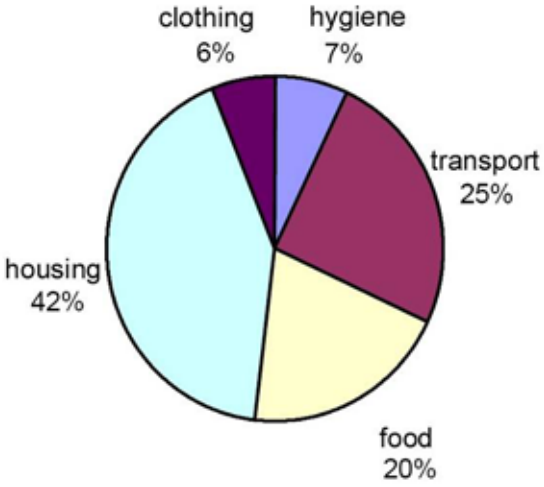
[3] http://www.greenpeace.org/international/campaigns/climate-change/take_action/12_steps.

[4] http://www.clintonfoundation.org/cf-pgm-cci-ar-live-the-green-life-10-easy-steps.htm.

Figure 11 Breakdown of energy consumption of an average Dutch household



Source: IVEM, 2000.

As the figure shows, most of the energy used by Dutch households is expended in the home (for heating, electrical appliances, etc), on transport and on food. In most other western homes the situation is not significantly different.

Proceeding from the basic truths embodied in this figure and the criteria cited above, we have broken down the discussion into the following four chunks:

1 Showering and gaming - energy consumed directly in your own home.
2 Meat and tomatoes - energy and land used indirectly for home activities.
3 Cars and planes - energy for passenger transport.
4 Coal and steel - energy for industrial processes and energy supplies.

In the next four sections we shall explore each of these in turn.

2.4.1 Chunk 1: Showering and gaming

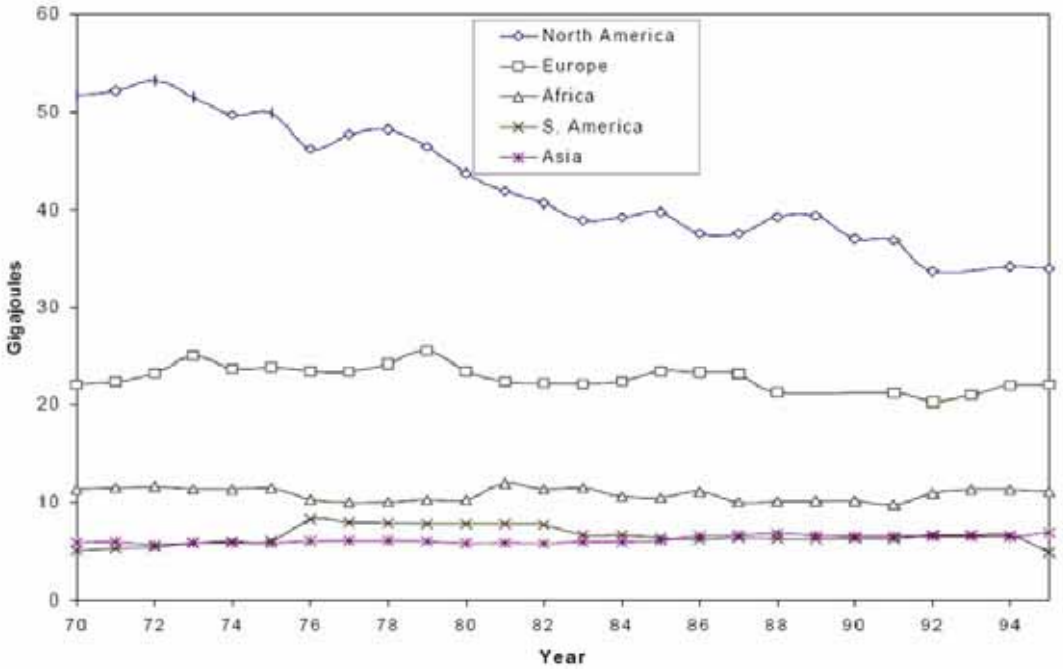
Showering, gaming and all the other everyday activities carried out in a home kept at a comfortable temperature are all things that require energy. This chunk of the discussion is concerned with direct energy consumption in households: heating and air conditioning, electricity for lighting, domestic appliances, food preparation, communications, entertainment and hot water supply. Household activities involve indirect energy use, too, but this is treated in Chunk 2: Meat and tomatoes.

Many governments have introduced policies to reduce direct household energy consumption. Often there are requirements for the energy-efficiency of newly built homes, for example, and many electrical appliances are now more energy-efficient thanks to government regulations. But there is still plenty you as a consumer can do to reduce the amount of energy you directly use, particularly electricity.

Direct energy use as a source of greenhouse gases

As we saw in Figure 9, at the global level households and offices are together responsible for about one-tenth, or 10%, of the world's greenhouse gas emissions. This figure does not include emissions from power plants, however, part of which need to be assigned to households. Altogether, households in fact account for 20-25% of the world's greenhouse gas emissions due to direct energy use. When looking at direct energy use itself, about one-quarter to one-third of the world's direct energy consumption is due to households. Expressed per capita, as in Figure 12, there are major regional differences, though: the average South American or Asian uses four to six times less energy than a westerner.

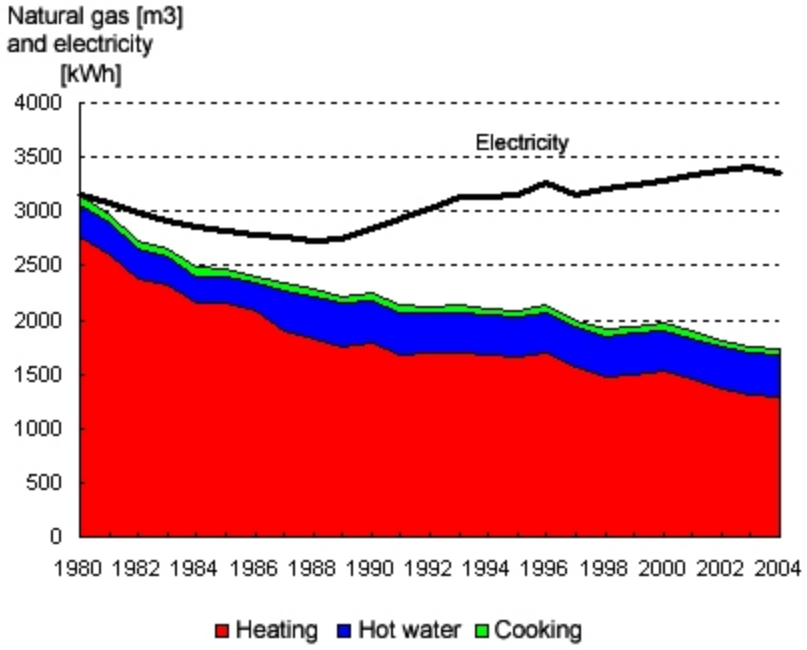
Figure 12 Direct household energy consumption per capita in various regions



Source: United Nations Statistics Division.

Household energy consumption has not stayed constant over the years. In north-west Europe, for example, the amount of energy used for heating homes has declined as a result of better insulation (see Figure 13). In contrast, the amount of hot water used for showering, for example, has increased. Use of electricity has also risen substantially over the years, despite appliances becoming ever more efficient. This is because we are using more and more types of appliance, and using them increasingly often.

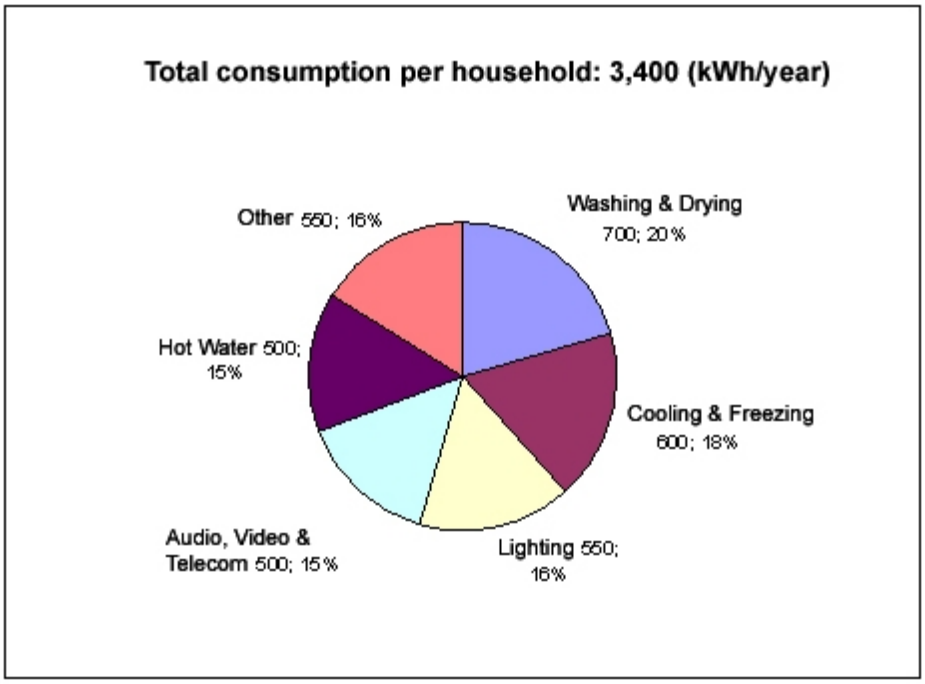
Figure 13 Trends in Dutch household energy consumption



Source: ECN.

A typical Dutch household uses about 3,400 kWh of electricity a year. So what is it all used for? Figure 14 gives a breakdown of the situation in the Netherlands.

Figure 14 Dutch household electricity consumption (kWh per year)



Source: Milieu Centraal.

As the figure shows, there is no one category that accounts for a disproportionate share of electricity consumption. But what kinds of equipment and appliances use most electricity, then? Table 2 lists some of the least efficient electrical appliances on the market and the amount of power they consume.

Table 2 Power consumption of inefficient household appliances (kWh per year)

Tropical aquarium	1,200
Air conditioner	400 - 700
Water bed	750
Old fridge/freezer	250 - 600
Plasma TV	220 - 600
Garden pond with pump	90 - 4,000
Electric boiler	1,900 - 2,100
Tumble dryer	600

Source: Milieu Centraal.

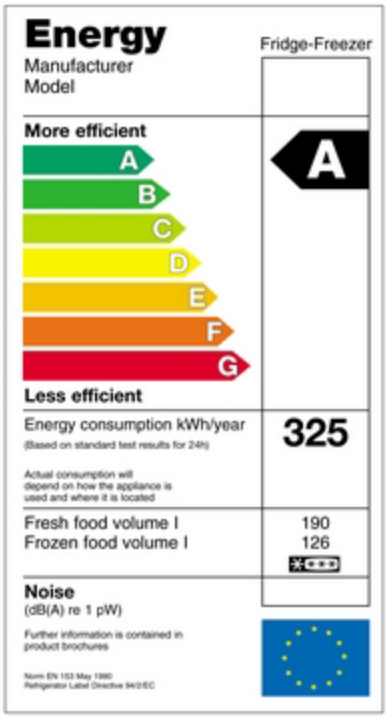
As Table 2 shows, certain appliances can substantially increase a household's average power consumption (3,400 kWh/y). A water bed, for example, requires more energy than the average household uses for washing and drying in a whole year. By consciously reflecting on the energy consumption of a new appliance before you buy it you can thus save plenty of energy and avoid a lot of CO_2 emissions.

Government policy to reduce direct energy consumption

The greatest cuts in greenhouse gas emissions at reasonable cost can be achieved through energy saving in the home (see Figure 10, above) and many governments have consequently introduced incentives for people to make such savings. Here we provide a few examples.

Many countries have subsidies that encourage home-owners to insulate their property or install double-glazing. Some governments have also set strict requirements on the energy efficiency of newly built homes. Through information campaigns and the labelling of shop goods, European consumers are now informed about the energy consumption of electrical goods (see Figure 15).

Figure 15 European energy label for electrical appliances



The Australian government is banning the sale of incandescent light bulbs as of 2010, from which date only compact fluorescent lamps will be available. These use about five times less energy than old-fashioned light bulbs and also have a much longer life. California is considering taking similar action. Lighting accounts for a substantial share of energy demand: worldwide some 20% of all power generated is used for lighting. In its report 'Light's Labour's Lost' the International Energy Agency has reviewed the policy measures available for promoting energy-efficient lighting (IEA, 2006).

