Climate OptiOns for the Long Term – Final Report

Volume C

European Dialogue

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Abstract

This report contains the results of the European Dialogue of the COOL (Climate Options for the Long Term) project. The European Dialogue is one of the three Dialogues within the COOL project, the other being the Nation Dialogue (focused on the Netherlands) and the Global Dialogue. The European Dialogue brought together some 40 non-governmental and governmental stakeholders from different countries around Europe to assess in a participatory way the strategy for far reaching greenhouse gas emission reductions in Europe in the long term (till 2050). The European Dialogue was organized in two major groups, the energy sector and the transport sector, which have met four times for 1-2 days in one and a half year. Following a backcasting methodology and with input from scientific institutions both groups have discussed and developed options that can contribute significantly to 80% GHG emission reductions in 2050, compared to 1990 levels. The final outcomes of this participatory process with a very diverse group of stakeholders are two strategic visions, which are shared by the participants of these dialogues. The strategic visions show that 80 GHG emission reductions seems technologically possible over a time period of 50 years. The major bottlenecks are to be found rather in non-technological factors: institutions, price signals, behavioral changes, and international developments.

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1. INTRODUCTION

M. Andersson, W. Tuinstra and A.P.J. Mol

1.1 The COOL project

The COOL (= Climate Options Over the Long term) project is a research project financed by the Dutch National Research Programme on Global Air Pollution and Climate Change (NRP) and has a twofold objective (COOL project proposal, 1998):

- developing strategic notions how drastic reductions of greenhouse gas (=GHG) emissions in the Netherlands can be achieved in the long term, in a European and global context, using a method of participatory integrated assessment;
- making recommendations for improving the methodology of participatory integrated assessment, in particular regarding (1) stakeholder participation, (2) utilisation of knowledge by stakeholder participants, and (3) facilitating the linking of the three geographic and political levels (NL, EU, global) by stakeholders.

This report especially focuses on the first, substantial, objective and then only with respect to the European context. The more methodological underpinnings and outcomes of the COOL (Europe) project (second objective) are put together in another study, together with the methodological outcomes of the COOL National and the COOL Global projects. The substantial outcomes of these latter two projects are also reported separately.

The COOL project aims to identify (elements of) viable strategies for drastic GHG emissions reductions (= 50-80% by 2050) for the Netherlands, in a European and global context. In fulfilling this objective the COOL project has three main characteristics: it concentrates on drastic emission reductions of GHG, it looks especially at the long term, and it identifies strategies and options in a participatory way by giving various non-governmental and governmental stakeholders a prominent place.

The COOL project aims at rather strict limits. A stabilisation level of 450 ppm CO2 (or roughly 550 ppm of CO2 equivalent, including the effect of other greenhouse gases) would require a 15-25% global emission reduction around 2050 compared to current levels. And it would require a much higher (50-80%) cut in industrialised countries (including Europe), given the much higher emissions in per capita terms of industrialised countries and the need to make room for improving the welfare level of developing countries significantly.

In being able to deal with such drastic emission reduction a long time span is essential. The COOL project takes 2050 as its time horizon. But it tries to identify what kind of measures have to be taken at different points in time in order to reach these drastic emission reductions over 50 years. As such the COOL project connects the long term to more short term actions and measures.
Finally, in identifying, prioritising, selecting and designing various options, measures, policies and technologies to reach drastic emission reductions of GHG the COOL project uses a participatory approach. It is not in the first place the scientists who take the floor in building scenarios to show what should be done to reach these emission reduction pathways, but rather groups of different stakeholders. With input and information from science and scientists these stakeholder groups are given pride of place in discussion various options, in selecting the criteria to prioritise these options and to built strategies that aim to drastically reduce GHG emissions in specific parts of society.

1.1.1 The multi-layer character of COOL

The COOL project consists of three subprojects, a national, a European and a Global dialogue. They are linked in the following ways:

- A common goal: strategic assessment of options for long-term climate policy.
- A common problem definition: How can GHG emission reductions in the order of 50-80% as compared to 1990 levels, be realised by 2050?
- A common approach and methodology, i.e. the engagement of heterogeneous stakeholder groups, the construction of future images and the use of a backcasting method (see below).

Figure 1.1 presents the general framework of the COOL project, with both the three substantive subprojects, as the more methodological evaluation objectives.