Many governments support renewable energy financially, by means of subsidies or tax breaks, for example, for consumers and companies using renewable energy or building a wind farm, say.

One key instrument that governments have at their disposal are 'green taxes'. In recent years many countries have modernised their tax system with the aim of making energy-intensive products and services less appealing to consumers and businesses, with climate-friendly products and services becoming relatively cheaper. Denmark, for example, now has a so-called carbon tax on fossil fuels like coal, diesel and kerosene. The revenues are use to fund renewable energy projects and energy conservation (OECD, 1995).

What can *you* do?

Everyone likes to live in a home with a comfortable temperature and adequate lighting. Computers, TVs and other electrical appliances make life easier as well as more fun. But don't forget that every appliance you use, all your hot water, all your central heating and air conditioning systems consume energy. Things like

showering and gaming do have a direct impact on climate change. So before you go out and buy a new appliance or gadget, make sure it's a conscious choice - and do the same whenever you use it! To reduce the greenhouse gas emissions due to activities in you own home, follow the three golden rules from section 2.3, reiterated below. If you you're not yet living in a home of your own, it may be hard to take the following steps, but there's no reason you shouldn't try to persuade your parents or house-mates to start taking action. Also, remember these hints for later, when you do possess your own property.

Minimise your energy consumption

- Replace old window panes with double-glazing (HR++ grade) and improve your home by insulating the floor, cavity-walls, loft and roof.
- Replace your old central heating system with a high-efficiency heater and make sure the system gets regular maintenance.
- Turn your central heating down a degree or two and put it on the night-time setting half an hour earlier.
- Avoid using air-conditioning systems if you can, using a fan, for example; if you do buy an airco, have a good look at the energy label.
- Use power sockets with on-off switches for your adapters, to ensure that energy is not being wasted when equipment is on stand-by.
- Replace old incandescent light bulbs with compact fluorescent ones.
- To save (heated) water, fit a low-energy shower head and take shorter showers; use a solar boiler for your hot water.
- Only use appliances with an A-label or better for energy use.
- Say no to energy-guzzlers like tumble dryers, plasma TVs and water beds (see Table 2).

Use renewable sources

- Switch to 'green' electricity (wind, water or solar).
- Switch to 'green' gas (e.g. biogas).

Compensate for fossil energy

- There are many organisation that can help you make your life 'climate-neutral'. Remember the warnings given in section 2.3 when finding a *bona fide* one.

2.4.2 Chunk 2: Meat and tomatoes

Besides their direct energy consumption (cooking, heating, electricity, etc.) households also use a lot of energy indirectly. It has recently been calculated, for example, that the climate impact of the meat eaten by the average Western consumer is greater than that due to car use[5]. Indirect energy consumption is the energy required for producing and transporting food, building houses and producing consumer goods (clothing, appliances, flowers, etc.), as well as for processing all the waste that arises. It is not only carbon dioxide that is emitted; the landfilling of waste leads to methane emissions, for example, while agricultural fertilisers cause nitrous oxide emissions. This chunk of the discussion

[5] Source: CLM, the Netherlands.

is concerned with indirect household energy use, as embodied in meat, tomatoes and other products.

Very few of the world's governments have adopted policies addressing the indirect energy consumption of households. There are scarcely any regulations concerning the amount of energy used to produce consumer goods, for example. However, many governments have taken structural steps to increase the 'climate-friendliness' of industrial processes, waste processing and freight transport in their country.

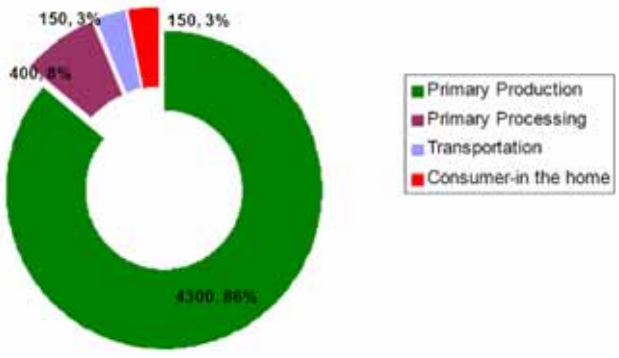
There are still plenty of ways for you as a consumer to do something about your indirect household energy consumption, though. In this way you can reduce not only your greenhouse gas emissions but also the amount of space that is ultimately required to produce the goods you consume. If that 'indirect land use' is reduced, there will be more room for growing biofuels, for example (see section 2.4.3). In this way you can enhance the impact of what you do.

Indirect energy use as a source of greenhouse gases

Overall, indirect household energy consumption is responsible for a substantial share of the world's greenhouse gas emissions, but it is hard to calculate exactly how much. It is estimated, though, that emissions due to indirect energy use are at least equal to those caused by direct energy consumption for cooking, heating, electrical appliances and so on.

As an example, Figure 16 gives a breakdown of the greenhouse gas emissions associated with the entire 'life cycle' of a kilo of pork, from the pig's birth through to the slice of meat on your plate. As can be seen, direct energy consumption (red segment), i.e. that over which the consumer has direct control, generally accounts for only a small fraction of overall greenhouse gas emissions. Cooking the slice of pork in your kitchen accounts for only about 3% of total life cycle emissions, over 95% of which are due to indirect energy use, above all to emissions of methane and nitrous oxide in farm-related processes. These percentages may vary somewhat, depending on methods of production and kitchen preparation.

Figure 16 Breakdown of greenhouse gas emissions in the life cycle of an average kilo of pork

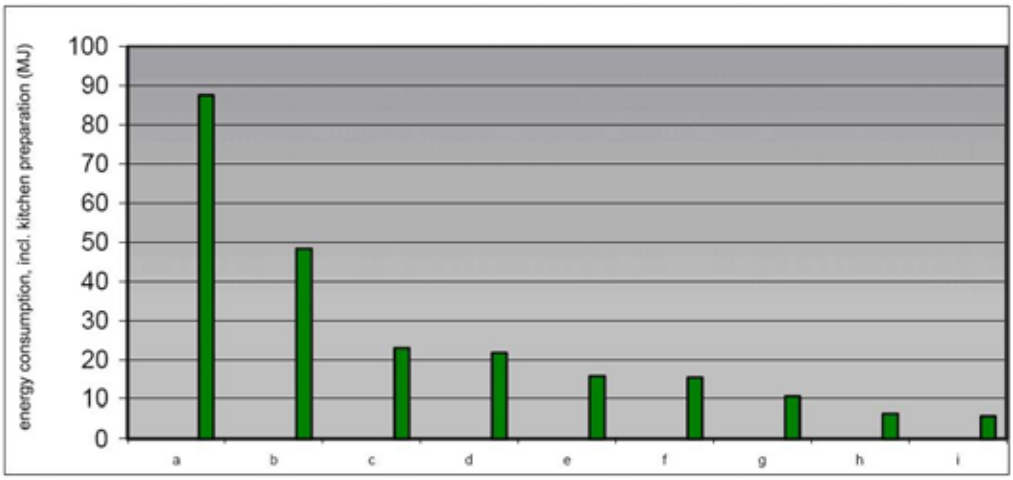


Source: MBS, 2006.

The main option for reducing the climate impact of meat is therefore simply to eat less meat and switch to alternative sources of protein. Some of these alternatives produce five times less greenhouse gases per gram of protein and require 10 times less farmland.

In the western world most products are available in a range of varieties. For example, you can choose between vegetables in a can, in a glass jar, fresh from the greenhouse or fresh from the field. Many fresh vegetables are imported from warmer regions or specialised growing districts. All these varieties of vegetables are produced using vastly different amounts of energy, as shown in Figure 17.

Figure 17 Energy consumption associated with different varieties of vegetables eaten in the Netherlands (NL)



a = fresh vegetables grown outdoors, imported by air
b = greenhouse vegetables grown in NL
c = deep-freeze vegetables, cardboard packaging, NL
d = industrially processed vegetables, disposable glass packaging, NL
e = industrially processed vegetables, returnable glass packaging, NL
f = industrially processed vegetables, canned, NL
g = fresh vegetables grown outdoors, imported by road
h = fresh vegetables grown outdoors, imported by inland shipping
i = fresh vegetables grown outdoors, NL

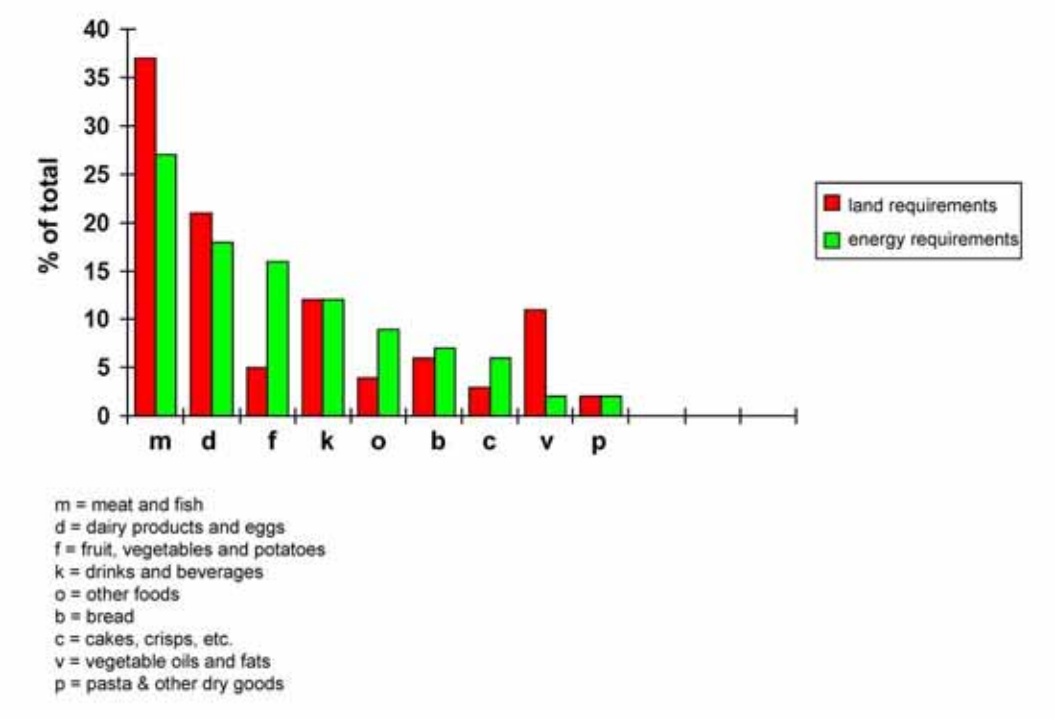
Source: IVEM, 2000.

Locally produced vegetables grown outdoors require the least amount of energy, while vegetables imported by air require the most (to import one kilo of vegetables from another continent takes about three litres of aircraft fuel). Vegetables grown indoors in local greenhouses also require lots of energy: to produce a kilo of greenhouse spinach takes about 18 times as much energy as growing it outdoors (IVEM, 2000).

Besides greenhouse gas emissions, land use is another key issue to bear in mind here. Some products, such as meat, require large tracts of land (for producing animal fodder), while other kinds of food are far more efficient in terms of land use. When scaled up for many millions of people, this land use may be at

the expense of nature as well as human food supplies. Figure 18 shows the energy requirements and land use associated with various kinds of food as a percentage of the total energy and land requirements of a typical Dutch meal.

Figure 18 Relative energy and land requirements of the constituents of a typical Dutch meal



Source: IVEM, 2000.

As the above figure shows, animal products like meat, cheese and other dairy products account for a fairly substantial share of the energy and land requirements of a typical meal. In terms of land use, potatoes and pasta are the most efficiently produced food items.

Not all these food items can be directly replaced, nor are they interchangeable. You can't simply replace meat by potatoes, for example. But its environmental impact is an additional reason for following the recommendations of nutritional experts to eat less meat and more vegetables for health reasons. Alternatives to meat like tofu (not shown in the table) can score up to five times better on energy and ten times better on land use.

Government policy to reduce indirect energy consumption

Compared with direct energy consumption, indirect household energy consumption is given far less attention by policy-makers around the world. To our knowledge, there are no regulations on the 'energy content' of consumer products anywhere in the world. One thing many governments have done, though, is to introduce legislation on packaging, such as deposits on bottles and schemes to collect and recycle packaging waste. On average, the environmental impact associated with product packaging is about 10% of that of the product and

packaging combined, though this figure is less for many food items such as meat and dairy products (because of their high intrinsic impact). Nonetheless, there has always been far more environmental policy addressing packaging, because this is all-too-visible waste that ends up with the consumer. The many environmental impacts associated with the products themselves are far less conspicuous.

As things stand at the moment, governments tend to address indirect energy consumption by proxy, via their general energy policies for industry, waste processing and freight transport, for example. In the Netherlands, for instance, there are plans to create a separate carbon emissions trading scheme for greenhouse horticulture (indoor fruit and vegetables). There are also many examples of energy-saving targets being introduced for specific sectors, both voluntary and compulsory. Flower-growers in the UK, for example, have negotiated an energy-saving agreement with the government.

What can *you* do?

Buying something new is fun and many people love an afternoon's shopping for clothes, for example. Bear in mind, though, that each and every product takes a certain amount of energy to produce and distribute. When you're considering whether or not something's worth buying, don't lose sight of this 'embodied' energy, with the greenhouse gas emissions it implies.

When you do decide to buy something, choose the most climate-friendly option available. In the case of vegetables, for example, opt for local, seasonal vegetables grown outdoors rather than greenhouse vegetables or produce flown in by plane. Eat vegetarian (if you don't do so already), at least now and again, rather than sticking to meat; that not only saves energy, but also reduces pressure on farmland (see Figure 18). Eating vegetarian food one day a week will reduce your emissions by 220 kg CO_2 a year. You then also cut back on land use, freeing up space for growing crops for biofuels to drive your car (saving a further 310 kg CO_2 a year)[6].

When you buy new appliances or other things, why not go to a second-hand store or car boot sale? This will save money, too! Auction websites like eBay are useful here, but also local newspapers and recycling centres can often point you to the second-hand article you're looking for. When you throw something away, try and get it recycled whenever you can. In many countries glass, paper, household chemicals, electronic goods and organic waste can all be disposed of separately. Old clothes can be given a deserved second lease of life by donating them to charities involved in development aid or helping the homeless. When you don't or can't buy second hand, you could think about compensating for the greenhouse gas emissions caused by your new article's production. As mentioned earlier, there are now credit cards that automatically compensate for such emissions.

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[6] Source: CE Delft.

Finally, before you make your purchase, give proper consideration to how much of something you really need. In western countries vast amounts of easily perishable foodstuffs are simply thrown away, for example. Keep track of how much of the stuff you buy you're not actually using, and adjust you portions accordingly. If you read Dutch, you can do the 'throw-away' test on the website of Milieu Centraal[7]. In many cases, smaller (one-person) portions are better for the climate, even though they are fairly heavily packaged. The energy benefits then outweigh the impact of a little more packaging waste. This holds particularly for energy-intensive products like meat and dairy foods.

To summarise:

1 Be selective in what you buy.
2 Go for the climate-friendly option (vegetarian meals, local and seasonal vegetables & fruits).
3 Go for second-hand goods, recycle your throwaways, or buy climate-neutral.
4 Buy the right amount.

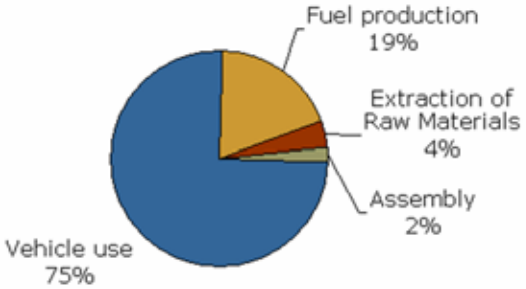
2.4.3 Chunk 3: Cars and planes

Cars, planes and other means of transport are a major source of greenhouse gas emissions. In order to reduce these emissions, many countries have policies promoting fuel-efficient vehicles, biofuels and public transport. You yourself can contribute by buying an efficient car (or asking your parents to), for example, by travelling less far and less often, and by cycling, walking and using public transport whenever possible.

Transportation as a source of greenhouse gases

Taken together, cars, vans, lorries, trains, aircraft, ships and other forms of transport are responsible for about one-seventh of the world's greenhouse gas emissions. We are talking here about the direct emissions of CO_2 caused by the combustion of fuels like petrol, diesel and kerosene. The indirect contribution of transport is far greater, though, because crude oil recovery and processing to liquid fuels also give rise to major emissions of greenhouse gases. And on top of this come the emissions occurring during production of the vehicle itself (see Figure 19).

Figure 19 CO_2 emissions during the entire life cycle of a car

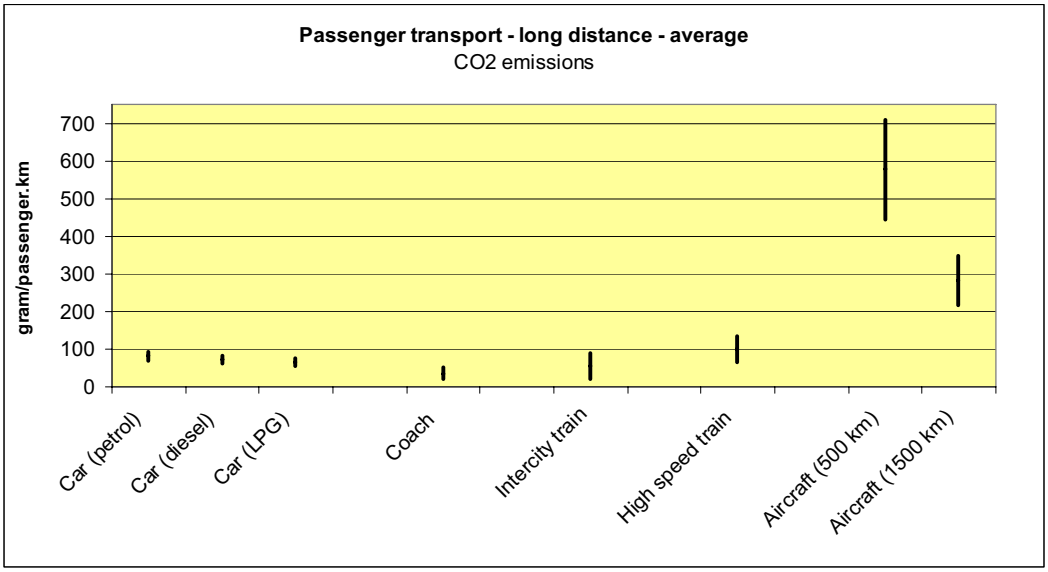


Source: World Resources Institute.

[7] www.environmental centraal.nl/files/PDF/weggooi-test.pdf.

There are considerable differences in the amount of CO_2 emitted by the various modes of passenger transport, as Figure 20 shows.

Figure 20 CO_2 emissions of various types of transport (gram per passenger per kilometre)



Source: CE Delft, 2003.

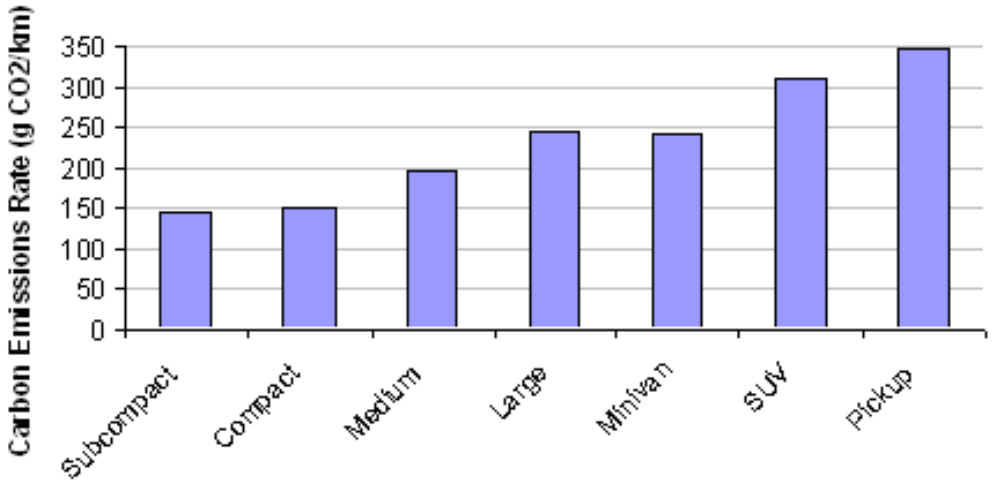
Perhaps the most noticeable thing is the huge difference between the emissions per passenger-kilometre of aircraft and other modes. Apart from cycling and walking, coaches are the most efficient form of transport (provided they are fairly full, of course). A train journey generally causes less CO_2 emissions than a car trip, but this obviously depends on the number of passengers, the fuel efficiency of the car and the driving style of the person at the wheel. High-speed trains use more energy than a normal intercity train, but not as much as planes. Especially on short flights, the per-kilometre CO_2 emissions of aircraft are extremely high. This is not to say that intercontinental flights score well on CO_2 emissions, though. Because of their long duration, these flights give rise to far greater overall emissions than short-haul flights.

Air travel
Travelling by air requires vast amounts of energy and produces huge quantities of CO_2. A return flight for two between Europe and the United States generates as much CO_2 as an average Dutch household does in an entire year.

Besides CO_2 aircraft also create condensation trails, or 'contrails', high up in the atmosphere, which are thought to lead to increased formation of cirrus clouds. The overall impact of these contrails is two to four times greater than the effect of the aircraft's CO_2 emissions alone (IPCC, 1999).

As noted above, CO_2 emissions depend not only on the type of vehicle you use for your trip, but also on its fuel efficiency and how it is driven. Large, heavy cars are generally a lot less efficient than smaller, lighter vehicles (see Figure 21).

Figure 21 CO_2 emissions of different-sized cars

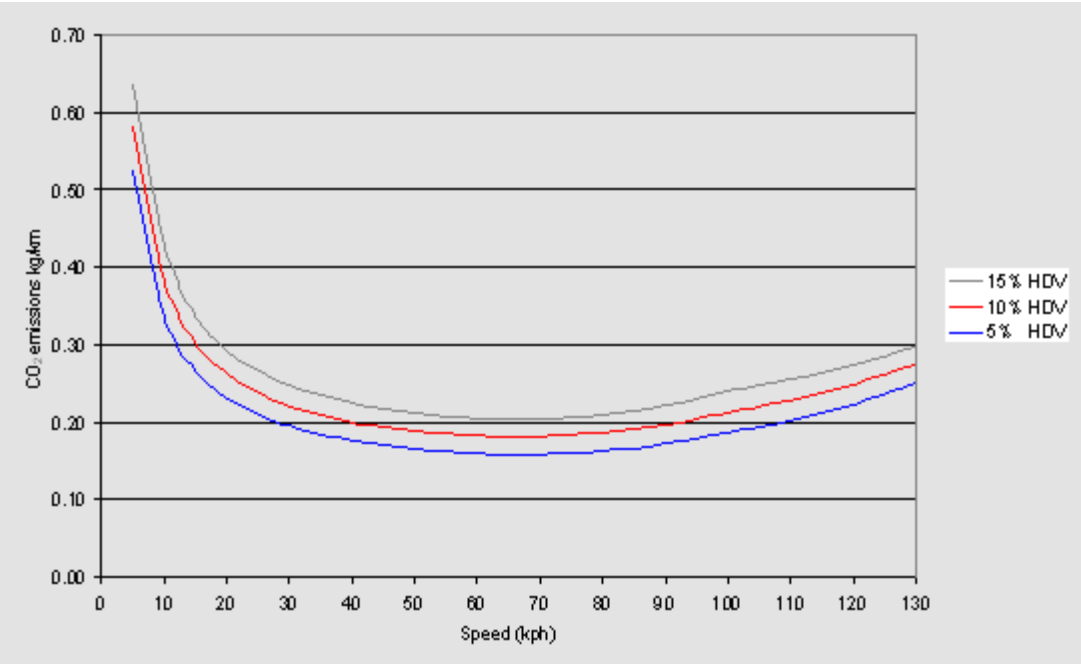


Source: World Resources Institute.