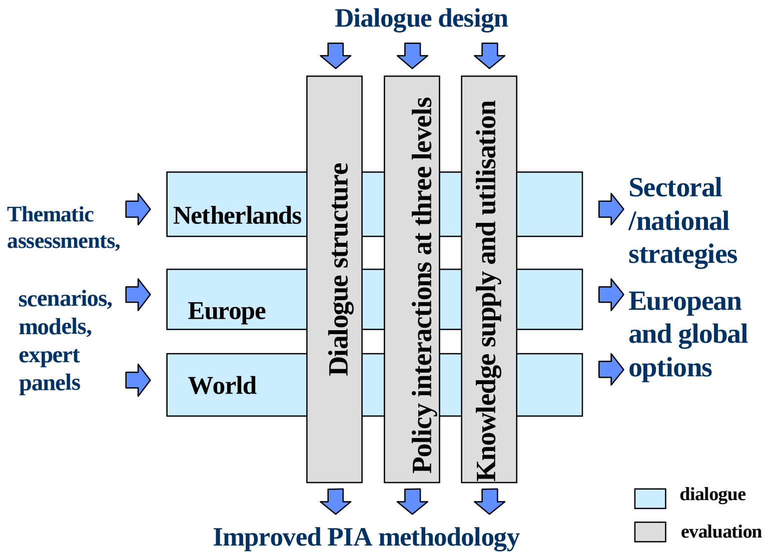

Figure 1.1 General structure of the COOL project

1.1.2 The contents of this report

This final COOL Europe report contains the substantial outcomes of the COOL Europe project. In this introductory chapter the structure and working method of the COOL Europe project is outlined, and the choices made are explained. The subsequent two chapters contain the so-called Strategic Visions of the energy group (chapter 2) the transport group (chapter 3) respectively. These strategic visions are the outcomes of the deliberations in the two COOL Europe dialogue groups. These two chapters have been written under the responsibility of the participants of the Dialogue groups. In the final chapter the two strategic visions are compared and analysed. Several annexes give more detailed information on the backgrounds of the strategic visions.

1.2 COOL Europe: a sectoral focus on energy and transport

The COOL Europe project was organised along sectoral lines. There were several reasons for following such a sectoral approach (in stead of for instance an approach along lines of nation-states). First, a focus on sectors is an innovation compared to the hitherto domination of national states in EU climate policy. Second, a sectoral focus could build upon substantial sectoral scenarios into the future, and thus link more economic-technological prospects with the normative requirements of greenhouse gas emission reductions. Third, a sectoral focus increases the possibility to focus the discussion and to give the discussion more relevance for the participants. Finally, a focus on sectors would allow a closer link with the national dialogue of COOL Europe, although it would deviate from the Global dialogue in COOL.

The COOL Europe project is focused on two sectors: energy production and transport. The energy sector was selected for two main reasons. First, the burning of fossil fuels accounts for the majority of the EU carbon dioxide emissions. Second, the European energy sector is in a period of major transition, not only with respect to liberalisation and merging but also being at the eve of a jump to non-fossil fuels. The transport sector has been selected because it accounts for 26 per cent of total EU carbon dioxide emissions. Carbon dioxide emissions from transport are estimated to increase substantially in the future due to increases in travel, especially air travel and freight transport.

These two sectors have also been studied in the COOL National project, which makes comparisons between the two projects possible. It also enables economic use of resources in the COOL project, in terms of background studies, exchange of technical information, and drawing on similar resource persons.

1.3 Methodology of COOL Europe

In developing strategic notions for a future with low greenhouse gas emissions and assessing the various options that can contribute to such a strategy the COOL project deviates from more conventional studies on two major methodological point. First, in designing and assessing the various pathways and options it uses a participatory approach, often labelled participatory integrated assessment (PIA) or participatory policy assessment (PPA). Second, in designing and constructing the pathways and various options to reach radical greenhouse gas emission reduction the COOL project follows a backcasting rather than a scenario or forecasting methodology. We will shortly introduce both methods.

1.3.1 Participatory Integrated Assessment

Participatory Integrated Assessment starts from the assumption that designing policies and strategies and assessing their contribution in reaching final goals improve when these activities and processes are not restricted to a small inner-circle of scientists and policy-makers, but also involve interest groups and civil society. Particularly regarding complex, unstructured environmental problems where scientific investigations have their limitations, a broader involvement of different actors would add meaningful information, new insights and a less narrow and less technocratic view on causes and solutions. More specifically, the arguments in favour of a more participatory approach can be summarised as follows (cf. Funtowicz and Ravetz, 1993; Dunn, 1994; Fisher, 1990; Hisschemöller and Hoppe, 1996; Wynne, 1996; Irwin, 1995; Dryzek, 1987; Mayer, 1997):

- It helps to bridge the gap between a scientifically defined environmental problem and the experiences, values and practices of actors who are at the root of both cause and solution of such problems;
- Participation helps in clarifying different, often opposite, views and interests on a problem, making problem definitions more adequate and broadly supported;
- Participation has an important learning component for the participants
- Participation in the scientific assessment may improve the quality of decision-making, not by taking over the role of scientific expertise but by adding and complementing it with other dimensions. As such it increases feasibility, prevents implementation problems, reinforces the commitment of stakeholders, increases the democratic content, etc.

At the same time participation can also disturb policy-making and assessments, as several scholars point out (cf. Seley, 1983; Douglas and Wildavsky, 1983): stakeholders can be considered incompetent; they can have a major interest in a specific decision or non-decision and thus frustrate optimal solutions; participation can result in decisions that favour the more powerful and resourceful groups; and the process of participatory policy-making or assessments can become improductive when it is time-consuming, conflict-enhancing and cannot live after the promises of democratic decision-making that are included in it.

1.3.2 Backcasting

The second main methodological characteristic of the COOL project is a backcasting approach. According to one of the founding fathers of backcasting, Robinson (1990), "the major distinguishing characteristic of backcasting analysis is a concern, not with what futures are likely to happen, but with how a desirable future can be attained. It is thus explicitly normative, involving working backwards from a particular desirable future end-point to the present in order to determine the physical feasibility of that future and what policy measures would be required to reach that point". Backcasting is claimed to be especially suited for long-term problems due to its problem solving characteristics. Initially it has been developed especially in energy studies, to be broadened later to other sectors such as transport and infrastructures (Dreborg, 1996). Rather than analysing possible scenarios for the long-term and in that way forecasting the possible and likely development paths of a social system, backcasting takes a desirable long-term future and analyses backwards what different actions, steps and conditions are crucial at various points in time, up until the more recent point in time, to reach that final normative objective. Backcasting should thus be seen in line with Constructive Technology Assessment (Schot, 1992), Transition Management (Rotmans, et al., 2000), and more normative branches of Ecological Modernisation (see Mol and Spaargaren, 2000). In practice, however, the contrast between backcasting and forecasting methods and techniques is not that sharp, as a backcasting methodology uses for partial sub-problems on a limited time frame often forecasting exercises.

Within the COOL Europe project the methodology of backcasting has been operationalised in five main steps (cf. Figure 2). The first step is the definition of the problem and setting the criteria for a solution (climate change by greenhouse gas emissions and 80% CO2 emission reduction between 1990 and 2050 for the OECD countries, respectively). The second step is the development of a so-called "image of the future", an image of the social system or sector in 2050 that meets the requirements set by the criteria. The third step is the path analysis. An analysis is made of the pathway from the image of 2050 up to today to identify the transformations that are necessary, the lead-time for different options that can contribute to such transformations (e.g. rate of development and diffusion of fuel cell technology), the crucial actors and conditions that make such options work, and the starting time to make these options contribute to the final image. Step 4 is a comparison of current trends – not only in greenhouse gas emissions, but also in energy production and use, transport demand and supply, agricultural production and consumption – and the desirable trends according to the path analysis. This policy or gap analysis provides us with ideas on the necessary policies for the coming years to close this gap between existing and desirable trends and set in motion the required social transformations. Finally, the last step entails the formulation of an integrated strategic vision, in which the outcomes of the former four steps are integrated into one document that brings together the possible options and necessary measures to be taken, the time paths for these options and measures, the conditions that support these options and measures, and the coalition of actors that are crucial for implementing these options and measures.

The crucial aspect of backcasting studies is not so much constructing the long-term future or designing a recipe for a pathway to a desirable future, an impossible goal in the current times of reflexive modernity. Backcasting is a tool that informs us on the possibilities for radical changes, and it highlights the pros and cons, the conditions for and consequences of different strategies, options and solutions that contribute to these radical changes.