On average, a sports utility vehicle (SUV) emits twice as much CO_2 per kilometre as a small, compact car. Although this is due mainly to the far greater weight of an SUV, the fuel consumption of such vehicles is also governed by engine technology. With its hybrid engine, a car like the Toyota Prius, for example, has about half the CO_2 emissions of other cars in the same size category.

Finally, how the car is used and driven is also of influence on the vehicle's ultimate CO_2 emissions. Figure 22 shows how the CO_2 emissions of road traffic vary with driving speed.

Figure 22 Road traffic CO_2 emissions as a function of speed



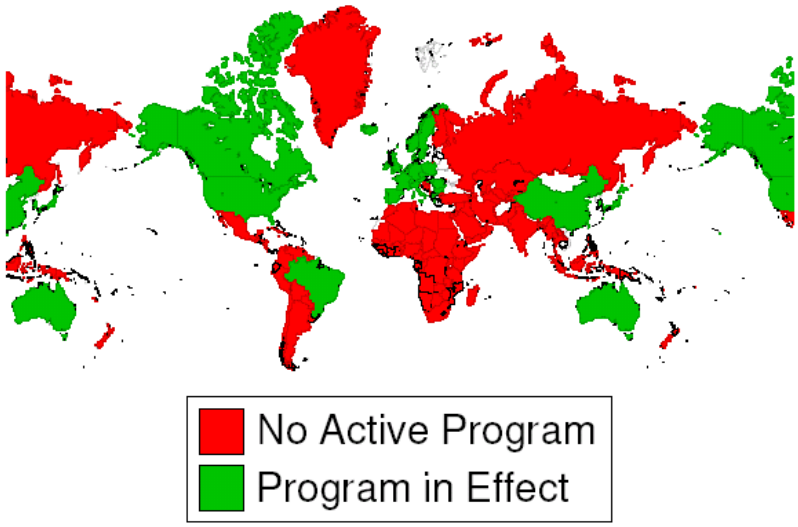
Source: UK Highways Agency.

As can be seen, driving at snail's pace gives rise to relatively high CO_2 emissions (per kilometre), while at high speeds, too, emissions are above average. Beyond an optimum cruising speed of about 70 km/h, the general rule is: the faster you drive, the more CO_2 you emit per kilometre.

Government policy to increase transport efficiency

Many of the world's countries have introduced programmes to increase the fuel efficiency of transportation systems and reduce the associated CO_2 emissions (see the map in Figure 23). Below we provide a few examples (see also CE Delft, 2006).

Figure 23 Countries with programmes to improve vehicle fuel efficiency and cut vehicle CO_2 emissions



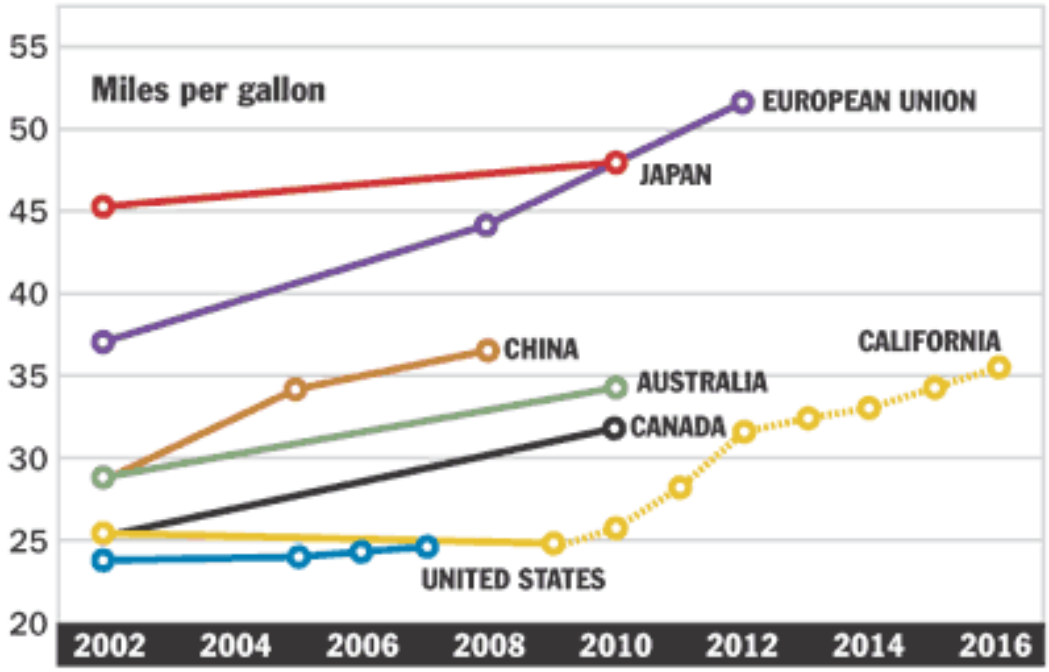
Source: Walsh, 2006.

Fuel-efficient cars

In Europe voluntary agreements have been negotiated with auto manufacturers on the fuel efficiency of cars sold in the European Union. As things stand at the moment, though, it seems unlikely these requirements will be met in practice. When buying a car, today's consumers are also given information on its fuel efficiency in the form of an energy label (similar to Figure 15). The European Union also has plans to index the vehicle tax paid on a car to its CO_2 emissions, making 'gas-guzzling' models relatively more expensive. In some European countries this kind of tax is already in place.

In California, from 2009 onwards car CO_2 emissions must meet efficiency standards agreed with vehicle manufacturers. It should be noted, though, that these targets are less ambitious than in Europe and indeed still far below *current* fuel efficiency in Europe and Japan. (see Figure 24). In the US substantial funds are being invested in research on more efficient vehicle technologies.

Figure 24 Fuel efficiency of passenger cars in various regions and countries



Source: Pew Center on Global Climate Change.

Biofuels

Biofuels are produced from plants like corn and oilseed rape, which take up CO_2 from the atmosphere as they grow. Such fuels have only a limited part to play in reducing greenhouse gas emissions, however. In some parts of the world like Brazil they are already in widespread use, but elsewhere conventional petrol and diesel are still generally more expensive than biofuels and most drivers therefore still fill up with these fossil fuels. The European Union has now drawn up regulations stating that in 2010 5.75% of all motor fuels sold must consist of biofuels (10% in 2020). Such targets have also been proposed in other countries: USA (2.78% in 2006, 30% in 2030), India (20% in 2020), Brazil (25% in 2006), Canada (3.5% in 2010), Japan (3% in 2006, 10% in 2010).

Besides their relatively high price, for the time being at any rate, biofuels also have a number of other drawbacks. This is because to grow biofuel crops you need farmland. If biofuels become too popular, they will start competing with nature and agriculture for available land. In the worst-case scenario this could lead to the extinction of plant and animal species and serious problems with the world's food supplies (CE Delft, 2007a). Nor are biofuels in fact climate-neutral, as is often presumed. Among other things, this is due to the fact that biofuel crops generally need artificial fertilisers, leading to large emissions of nitrous oxide. As a result, the net gain of biofuels in terms of greenhouse gas emissions may lie anywhere between 30 and 90% relative to petrol or diesel (climate-neutral is 100%). It is therefore important that research is carried out on new kinds of biofuels that are both more efficient in terms of land use and achieve greater savings on greenhouse gas emissions.

Air travel

Finally, the European Union has plans to include aviation in its carbon emissions trading scheme (see section 2.2). This would give airlines an incentive to burn fuel more efficiently, or otherwise pay for their greenhouse gas emissions.

What can *you* do?

A car is obviously a very useful and comfortable means of transport, and aircraft take you to your holiday destination in next to no time. But bear in mind just how much energy motorised transport requires. The faster and further you travel, the more energy you use and the more greenhouse gases you emit. To reduce these transport emissions, the same three golden rules again apply: first use as little energy as possible, then try and ensure that as much as possible of the fuel you do use comes from renewable sources (biofuels), and finally have your fossil energy use compensated for.

Minimise your energy consumption

- Travel as little as possible, i.e. less often and less far (it's better to take a long holiday somewhere close than go on lots of trips to far-away destinations).
- Avoid air travel, especially intercontinental flights.
- Use public transport whenever you can or, better still, cycle or walk.
- If you must use a car, make sure it's an energy-efficient model (for examples, see www.epa.gov/autoemissions or www.fueleconomy.gov).
- Adopt an efficient driving style: change through gears quickly, maintain a constant cruising speed, keep your tyres at the right pressure, and don't drive too fast (for tips, see www.ecodrive.org).
- Try not to use air conditioning in a car.
- Share a car with others; join in a car pool or, on safe routes, hitch-hike.

Use renewable sources

- If possible, fill up with biofuels (bio-ethanol, bio-diesel).
- Remember, though, that the production of bio-fuels may have a negative impact on nature, biodiversity and food supplies.
- For this reason, check if the biofuels you buy come with a guarantee they've been produced sustainably.
- With electric vehicles, use 'green' electricity.

Compensate for fossil energy

- Compensate the CO_2 emissions of your (overland or air) journey via a *bona fide* organisation; inquire about the sustainability of the compensation projects you are supporting.
- Buy fuel and tickets with a credit card that automatically compensates for greenhouse gas emissions.

2.4.4 Chunk 4: Coal and steel

This chunk of the discussion considers the heavy, energy-intensive industries: producers of electricity, steel, fertilisers, fuels, cement, aluminium and so on. Over the past few decades, governments in many countries have managed to achieve substantial improvements in industrial energy efficiency, but because demand for the products in question has continued to rise, the total amount of energy consumed by this sector has nevertheless increased. Although individual citizens have little influence on the actions of large, energy-intensive industries, if they act in concert together they can exert a measure of influence.

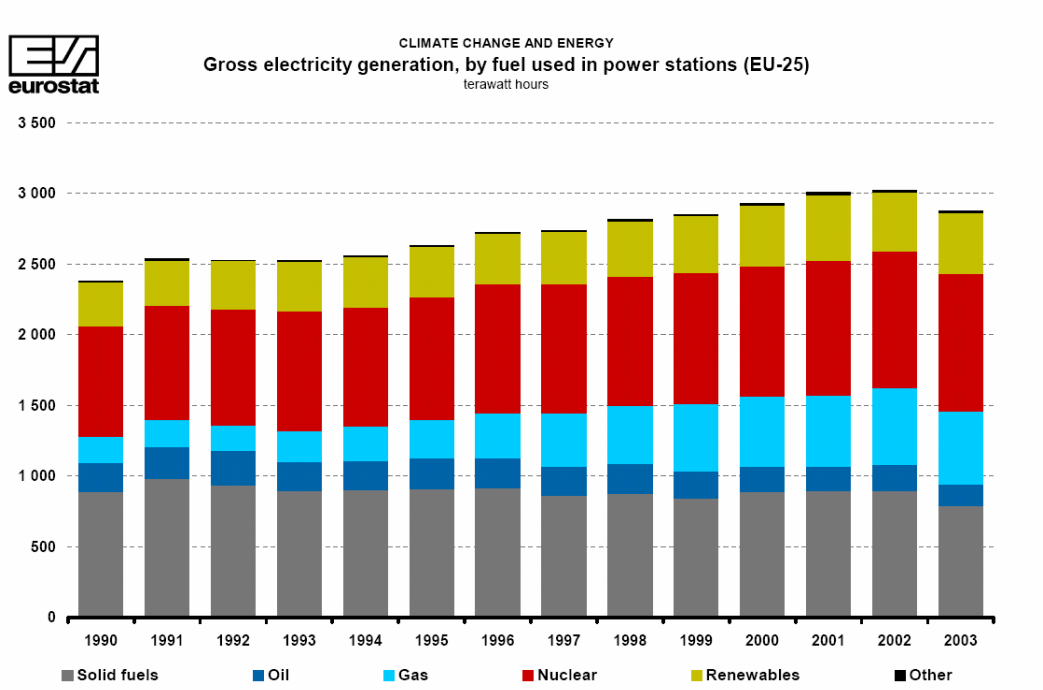
Energy-intensive industry as a source of greenhouse gases

Energy-intensive industrial processes are responsible for almost 40% of greenhouse gas emissions (Figure 9). Of that 40%, roughly half is due to electrical power generation, with the other half deriving from heavy industry (refineries, steel production and the chemicals industry).

Power stations

Most of the fuels burned in electrical power stations are non-renewable, as illustrated in Figure 25 for the situation in the European Union.