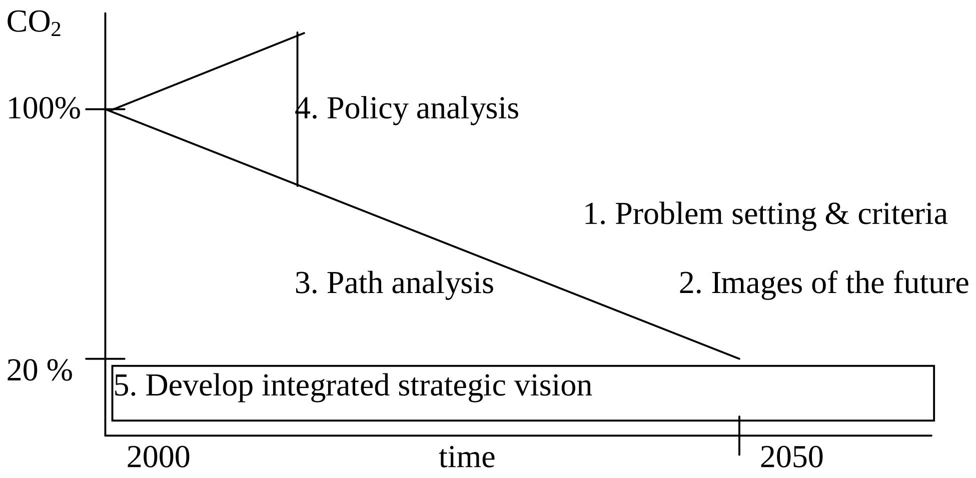

Figure 1.2 Main steps of backcasting

1.4 Working methods: workshops and participants

Some basic rules of the game were at the foundation of the dialogue process, among which the fact that participants participated on personal title, the acceptance of the starting position of 80 per cent emission reduction in 2050, the commitment to participate in the four workshops, and the acknowledgement that climate change is a problem that needs to be solved. Both sector groups involved some 20 representatives of industry, NGOs, governmental organisations (national and local) and the European institutions. In addition, the ambition to involve people from all parts of Europe was partly met, as it proved impossible to include people from the Southern member states. Several participants came from candidate states in Central and Eastern Europe. On average between 10 and 15 members of each sector group were present at each of the four workshops.

The core of the COOL European Dialogue was formed by the workshops. It was in these series of four workshops, both for the energy and transport sectors, that the images of future low green house gas emission sectors were connected with long-term sector strategies (2000-2050) and more short term climate measures and policies in a participatory process between non-governmental stakeholder representatives, policy-makers and scientists. The dialogues on transport and energy production were aimed at leading to the elaboration of strategic visions on how an 80 per cent reduction of carbon dioxide emissions from these sectors could be achieved in 2050.

The two dialogue groups formulated future images on the basis of existing (sector) scenarios, relevant data provided by the COOL project team, and the knowledge base of the participants themselves. These future images were the social constructions by the dialogue groups of a society in 2050, which has reached the 80 per cent emission reduction goal. From that the dialogue groups started backcasting towards the present, indicating what kind of (economic, technological, environmental, socio-cultural) information, scenario studies, models, etc. they need for developing a path analysis from the future image to short term measures. A demand driven input of science into the participatory policy-making process was followed. The energy consultancy firm Ecofys (Utrecht, the Netherlands) and the Environmental Strategies Research Group (FMS) (Stockholm University, Sweden) provided the dialogue groups with relevant scientific information. The distinct phases of the COOL Europe project are presented in Table 1.1.

The preparation for selecting the participants in the two dialogue groups of COOL Europe started in late spring 1999 and the strategic visions were concluded in spring 2001.

Table 1.1 The COOL Europe workshops

Workshop 1 **Future images**	***Aim:*** Discussing and designing low GHG 2050 picture(s) for the energy and transport sector in Europe.	***Input:*** • Background material on back-casting • Future images elaborated by the national dialogue • Sectoral long-term scenarios • Technological options	***Output:*** • Draft future images agreed upon by participants • Proposals for coming workshops (scientific input, questions to be addressed etc.)
Interview round I with members of both sector groups			
Workshop 2 **Path analysis**	***Aim:*** • Identifying key Options • Scanning the European context	***Input:*** • Future images (elaborated by project team) • Tentative path analysis including scientific assessment of options	***Output:*** • Revised future images • Stories written by subgroups (bio-energy, decentralisation, aviation and general transport strategy) • Strategic elements of sectoral strategies
Interview round II with members of both sector groups			
Workshop 3 **Options and key issues**	***Aim:*** • Discussing the European framework for long-term Climate policy • Backcasting exercises for key options • Formulating short-term actions, and major policy choices and opportunities	***Input:*** • Path analysis for the energy and transport sectors • Framework for future visions • Participants' own input papers • Expert papers on ICT and globalisation	***Output*** • Format for strategic visions • Elements of strategic visions
Commenting on first draft version of strategic vision			
Workshop 4 **Towards strategic visions**	***Aim:*** • Refinement of strategic visions • Feedback from policy panel	***Input:*** Second draft strategic visions	***Output:*** • Revisions of strategic visions for the energy and transport sectors • Agreement on finalisation
Finalisation	Finalisation of strategic visions based on the outcomes of workshop 4		

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2. STRATEGIC VISION FOR THE EUROPEAN ENERGY SECTOR

The strategic vision on energy has been produced under the responsibility of and with significant contributions of the following participants of the COOL European Dialogue: J-P Boch, TotalFinaElf, France; R. Bradley, Climate Network Europe; P. ten Brink, Ecotec Belgium; P. Carter, EIB, Luxembourg; C. Egenhofer, CEPS, Belgium; J. Henningsen, consultant, Denmark; E. Hille, consultant, Poland; L. Jansen, Sustainable Technology Development, the Netherlands; T. Kram, ECN, Netherlands; G. McGlynn, Australia; P. Metz, e5, the Netherlands; S. Minett, Cogen Europe; J. Pretel, Czech Hydrometereological Institute; M. Sadowski, National Environmental Fund, Poland; H-J Stehr, Danish Energy Agency; B-O Svanholm, Birka Energi, Sweden; J. Szonyi, Wageningen University, the Netherlands; R. Thomas, Shell Foundation, UK; and D. Vorsatz-Urge, Central European University, Hungary. The editors of this strategic vision were: M. Andersson, T. Kaberger, A.P.J. Mol and D. Phylipsen.

2.1 Introduction

2.1.1 Global climate change and the long-term challenge

Our climate is changing. Scientific evidence is getting strong that human activities leading to emissions of greenhouse gases to the atmosphere are, at least partly, the cause of this climatic change. Based on a range of scenarios about developments over the next 100 years, all projections show a further increase of global average temperatures, in the range of 1.5-6 degrees C above today's levels. Such changes, that would entail even much higher regional temperature increases and changes in precipitation patterns can lead to serious negative effects on human health, the economy and nature.[1]

The United Nations Framework Convention on Climate Change specifies as its objective to stabilise GHG concentrations in the atmosphere at such a level and within such a timeframe that no dangerous interference with the climate system occurs, threatening food supply, natural ecosystems and sustainable development. Scientific consensus exists that for such stabilisation global GHG emissions have to go down to less than 50 per cent of current values. Thus the challenge of controlling the risks of climate change in accordance with international agreements means that drastic emission reductions are inevitable and that they may have to be realised over a relative limited period of time. Is this doable? And what would it require? What does it mean for de-

[1] IPCC (2001). Third Assessment Report. Summary for Policymakers.

veloping countries trying to combat poverty and improve the living conditions of their people? And what does it mean for industrialised countries that have built their current prosperity on fossil fuels and an energy intensive development pattern? Those are the key questions when looking at ways to control climate change in the long term.

2.1.2 The 80 per cent target

To stabilise atmospheric carbon dioxide levels means that global emissions must not be allowed to exceed the combined absorption capacity of the oceans and the biosphere. It would require a 15-25 per cent global emission reduction compared to current values around 2050. In the COOL Europe project it is assumed that this commitment would imply an 80 per cent reduction target, compared to present emissions, for the presently richest part of the world. It is this target that has been the starting-point for this project.

2.1.3 Participation

The European dialogue has focused on two sectors: energy and transport. The two most distinct features of the COOL Europe project are its focus on the long term and its focus on radical carbon dioxide emission reductions. Most other research activities on climate policy so far have focused on the short term and on incremental changes.

The Dialogue has relied on a broad set of European stakeholders to develop these insights. Participants in the COOL Europe project have been (1) policy-makers at the local, national and international level; (2) representatives of the private sector, (3) representatives of environmental NGOs, and (4) representatives of the scientific community.