Figure 25 Electricity generation in the European Union, broken down by fuel type



Source: Eurostat.

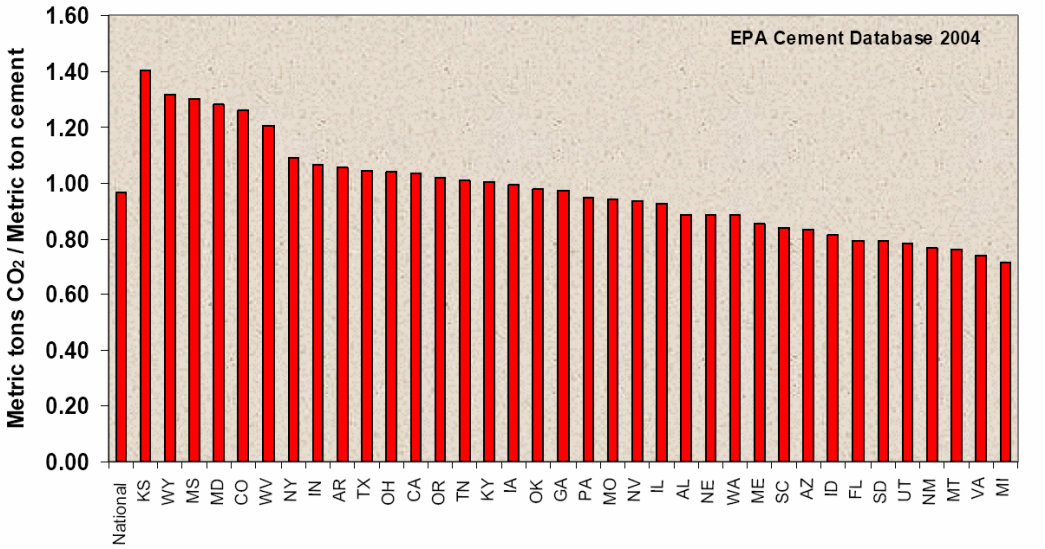
Per unit of electricity generated, coal-fired power stations (in the figure: 'solid fuels') produce far more CO_2 than oil- or gas-fired plants. As the figure shows, nuclear power accounts for a sizeable share of Europe's energy supply. There are people who advocate tackling climate change by building more nuclear power

plants. Although they have a point here since nuclear fission generates no CO_2, not everyone favours this solution. The energy required for extracting and processing the uranium ore and reprocessing the spent fuel later is generally fossil-based and is likely to increase as the richest ores are depleted. Over time, then, the net impact of nuclear power on reducing CO_2 emissions will decline. On top of this, there are the problems associated with processing and storing the radioactive waste, which remains hazardous for many thousands of years. Nuclear power is thus a controversial means of tackling climate change (see also Rathenau, 2004).

Industrial processes

There are huge differences in the amount of CO_2 emitted by various kinds of industrial processing plant and equipment with similar purposes. There are consequently still many options available for reducing the emissions of energy-intensive industries. As an example, Figure 26 shows the CO_2 emissions associated with the production of one tonne of cement in various states in the USA.

Figure 26 Comparative CO_2 emissions of the cement industry in various US states



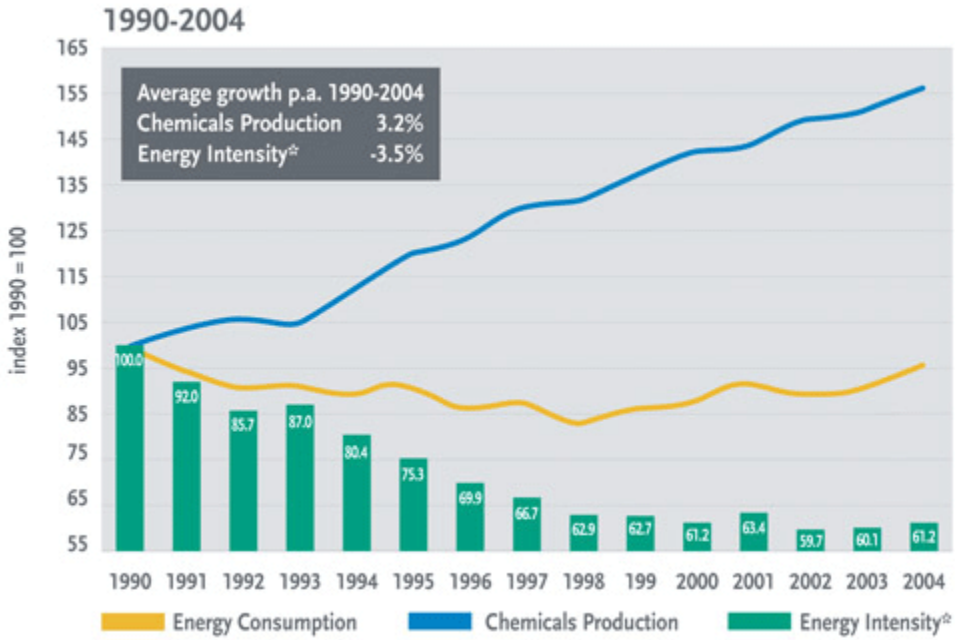
Source: EPA cement database, 2004.

As the graph shows, there are substantial differences in the CO_2 performance of the cement works in the various states, with a tonne of cement produced in Kansas generating almost twice as much CO_2 as in Michigan. This means that in theory there is still a great deal of scope for emission reduction.

Worldwide, the energy efficiency of the energy-intensive industry has improved. In other words, the amount of energy required to produce a unit of product has been gradually falling and so too, therefore, have greenhouse gas emissions per unit. While this so-called energy intensity has declined over the years, though, *total* energy consumption has in fact risen. This is because of growth in global

demand for electricity and all the other products of the energy-intensive industries. Growth in demand has thus outstripped improvements in efficiency. A typical example is shown in Figure 27.

Figure 27 Energy consumption of the chemical industry in the European Union



Source: Cefic.

As Figure 27 shows, the energy consumption of the European chemicals industry (yellow curve) remained roughly the same between 1990 and 2004, even though the production processes used became increasingly energy-efficient over the same period.

It is therefore not only up to the industries itself to cut their greenhouse gas emissions, for the customers buying their products can also play their part by reducing demand for those products. If the world's population started eating less meat, for example, there would be less growth in demand for the chemical fertilisers used to grow animal fodder. And if growth in demand for fodder slows down, efficiency improvements at fertiliser production plants can start kicking in to reduce overall energy consumption.

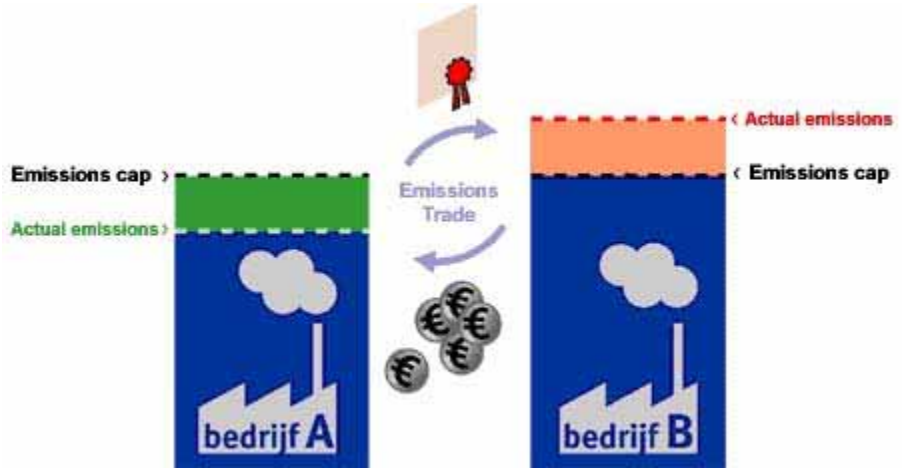
Government policy on energy-intensive industry

In many countries and regions governments have introduced policies to encourage energy-intensive industries to make more efficient use of energy and other resources. One problem facing many governments, especially in small nations, is that energy-intensive industries are often not bound to any one country. Over-stringent legislation in one country may prompt a company to move its operations elsewhere, with all the consequences for jobs implied. This is one of the reasons why governments frequently cooperate on these issues.

Emissions trading

As mentioned earlier, in 2005 the European Union introduced a collective scheme for trading in so-called CO_2 emission allowances, with all energy-intensive industries in principle participating. At the start of each successive phase of the scheme, each such industry is allocated a certain number of allowances, giving them the right to emit CO_2 up to a certain ceiling, or 'cap'. In each subsequent phase these caps are then progressively reduced. Companies that opt to take measures to reduce their emissions below their allocated limit can sell their surplus allowances to other companies discharging in excess of their ceiling. This gives industries an extra incentive to cut their CO_2 emissions. This European emissions trading scheme, or EU ETS as it is known, ensures that the aggregate CO_2 emissions of energy-intensive industries are guaranteed to decline. This is an improvement on agreements relating solely to energy conservation, a route often leading to a situation in which all the gains are often simply offset by increased demand, as demonstrated above.

Figure 28 Emissions trading



Source: Ecofys.

Underground CO_2 storage

Another solution on which government and industry often cooperate is research on technologies for capturing the CO_2 emitted by heavy industry and storing it underground (often referred to as 'sequestration'). In Norway trials have already been staged, with the CO_2 otherwise emitted during natural gas recovery being pumped back into the sea-bed (Sleipner project). In Canada the CO_2 generated by a coal gasification plant is now sequestered in an oil field (Weyburn project). And in Algeria CO_2 from the InSalah gas field is separated off and returned underground. The volumes of gas involved are fairly substantial: over 1 million tonnes of CO_2 per project per year. On its own, though, sequestration is not enough. For comparison: in 2004 the world's annual CO_2 emissions totalled over 25,000 million tonnes (IEA, 2006).

Renewable energy

Another option is to use more renewable energy rather than fossil fuels for electrical power generation. Some of the offshore wind farms installed in the North Sea and the Baltic now supply electrical power to over 100,000 homes, for example. Wind farms like these are now also planned off the coast of North America.

Figure 29 Wind farm off the Danish coast

Source: Dong Energy.

Other options

There are plenty of other options available for reducing the greenhouse gas emissions of energy-intensive industries. When it comes to 'greening' the power plants, for example, the possibilities are plenty (for a review, see for example FOM, 2002). Industries can also cut back on energy consumption and emissions by working closer together: indoor fruit and vegetable growers can put the industrial CO_2 emissions to very good use, to cite just one example. Still, many of these opportunities are not yet being exploited. This is sometimes because the technology is still too expensive (as in the case of solar power, for instance). In some cases it is also because government regulations make it (unintentionally) difficult to achieve potential CO_2 savings. But the main reason is probably that many of the most effective measures require collaboration between many different (kinds of) organisations. And however brilliant an idea may be, such collaboration is often hard to achieve.

What can *you* do?

Energy-intensive industries allow you to live a comfortable life in a solid home where you can plug in all your electrical appliances and enjoy good and varied meals all year round. They also provide cars and planes and the fuels to power them. Cutting back on energy consumption is thus not only the responsibility of industry but yours, too. Most of the things around you required energy to make and therefore involved CO_2 emissions, and the same holds true for many of your everyday activities.

On your own, it's obviously difficult to move these energy-intensive industries to use energy more efficiently. If you appeal to industry collectively, though, as a group, there's a far greater chance of success. There are various ways of getting your voice heard.

Green savings accounts
If you have a savings account with a bank, it will be using some of that money to invest in all kinds of industries. At many banks there is little transparency as to where your money is being invested. In some countries, though, there are banks that offer 'green' savings accounts. In these kinds of accounts, the money you save is invested exclusively in projects that meet certain environmental and/or social criteria.

Figure 30 Award for banks offering 'green' savings accounts

There are banks, for example, that invest principally in renewable energy. By putting your savings in a 'green' account, you can ensure that climate-friendly projects have a better chance of getting off the ground. If you're looking for a bank where you can open a 'green' savings account, visit www.equator-principles.com. Similar options are available for 'green' stocks and shares, and there are even 'green' mortgages.

Contact politicians
In most democracies you can write to your Member of Parliament and other (e.g. local) elected politicians, or contact them some other way. By letting your voice be heard you can try and convince them of your ideas. Again, there will obviously be more impact if it's a group that's putting the ideas forward. So if you have strong ideas about how to tackle climate change, try and find support for them and then put them to local or national politicians.