Four workshops have formed the core of the COOL European Dialogue. Long-term sector strategies (2000-2050) have been connected with climate policy in a participatory process. The workshops have followed a sequence focussing on elaborating (1) Future Images of 2050, (2) a Path Analysis connecting these Images to the present, (3) Short-term actions needed to reach long-term goals, and (4) Strategic Visions which integrate the former three. Backcasting has been used in the COOL Europe workshops. Backcasting or anticipatory scenarios are backward directed, i.e., they start from some normative final state, and explore the preconditions and strategies that could lead to this state.

The scientific input material for the COOL Europe process was prepared by Ecofys in the Netherlands. Its key input document, entitled "Long-term energy futures: towards a low carbon world", can be found in Annex 1.

2.2 The European energy sector

The burning of fossil fuels accounts for the majority of the EU carbon dioxide emissions. The European energy sector is in a period of major liberalisation with the purpose of increasing competition and removing national trade barriers. In particular the markets for electricity and gas are changing. This is changing the context for climate policy. Figure 2.1 shows the fuel mix in final energy consumption in Europe in 1990.

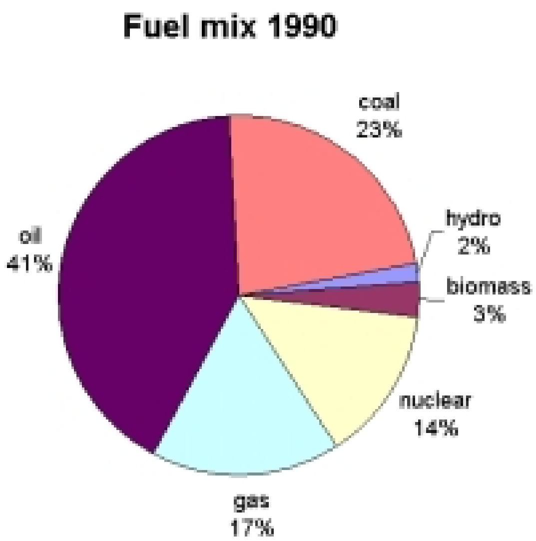


Figure 2.1 Share of different fuels in final energy consumption in Europe in 1990 [2]

[2] Note that the absolute energy consumption figures are valid for the EU-15. Relative shares can be used as approximations for wider regions as well. Nuclear power and hydro power are converted according to the conventions used by the European Commission and the PRIMES model.

2.3 Images of the future (2050)

Based on the contributions during the first and second COOL Europe workshops two future images have been quantified to serve as the starting point of the backcasting process. Both these images of the European energy system in 2050 meet the criteria of 80 per cent reduction of the carbon dioxide emissions compared to 1990 levels.

In the ***biomass-intensive image*** biomass has the largest share of the fuel mix (see Figure 2.2 below). Besides biomass wastes, energy crops will be grown, which are expected to require 80 Mha, or 17 per cent of total land area in Europe (cropland currently covers 140 Mha, or 30 per cent of total land, with forests and woodlands covering 33 per cent). About 80 per cent of land demand for energy crops can be met using excess croplands, starting with currently set-aside land. This land is assumed to be used for dedicated energy crops with significant net energy yields.

In the beginning of the dialogue many of us feared that the biomass-intensive image could pose too high demands on land available for energy crops in Europe. A larger share of wind power as well as more, large-scale solar photo-voltaic (PV) electricity production were suggested as a less land-intensive route for energy supply. Therefore, a second image was developed, which is less biomass-intensive. We refer to this image as the ***solar hydrogen image*** (see Figure 2.2 below). In the solar hydrogen image, solar PV generated electricity is used to produce hydrogen. The hydrogen may be used for electricity and heat production, but also as a transport fuel. It has been estimated that the amount of land used for energy crops in this image is limited to 75 per cent of the excess farmland (about 50 Mha, compared to 80 Mha in the biomass-intensive image). This leaves room for other land uses, such as recreation, extensive farming, etc. (A comparison between the two future images developed in the COOL Europe process and other international energy scenarios can be found in Annex 2.)

It is noticeable that none of these two future images assume any role for coal and nuclear power in 2050 (see Box 1). Moreover, both images assume that there will be a sharp increase in the use of natural gas. Oil will still be used but considerably less than in 1990.

The amount of land required in the solar hydrogen image is smaller than in the biomass-intensive image. Since the land demand is limited to 75 per cent of expected excess croplands, there will also be room left for other activities with a demand for land.

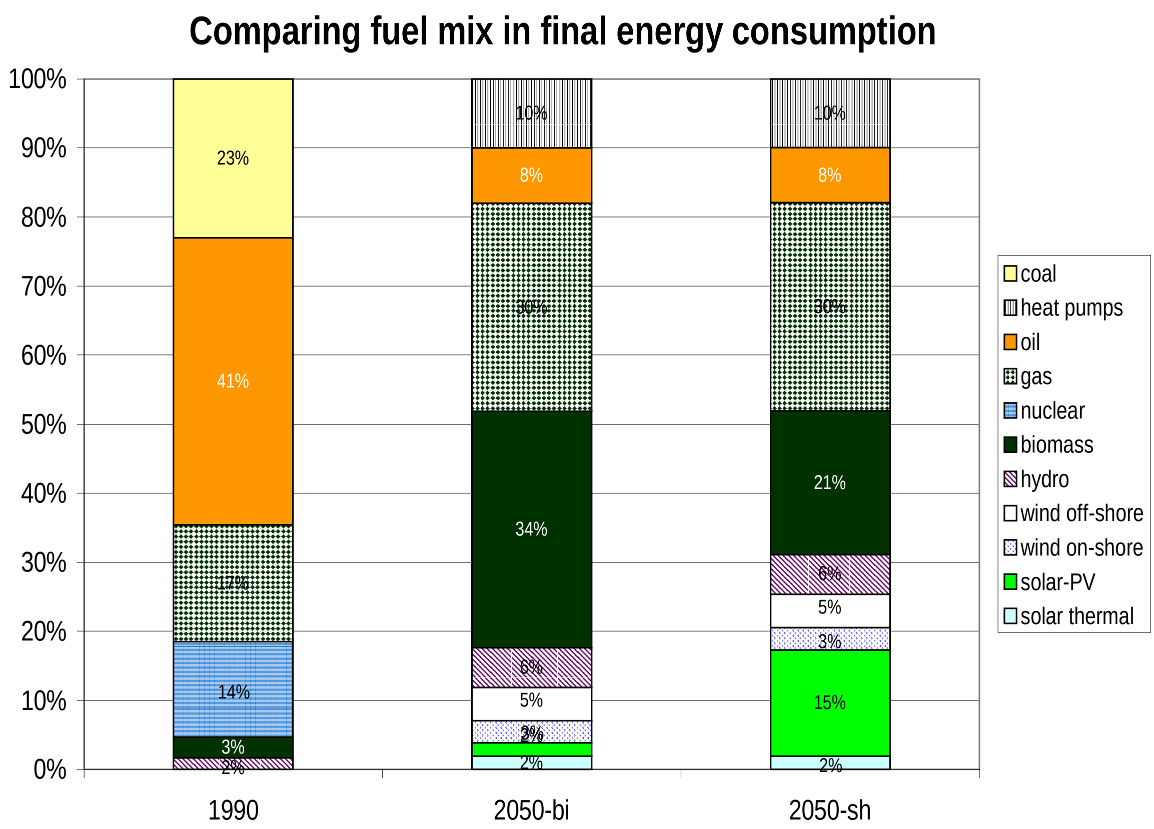
Land demand is therefore not expected to be a problem in the solar hydrogen image. Biomass will, however, still contribute a substantial part to the energy supply in 2050. The introduction of solar PV has to be much larger in the solar hydrogen image than in the biomass-intensive image. Therefore, technological breakthroughs, substantial cost reductions and strong policy actions have to be attained to an even larger extent than in the biomass-intensive image.

Both images assume that the economy continues to grow, while the demand for final energy is constant. Growing sectors of the economy are assumed to be the less material and energy intensive, and technologically improved efficiency is assumed to keep pace with growth.

Stability of supply is a bigger issue in the solar hydrogen image than in the biomass-intensive image, since the contribution of intermittent sources is larger than in the biomass-intensive image. However, large part of the PV capacity will be used for fuel production, which also serves as an energy storage system.

Connecting the electricity and transport fuel systems with hydrogen as a common fuel may in fact contribute to reduce the price fluctuations. Fuel stored acting as a buffer for transport purposes would also be useful to match imbalance in demand for electricity and the energy production from wind and solar PV.