One of the best places to start is perhaps the C40 network, made up some of the largest cities in the world that have committed themselves to tackling climate change. The network is collaborating with the Clinton Climate Initiative. For a list of the cities participating and more information, go to www.c40cities.org.

Join an environmental organisation
If direct correspondence with politicians is not your thing, you can also go about it indirectly, as it were, via an environmental organisation. Many such organisations see it as one of their main aims to influence politicians and the boards of major corporations. In section 2.2 we already mentioned Green4sure, the green energy plan drawn up by the Netherlands' largest environmental and trades unions organisations. Another example is the 'Energy [r]evolution' plan launched by Greenpeace International (see www.energyblueprint.info). These plans seek to feed politicians and industry with ideas on how to work towards a green energy future.

By becoming a member of an environmental organisation you support their work. Major international organisations include:

- Greenpeace: www.greenpeace.org.
- Friends of the Earth: www.foe.org.
- WWF: www.wwf.org.

But there are many other groups and organisations working on tackling climate change and related issues, and there are sure to be initiatives in your area or region. So go and check them out!

3 Consequences and adaptation solutions

3.1 Introduction

In chapter 2 the causes of climate change have been discussed extensively. The boost of the global greenhouse effect is mainly caused by high concentrations of the substances carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Mitigating measures will be required to reduce these.
At this moment we can conclude that the mitigating measures still have to take effect, but that the consequences of climate change are already visible.

3.2 Consequences

The visible consequences are countless. For instance, temperatures are rising, polar caps are melting, sea level is rising, the desertification increases and the winters in Europe become ever wetter.

It has been scientifically demonstrated that Mount Kilimanjaro through the years contains less and less snow as a consequence of global heating. It is questionable whether this mountain in Tanzania will be covered with snow at all in 50 years.

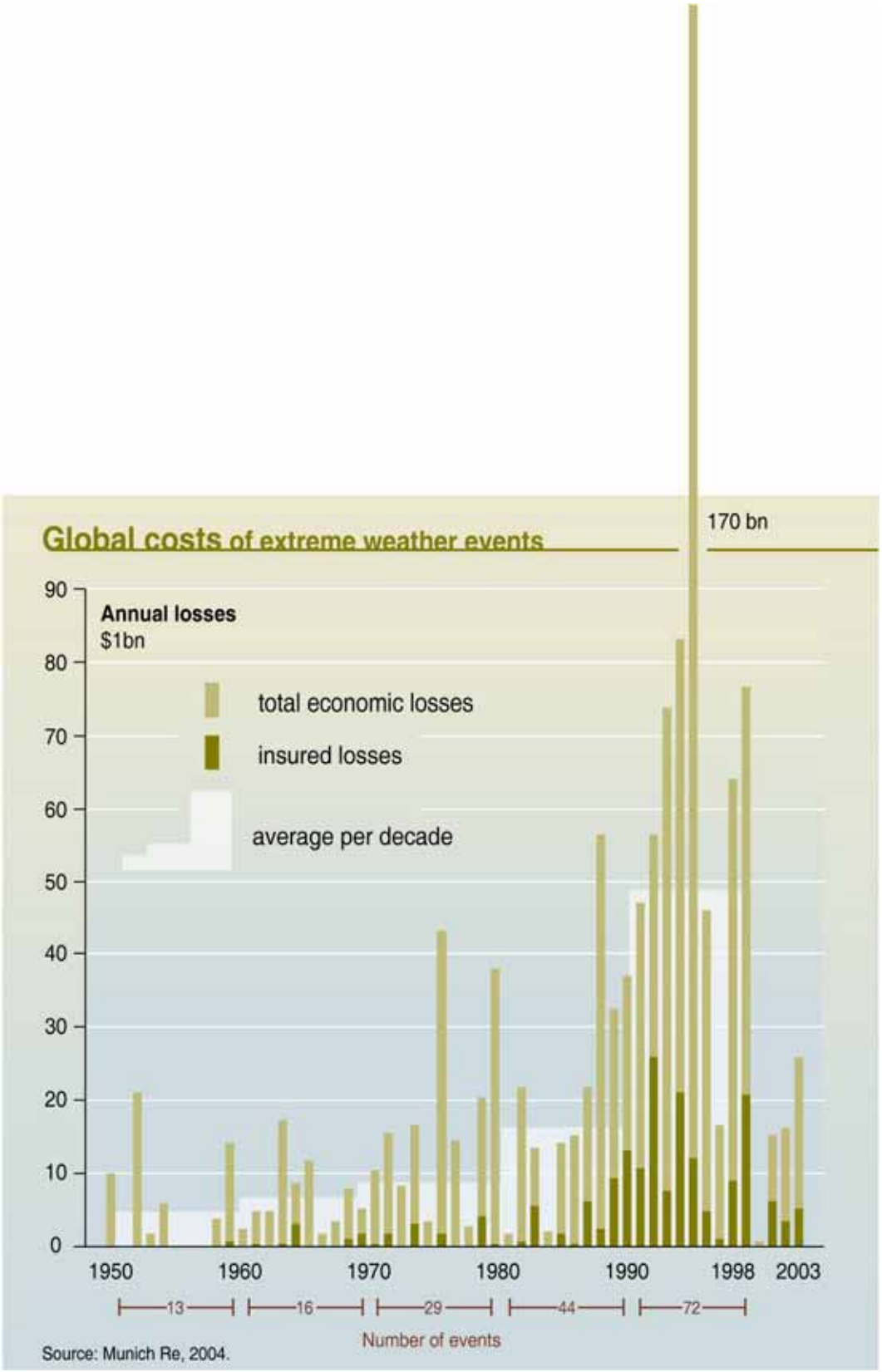
It is also concluded that the number of natural disasters increases more and more. Tsunamis, floods and extreme drought occur more frequent than in times past.

Figure 31 represents the costs of natural disasters in the course of time. The figure clearly shows that the frequency of the number of reported natural disasters increases. In the period 1950-1960 worldwide 13 natural disasters have been registered, against 72 in the period 1990-1998.

What's more, the costs of the natural disasters are increasing, which is an indication for the fact that the disasters become more and more extreme.

So, all in all, we shall be very concerned about the effects of climate change. Now already the consequences are clearly demonstrable and most likely they will only increase in extent and frequency in the future.

Figure 31 Global costs of extreme weather events



3.3 Solutions

Like the mitigating solutions, the adaptive solutions are also quite complex in nature, since they concern far-reaching consequences that cannot be dealt with easily.

3.3.1 Sea level rising / floods / water nuisance

Sea level rising/floods
When considering the rising of the sea level and the increased possibility of floods in the Netherlands we reach the conclusion that there are two courses to a solution. On the one side the Dutch can protect their country even better by raising the dikes and reinforcing the coastal areas. But by doing this, the consequences in case of a failure (the bursting of a dike) will only be worse. In fact, raising dikes will only be like building a high protecting wall around the country, creating a kind of 'bath tub' at the same time. If the protection wall fails the consequences will be greater.

Another adaptive solution is learning to live with floods. Instead of concentrating on reinforcing the protecting areas (dunes and dikes) we rather put our efforts in limiting the consequences. This too will reduce the risk. After all, risk is defined as opportunity x consequence. If the opportunity remains the same, but the consequences are less severe, the risk will decrease. And exactly the limiting of the consequences can be started off on local government level. You could think of local policies like 'no constructions in lower areas of the country' or on the contrary 'specially adapted constructions in lower areas of the country'.

In other parts of Europe such as England and Germany one is already busy along this line. In the first case (section 3.4) this matter will be further pursued.

Water nuisance
Apart from floods and other natural disasters such as tsunamis there is also local water nuisance caused by local showers. Europe has been swept by these the last couple of years. Particularly in the summer season occur increasingly heavy, short-lived showers. The nuisance caused thereby is streets that are flooded, sewers that run over and cellars that fill up. Especially the metalling of the soil (asphalting and paving) causes a faster flowing down of the water.

After the water nuisance of the early nineties one came to realize that the boundaries of the water control system are in sight. Pumping away all of the surplus water is no option on the long term. To be sure of dry feet in the future, the water needs to have more space.
The Dutch contribute their bit towards the changes in the water management in many ways. The Netherlands urbanizes in a tearing rush. The population increases, the economy continuous to grow, the number of farms decreases and the quantity of stone and asphalt increases. Which means there is less and less space for water. This process started already decades ago and will continue in the future. Where roads and streets lie and houses and businesses stand, the water cannot penetrate into the soil. The draining to the surface waters goes

much faster. Because of this the water control systems becomes less and less flexible, whilst we need more flexibility because of the climate change.

In the second case (section 3.5) this matter will be further pursued.

3.3.2 Drought/desertification and heat

Drought and desertification
About 40 percent of the earth's surface is taken up by deserts and dry areas, scattered over all continents. In total some 2 billion people live here. According to the influential 'Millennium Ecosystem Assessment' (MA) - the investigation of the changes of the eco systems on this planet, performed between 2001 and 2005 by 1,400 scientists - today 10 to 20 percent of that surface has been severely affected by erosion and further drying out. In an ever increasing pace fertile grounds are lost and water basins dry out. One fears that some seven basins spread around the world by 2025 will be severely under threat of drying out and that 14 of the most important drainage basins in the drought areas by 2025 will contend with salinization and water shortage.

Desertification is an expression that is used for both the advance or expansion of a desert, and the coming into being of new desert areas. These developments can be caused by both climatological circumstances and by man.
The climatological cause of desertification lies simply in the fact that areas can dry out when the precipitation decreases. If the lower threshold of 250 mm per year is no longer reached, we call this a desert area.

As for human causes there are more possibilities. Man can cause drying out of an area in different ways. Note that desertification can only occur if the climatological circumstances are suitable for that. For example, it is easier to let an area in Chad desertify than an area in Northern Europe. The causes mentioned underneath often result in uselessness of agricultural land, by which the area is left to nature and will by itself silt up, become saline and dry out and thus becomes unusable. In that case we talk of desertification.

Human causes of desertification are:
- Covered areas are burnt or cut down, for the wood and for the preparation of new agricultural land.
- Slopes are worked with farming machines, which causes accelerated erosion.
- Soil on slopes is worked in the wrong direction, which causes accelerated erosion.
- Agricultural land is exhausted due to the growing of one single type of crop: monoculture.
- Extraordinary exploitation of groundwater. This causes the ground water table to drop and the salinity to increase.
- Irrigation of agricultural land also leads to salinization and on the contrary to rising of the ground water table, causing the plants to drown.
- Reclamation for the agriculture of natural covered land.
- Water erosion leads to the washing away of agricultural land.

- Population growth leads to intensive use of, and increasing pressure on the agricultural land.
- Weak vegetation is used to pasture the cattle, by which an area becomes more vulnerable.

Furthermore desertification is a problem that affects to a considerable extent those countries and communities economically already in a weal position. Agricultural groups will be the first to encounter the pernicious consequences of the ever less rich harvests and the disappearing of fertile soil layers and vegetation. 250 million people already saw their quality of life seriously diminished by the ever more infertile land on which they are dependent and another 1 billion of others in 110 countries are endangered direct or indirect.

Moreover, the situation worsens noticeably. In Africa already half of the land has become unusable, and Asia turns into one big sandpit at a great pace. But also in America and Europe, where forest fires even recently reduced millions of hectares of land to ashes, some regions have become increasingly unusable to man.

The UN-plan that was passed in 1994 underlines a 'bottom-up'-approach, with which one wants to find particularly local solutions to prevent desertification together with the local communities. One tries to find the solution in sustainable development, tackling social, economic and ecologic problems at one time. A similar attitude requires quite a co-ordination and close collaboration between regional, national and international bodies, but environmentalists are not convinced that the political will to take measures is strong enough to turn the tide.

To resist the advancing desertification, in 1994 the Convention to Combat Desertification (CCD) was established, as a consequence of the Earth summit of 1992. The Convention, which in the meantime has been signed by 191 countries, entered into force in December 1996. To make degraded ecosystems fertile again is a long lasting process and requires an integrated approach of rural development, expansion of irrigation systems and application of new technologies. Still, it is possible. In China the quantity of fertile soil vanishing yearly dropped between 2000 and 2004. In February the Chinese government launched a plan to reclaim 250.000 square kilometres from the desert by 2020 by means of planting trees and grass. Also, the Chinese government wants to invest in dry regions in the efficient use of water and renewable energy sources, such as wind and water. Furthermore it is the opinion of the UN-Environmental organisation (UNEP) that where it is difficult to turn the tide, one should make a virtue of necessity. The story of a report that was published 5 June ran as follows: 'As long as deserts become more inhospitable and less suitable for human habitation, we must be imaginative and take advantage of the new situation'. UNEP sees an important potential particularly for the exploitation of solar energy, fish-production, research of the medicinal properties of desert plants and the breeding of crops resistant to drought and salinity. Also, new technologies to develop more efficient irrigation systems and to desalinate estuaries could help.

In the third case (section 3.6) this matter will be further pursued.

Heat
Temperature rise caused by climate change can in extreme situations (heat) have a direct negative impact on the human health. Possible health effects in Europe are: problems by heat stress, increase of the spreading of Lyme's disease, effects of bad air quality (summer smog) and an increase of allergies. Population groups at high risk (such as the elderly, children or asthmatic people) may experience stronger effects (a greater sickness burden).

Policy can play an important role in the limiting of the health effects of climate change. The Netherlands ought to be capable to resist certain health effects of climate change, by means of the maintaining/improving of existing policies or with new policy decisions. Little is known about biological or passive adaptation of man to climate change (for example acclimatization, immunization). Possible policy options/adaptation possibilities are amongst others:

- Improving of living conditions - e.g. air conditioning, ventilation.
- Improving of preventive/curative health care - e.g. personnel with special educations, vaccination.
- Monitoring/alarm systems.
- Public information / education.

Some adaptation possibilities will be more effective and/or cost-effective than others.

In the fourth case (section 3.7) this matter will be further pursued.

3.3.3 Heating and melting of the polar caps

According to researchers of the University of Colorado, the melting of the Northern polar cap will happen three times faster than the Climate commission of the UN thinks. According to the Climate commission of the UN in 2050 it will be so warm that the Northern polar cap will vanish completely during the summer.
However, researchers of the University of Colorado bring an even more alarming message in a press report. Julienne Stroeve of the American university claims that the melting of the polar cap will happen three times faster than determined by the UN commission.
Whereas several months ago the Intergovernmental Panel on Climate Change (IPCC) of the UN still argued that the Northern polar cap melts away with a rate of 2.5 percent per ten years, Stroeve claims that the polar cap diminishes about 7.8 percent each decennium.
The melting of the polar caps obviously results in rising of the water level. Liquid water as it happens has more mass than ice. Apart from that, the liquid water will expand too because of the global heating. This will cause the water level to rise even faster.

Snowball
Also, the crumbling off of the polar caps will speed up the global heating process. Because the polar caps melt away, less solar rays are reflected by the white ice. The increased water quantity formed around the polar caps because of the melting, absorbs the heat readily. This warmer water subsequently causes the polar cap to shrink even faster.

According to many researchers the consequences of global heating are considerable. The heating will not only cause the sea level to rise, but also more extreme weather types and the melting of glaciers. Apart from that, also animals will get into trouble because of the global heating. For example, research of the Alaskan Scientific Centre revealed some time ago that the chances of survival of polar bear cubs in the area around the Beaufort Sea have dropped substantially in recent years.

In the fifth case (section 3.8) this matter will be further pursued.

3.4 Case 1: Floods and dikes (sea level rising)

Increased discharge of rivers and the rising of the sea level threaten the low-lying areas. The inhabitants of the low-lying areas feel safe because of the dikes and dunes. Measures that can be taken are: higher dikes and dunes or modification of for example the houses. In this case the shifting of responsibility (from government to local authorities) is considered and increase of consciousness of youth. For example gaining points by modifications in the surrounding area to raise/strengthen the dikes.
The modifications can be either small-scale or large-scale:

- No wooden- or parquet floors and/or valuable equipment on the ground floor.
- Floating houses.
- Houses on poles.
- Prohibition to build houses in low-lying areas.

3.5 Case 2: Water nuisances

Water nuisances in urban areas have various causes. Often the dimensions of the sewer system are inadequate and there is so much metalled area (asphalt, pavements) that the water cannot drain away fast enough. In this case the player can enter into the role of municipal official. Points can be gained by creating more space for green (shrubbery/parks) and water (ponds) in the residential areas. Penalty points are awarded for the construction of new housing estates and streets with little space for water.

3.6 Case 3: Desertification (draught)

Deforestation and heating up are the causes that areas around the equator become dryer and hotter. In this case points can be gained for example by the economical management of water. These points can be used to buy trees that will prevent the desertification and provide for shade in the village of the player.

3.7 Case 4: Overheating (health)

People can encounter heat stress caused by the rising temperature and a good chance on heat waves (Europe). This is especially true for the elder. More deaths will be the consequence. There is a lot of very pleasant solutions to devise in cities to prevent this: more swimming water, cooling systems, more shade from trees, better air conditioning (in a sustainable way of course), etc.
Other consequences for man are more troubles by plagues. The tick is a good example in The Netherlands. Because of the failing of severe winters the animal spreads. Another example is the Asian tiger mosquito that has been spotted in The Netherlands and that can spread illnesses that normally occur in Africa.

3.8 Case 5: No ice, no polar bear (bio-diversity)

The melting of the polar caps changes the climate of life for the fauna on the Arctic. In this case attention will be paid to this aspect. The idea is that the player has the responsibility whether or not the polar bear will be extinct. The temperature at the Arctic can be controlled by certain behaviour. It concerns not only the space/climate of life of the polar bear but also the food supply.

4 Climate Quests

The online game 'The Climate Quest' is introduced by the Climate Change Oracle of Nostradamus, the scientist and seer who in 1555 predicted that a drastic climate change would take place around the millennium.
Children ages 10-14 are asked to help solve this oracle by solving questions/quests. The more quests are solved and levels are gained, the closer the player gets to the solution of the oracle.

The game aims to inform youngsters about the causes and consequences of climate change and challenges them to take action against climate change themselves.
It is an online serious game. The game is fun to play, and while playing, the youngster are handed relevant information. A serious game appeals to youngsters because it is offered through a medium that is very important in their every day live and relates to the way they see their world

Level 1: footprint
The first quest is for a player to determine his or her own climate footprint. How much time do you spend watching TV? Do you eat a lot of meat or canned food? How do you get to your holiday address? Do you have a lot of electrical appliances? All these things use energy, and the more energy you use, the more CO_2 is produced, multiplying the greenhouse effect. Each player has it's own avatar, with feet that show the size of the players footprint. Players can decrease their footprint by solving the quests, because this raises the player's awareness of the climate change problem and of the things he or she can to do him or herself to help battle this problem.

Linking with (inter)national policy
The quests deal with the causes, consequences and possible solutions for climate change, and cover a broad spectrum of climate-related and social topics, such as saving energy, (public) transport, fossil fuels, sustainable energy, sea level rise, CO_2 storage, energy consumption of household appliances, consumption, climate policy, new technological solutions, own responsibility, etc. If possible, links are made with current (inter)national climate policy. There are, for instance, quests that deal with the Kyoto protocol and with Dutch policy to effectively deal with possible flooding in the future.

Live Maps
Each quest is linked to a location on Earth. The player has to direct his or her avatar to that location on Live Maps to start the quest. For example, for the quest about palm oil, the player sends the avatar to Kalimantan, Indonesia, to investigate the consequences of palm oil plantations. For the quest about desertification the players avatar visits Azerbaijan, Kenya, China and Spain to discover the relationship between desertification and climate change. And for the

quest about transport, the avatar becomes a globetrotter, discovering the CO_2 emission of several modes of transport while travelling.

Number and type of quests

The first sixteen quests all use a multiple choice answer format. Multi choice ensures unambiguous answers that can be awarded with points. If the player has earned enough points, he or she moves on to the next level. Every time the player completes a level, they can play a climate mini-game.

Most of the quests are single-player, but some require sixteen players, joined in a guild. For guild quests, the players have to work together to successfully fulfil the quest.

Three example quests are presented in appendices A to C.

The number of Climate Quests can grow through addition of user-generated content. Teachers and NGO's can add their own quests, designing them in a fixed format. They can use multi choice answers or review the answers themselves. The last option can be used to stimulate students to undertake real life action against climate change and earn points for it in the game.

Background material

This background document was used to design the first sixteen quests. Additional information was used from the internet and existing education material, such as the Check it Out! material for the footprint. For some quests, the player needs to refer to internet sites to answer the questions asked.

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SME Advies

Climate change: causes, consequences, and solutions

Scientific background to the on-line platform Climate Quest

Background document

Delft, September, 2007

Authors: Rens Kortmann (CE Delft)
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A Climate Quest: Fart Farm

Title	Fart Farm
Location	Texas (USA)
Genre/theme	Farming
Introduction	Solve the climate mystery of the farting cow. A cow farts. This is because the grass ferments in the cow's stomach. Answer every question within two minutes. You'll find the answers on the internet or in the library.
Deadline	2 min. per question
Number of multiple-choice questions	5
Person or Guild (number of participants)	1 avatar
Objective/mission/task	see introduction
Oracle Level	3
Allocation of points	2 points for each correct answer. Minimum of four correct answers.

Content

Question 1. What gas does a cow's fart consist of?
a Laughing gas
b Methane
c CO_2

Pop-up: *Right. A cow's farts consist of methane. When food is digested in one of the cow's stomachs, bacteria produce methane.*

Question 2. How harmful is this gas compared with CO_2?
a 0.6 times as harmful
b 11 times as harmful
c 23 times as harmful

Pop-up: *That's right. The effect of methane is 23 times greater than that of CO_2. Yet methane contributes only 4-9% to the greenhouse effect. That's because there is much less methane in the air than CO_2.*

Question 3. Methane is a greenhouse gas and is 23 times more harmful than the greenhouse gas CO_2. Let's say that a farmer has 70 cows. One cow produces an average of 90 kilos of methane a year through cow-pats and farts. How much equivalent of CO_2 do the cows produce together?
a 274 kilos of CO_2
b 6,300 kilos of CO_2
c C. 144,900 kilos of CO_2

Question 4. Can you do something to reduce the amount of methane in the world?
a Yes, by travelling less by car.
b Yes, by eating less meat.
c No, I can't do anything about it.

Pop-up: *Right! If you eat less meat, fewer cows are needed and so less methane enters the air.*

Question 5. Cow manure can still produce energy and this energy is sustainable. What method is used to generate this energy?

a The manure is fermented to produce biogas, which produces energy when it is burned.

b The manure is burned, which immediately produces energy.

c The manure is gasified, producing biogas that supplies energy when burned.

Pop-up: *Right. Manure is wet and can therefore be fermented. This process produces biogas, which supplies energy when burned. The process also generates heat, which you can use to heat the farm, for example.*

B Climate Quest: Globetrotters

Title	Globetrotters
Location	
Genre/theme	Travel and transportation
Introduction	You go on holiday. Once you've arrived, you're assigned the location below. Part of your holiday consists of travelling by a means of transport. But how do you do this in the most environmentally friendly way possible?
Deadline	4 minutes per question = 55 minutes in total.
Number of multiple-choice questions	13
Person or Guild (number of participants)	1
Objective/mission/task	Go on a trip and find out what it costs.
Oracle Level	1
Allocation of points	

Question 1. Travel to the city with a population of 22 million that lies next to Popocatépetl. Then you'll get more questions.

Question 2. Great! You've arrived in Mexico City. What was the city called in the time of the Aztecs?

a Constantinople
b Tenochtitlan
c Hultzilopochtli

Pop up: *Oh dear/Right. In the time of the Aztecs, around 1500, the city already had a population of 200,000 and was called Tenochtitlan.*

Question 3. Find the highest building in Mexico City and enjoy the beautiful view. What is the highest building?

a Torre Mayor
b Templo Mayor
c Zocalo

Pop up*: Oh dear/Right. At 225 metres high, the Torre Mayor is not just the highest building in Mexico City but in all of Latin America.*

Question 4. The Torre Mayor will not be the highest tower in Mexico City for long. How high will the biggest tower in Latin America be in 2010, which is designed by Rem Koolhaas?

a 250 m.
b 300 m
c 350 m

Pop-up: *The tower with the name 'Torre Bicentenario' designed by the Dutch architect Rem Koolhaas, will be ready in 2010. It consists of two mirrored pyramids on top of each other and will mark the celebration of the Bicentenario: the two-hundredth anniversary of Mexican independence and the hundredth anniversary of the Mexican revolution.*

Question 5. You're standing on the Torre Mayor and can see the Pasea de la Reforma? What is it?

a A historical museum about the Reformation
b A park
c A major arterial road

Pop-up: *Right /Oh dear Pasea de la Reforma is a major arterial road through the city and is 12 km long.*

Question 6. Why is the city notorious for its traffic?

a The cars are not longer than 1.5 metres. Otherwise there is not enough parking space.
b The traffic causes a lot of smog that cannot escape because of the position of the city.
c All the cars are powered by hydrogen.

Pop-up: *Mexico City is one of the biggest cities in the world. It has a population of approximately 22 million and is continuing to grow. It is sometimes said that breathing the air for a day in Mexico City is like smoking a pack of cigarettes. Smog is intense and air pollution and can cause breathing problems in humans and animals. Particularly in the winter months when cold air hangs over the valley and, because of inversion, air is prevented from rising out of the city, the air is heavily polluted.*

Question 7. What substance do cars emit that causes smog?

a Carbon dioxide (CO_2)
b Nitrogen oxides (NO_x)
c Methane (CH_4),

Pop-up: *Right/ oh dear.* ***Nitrogen oxides (NO_x)*** *react with oxygen in sunlight to produce ozone. When there is no wind and the weather is stable, the ozone is not dispersed. We call this summer smog. Summer smog leads to health complaints and damage to (agricultural) plants. We call the mixture of mist and air pollution in the winter (mostly soot that comes partly from diesel cars) winter smog.*

Question 8. What greenhouse gas do cars emit?

a Methane (CH_4),
b Carbon dioxide (CO_2),
c Laughing gas (N_2O)
d Gases containing fluorine

Pop-up: *all of the above substances are greenhouse gases and contribute to an increased greenhouse effect. Cars emit CO_2.*

Question 9. Let's say that 100,000 cars use the 12 km long highway every day. They drive along it in the morning and back in the evening. The cars are petrol powered and consume 1:12 (1 litre of petrol per 12 kilometres). How much CO_2 would these cars emit? On the internet you'll find several calculation tool to help you out.

a 444 kg
b B .4 million kg
c C.444,000 kg (444 tonnes)

Pop-up: *Oh dear/Right. The 100,000 cars drive 24 km in one day. That makes 2,400,000 km or 2.4 million km. If you fill in the consumption as 1:12 (one on twelve or 1 litre of petrol per 12 kilometres) and fill in the fuel as petrol, you'll see that together the cars emit 444,000 kg of CO_2 per day. You yourself consume approximately 9,000-12,000 kg of CO_2 per year! Can you imagine what it would be like if there were a couple of million cars driving around Mexico City each day instead of 100,000?*

Question 10. How would you reduce the emissions?

a With a fuel that emits less CO_2 than petrol does, like gas (LPG).
b With more economical cars that can drive for longer on 1 litre of petrol.
c By carrying more people in the cars.
d By using public transport.
e A and C are right.
f B and D are right.
g A, B, C and D are right.

Pop-up: *Right/oh dear: The sort of fuel, how economical the car is, how many people drive with you, all can contribute to reducing the CO_2 emission per person per kilometre.*

Question 11. You have visited Mexico City and are flying from Mexico City's Benito Juarez airport to Charles de Gaulle airport in Paris.
How much CO_2 emissions will this one-way trip by aircraft cause? Find on the internet a CO_2 calculation tool to help you out!

a 1.05 tonnes of CO_2. Exactly the same as an Indian's yearly consumption of CO_2.
b **2.02 tonnes. Almost twice as much** as an Indian's yearly consumption of CO_2.
c 3.15 tonnes. Three times as much as an Indian's yearly consumption of CO_2.

Pop-up: *Right/Oh dear. 2.2 tonnes. That is almost twice as much CO_2 as an Indian emits in one year. And that's only a one-way trip!*

Paris. Find the Eiffel Tower and wait there for a few more questions.

Question 12. The Torre Mayor in Mexico City was 225 metres high, but how high is the Eiffel Tower?

a 230
b 300
c 324

Pop-up: *Right/Oh dear The Eiffel Tower is 324 metres high.*

Question 13. You climb the Eiffel Tower and see the gigantic city. As well as a metro network, Paris has had another system for reducing car traffic in the city since 2007. It's known as Vélib. What sort of system is this?

a A bicycle lending system.
b A Light-rail system.
c Tuk-tuks.

Pop-up: *In the summer of 2007, the Vélib's (Vélos Libres = free bicycles) bicycle lending system was introduced. Mayor Bertrand Delanoë wants fewer cars in Paris. The number of cycle lanes has doubled, there are now trams and the Seine embankments are closed to cars every Sunday in summer. Now a bicycle lending system has been introduced. You can borrow a bike at 750 places in the city. There are a total of 10,000 bikes available and there are going to be a lot more. In this way, as a Parisian or a tourist, you can travel across the city climate-neutrally, so without CO_2 emissions. Nice idea, don't you think?*

Question 14. It was a brief visit to the city. You decide to travel back to Amsterdam. How are you going to do that in the most environmentally friendly way? Use the table below for this.

a With a high-speed train that is not powered by nuclear energy (0.16).
b Modern car with two passengers, with a caravan. Diesel powered (0.25).
c With a modern car with four passengers, plus roof box. Powered by LPG (gas) (0.07).
d By coach on a regular timetable (0,06).
e With a modern, scheduled economy class flight on a 737-type aircraft (0.44).

Pop-up: *Right/Oh dear You'll get to Amsterdam in the most environmentally friendly way in a scheduled coach. That will involve the least emission of CO_2 and the least air pollution. The most environmentally unfriendly is the modern economy scheduled flight.*

Environmental pollution for a return trip Amsterdam - Paris per passenger

Mode of transport	Measure of environmental pollution
Coach (built in 2000), charter	0.04
Coach (built in 2000), scheduled	0.06
International train (without nuclear energy/ with nuclear energy)	0.09/ 0.07 *)
High-speed train (without nuclear energy/ with nuclear energy)	0.16/ 0.12 *)
Modern car (built in 2000), with four passengers, without caravan and without roof box, petrol/diesel/LPG	0.07/ 0.08/ 0.06 **)
Modern car (built in 2000), with two passengers, without caravan and without roof box, petrol/diesel/LPG	0.13/ 0.16/ 0.12 **)
Modern car (built in 2000) with four passengers, with roof box, petrol/diesel/LPG	0.08/ 0.10/ 0.07 **)
Modern car (built in 2000), with two passengers, with roof box, petrol/diesel/LPG	0.16/ 0.19/ 0.15 **)
Modern car (built in 2000) with four passengers with caravan, petrol/diesel/LPG	0.11/ 0.13/ 0.09 **)
Modern car (built in 2000), with two passengers, with caravan, petrol/diesel/LPG	0.21/ 0.25/ 0.20 **)
Modern charter/ low-cost airline, aircraft type 737-800 and 900	0.31/ 0.34 (between 0.17 and 0.58) ***)
Modern economy class scheduled flight, aircraft type 737-900 and 800	0.44/ 0.45 (between 0.24 and 0.76) ***)

*) Without nuclear energy/with nuclear energy. The calculations with nuclear energy lead to 25 percent less environmental pollution (less CO_2 emissions). But the problems with nuclear energy (such as radioactive waste) are not included. These cannot be expressed in "CO_2 equivalents".

**) Older cars (built before 2000) cause more environmental pollution than modern cars (built in 2000 and later). Older petrol-engined cars cause about 70% more environmental pollution than modern ones. Older cars that run on diesel and LPG cause 30 to 40% more environmental pollution than modern ones.

***) There is great uncertainty about the environmental pollution (air pollution, greenhouse effect) of air traffic. The best estimates have been used in the calculations. This leads to a value of 0.31/ 0.34 for charters and 0.44/ 0.45 for scheduled economy class flights. So the actual contribution of greenhouse gases can be 50% lower or 70% higher. That leads to a value between 0.17 and 0.58 for charters and between 0.24 and 0.76 for scheduled economy class flights.

Pop-up: *Welcome to Amsterdam! The next time you take a trip, you'll know which ways are the most climate-friendly. Have fun!*

C Climate Quest: Energy Dance

Title	Energy Dance
Location	
Genre/theme	Energy conservation
Introduction	Scientists, engineers and companies all over the world are busy searching for all sorts of ways of reducing the use of fossil fuels and saving energy. This will make it possible to make our stocks of fossil fuels last longer and we'll also emit less CO_2. The Netherlands, as well as other countries that have signed the Kyoto protocol, is obliged to reduce its CO_2 emissions compared with 1990.
Deadline	3 min. per question, 15 minutes in total
Number of multiple-choice questions	5
Person or Guild (number of participants)	1 avatar
Objective/mission/task	See introduction
Oracle Level	2
Allocation of points	-
Content	

Question 1. When you go to a discotheque and dance, your body uses up energy. However, your feet and dance movements can also generate energy. That's the idea behind the sustainable dance floor. The floor is constructed to convert the dance movements into electricity. The first sustainable dance floor will appear in Mytown, a discotheque in Rotterdam. What will they do with the generated energy?

a The energy will be used for cooling drinks.
b The energy will be recycled to the power company.
c The energy will be used for the discotheque's LED lighting.

Pop-up: *The energy that the sustainable dance floor generates will firstly be used for the lighting. This new idea for a sustainable dance floor was thought up in 2007 by the Sustainable Dance Club (SDC). Delft University of Technology is going to build it. Many world cities have already shown interest in the dance floor that can generate energy.*

Question 2. Here you can see an example of an idea for emitting less CO_2 and saving fossil fuels by generating sustainable energy from wind power. This is a wind turbine on the motorway. The idea is not yet economically feasible but who knows? Maybe you'll see these wind turbines over the motorway in a few years' time.

Why did they think of placing the wind turbine over the motorway?

a It looks less ugly in the landscape.
b Because of the traffic, there's more air displacement and thus more wind.
c A motorway has no obstacles and buildings, so there's always wind.

Pop-up B: *Right/Oh dear. When you drive a car from A to B, you don't just move yourself but also a huge amount of air. Scientists are looking for a way of capturing this air and converting it into sustainable energy.*

Question 3. Traffic lights using bulbs are increasingly being replaced with traffic lights that use LED lamps. What does LED stand for?

a Light Energy Diode.
b Light Emitting Diode.
c Light Energy Durable.

Pop-up : *Right/Oh dear. LED stands for light emitting diode. A diode is an electronic component that allows electricity to flow in one direction only.*

Question 4. Why are LEDs used in traffic lights?

a Because the lamps last a long time.
b Because of the different colours that are possible.
c Because the lamps are less likely to catch fire.

Pop-up: *Right/Oh dear: LEDs are little lamps that last a very long time – typically lasting 50,000 to 100,000 hours. By comparison, a normal bulb lasts about 1,000 hours. So, for example, traffic lights break down less often. These lamps also offer a solution for high buildings and places that are difficult to get at.*

Question 5. LEDs have another advantage: they use much less energy than a light bulb. LEDs convert 50 to 100% of the electricity into light, while light bulbs convert only 5%. Is the yield of an LED lamp higher or lower than that of a light bulb?

a Higher.
b Lower.
c The same.

Pop-up: *Right/Oh dear. The yield of an LED lamp is much higher than that of a light bulb. It's also getting much easier to buy lamps with an LED system for use in the home.*

Question 6. Why are LEDs used a lot in museums?

a They are small and unobtrusive.
b They use less energy.
c They produce no ultraviolet radiation and heat.

Pop-up: *Right/Oh dear. LED lamps produce no ultraviolet (UV) radiation or heat, which are harmful for paintings, for example. According to engineers, there will be more new applications for LED lamps in the future. If you would like to know more about LED lamps surf the internet or visit your local lighting store.*

Question 7. Can you find another technology or solution for saving energy? Write your answer below.

Climate Quest is gerealiseerd met financiële steun van de volgende partijen:

Ruimte voor Geo-Informatie

provincie limburg

msn

essent

Solland

solar | glass Scheuten

De volgende partijen werkten mee aan de realisatie van Climate Quest:

RPS

YELLOW Communications

SME Advies

International Hydrological Programme of UNESCO

CE Delft

GOAL043 scoren door innovatie

ALTERRA WAGENINGEN UR

wizzard web solutions

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