Figure 2.2 Share of different fuels in final consumption in Europe in 1990, the 2050 biomass intensive image and the 2050 solar hydrogen image. The heat pumps have a somewhat different position than the other energy sources listed here. Heat pumps consume electricity (here 0.7 EJ) to deliver six times as much heat. The electricity by the heat pumps is generated by the whole set of electricity generating options present. Note that the total energy consumption in the two images of 2050 is assumed to the same as in 1990. (See Annex 1.)



Box 1. Why are fusion and fission not included in the two future images?
Fusion was not considered by us to have any potential to be available at costs of production and distribution that could compete with the renewable sources available. The continued use of conventional fission reactors for energy supply was discussed during the first workshop. In the second workshop it was concluded that a small contribution from nuclear was unlikely. Either fission power was available using technologies that had managed the problems of costs, reactor safety, waste management and nuclear proliferation risks well enough for new reactors to be competitive, and then there may be a lot of nuclear power in the system. Or, renewables would continue to appear as the least costly supply of future energy. We eventually found the second the more interesting alternative to explore further, and hence all nuclear energy was removed from the future images.

2.4 Decentralisation

In an exercise at the first COOL Europe workshop each of us wrote down a few sentences about what we consider to be the key characteristics of a desirable energy system for Europe. It appeared that there were strong preferences for decentralised production of electricity, fuel and heat. In such system electricity will be generated by systems such as solar, wind (on-shore and off-shore) and combined generation of heat and power (CHP). Besides CHP, heat can also be supplied by heat pumps. The issue of decentralisation became an important theme in the following COOL Europe workshops.

Our group has concluded that recent technological development with conventional technology has supported decentralisation. With conventional technologies the economy of scale is decreasing with technological developments over the last decade. Computer control reduces the cost of monitoring and control, so that reducing the number of plants is not as important as a couple of decades ago. Costs of component failures in big plants are greater than in small. Construction times for large plants have proven much greater than for smaller. We have also noted that over the last decade the costs per unit generator capacity have decreased faster for small plants than for the largest.

In the electricity system the cost of transmission has become obvious as re-regulation introducing competition has revealed the relation between the cost of electricity production on the one hand and electricity distribution on the other. If distribution costs as much per unit electricity, on site production may be economical even if production at the site costs twice as much as central generation. Thus, the competitive market creates private incentives for local solutions that may be beyond what is economically rational from the systems perspective. The co-generation of electricity and heat is economical if the electricity production is situated close to the heat demand, thereby avoiding long heat transmission pipelines. This has made small electricity production units popular. To many owners of commercial buildings and to industry, the extra supply security of on site electricity generation capacity may appear as an important value, too. The new renewable sources of energy like solar radiation and wind energy are naturally decentralised and require decentralised transformation. The technologies to utilise these resources are becoming commercially viable. To utilise these resources, electricity regulations have to be adapted to decentralised generation thereby opening up also for decentralised solutions using conventional resources and technologies. In our group there have been some important discussions of terminology to describe these systems. Decentralised heat and energy production may be interpreted as meaning that the small distributed units operate independently only to serve local demand. However, economic optimisation of the operation of many distributed units may be very rewarding while relying on relatively inexpensive computer control systems.

The envisioned electricity system may be fed by a large number of distributed generators. The operation of each generator may be governed by availability of wind and solar energy, availability of local fuels as well as by demand of other services than the electricity demand. Still, the operation may be controlled by a centralised control system. Another paradox hidden by the decentralisation term is the character of the solar photo-voltaic industry. The PV applications may be decentralised, but the production of solar PV is likely to be a very centralised industry where the economy of scales may exclude small PV producers.

It should be noted that a few persons in the energy group preferred to take no position regarding decentralisation versus centralisation. They rather judge all technologies on their own merits regarding emission reduction and resource conservation. In their view, the desirable outcome will probably be a mix of small and large scale technologies (see Annex 3).

Box 2. A vision of decentralisation – a story written during a COOL Europe workshop. *From 2030 the market was already very different. Although grid electricity remained important, especially in bringing in technologies such as wind, far more consumption at point of use was through fuel cells and solar heaters. Some companies were offering full energy packages for the domestic sector through building maintenance packages, but industrial users stayed with more traditional power sources, using cogeneration, typically with natural gas. The prevalence of fuel cells in cars led to the practice of powering households from the same units. This meant a large decline in required capital stock for domestic energy provision. Because of the more rapid turnover of vehicle stock new energy technologies entered the market more rapidly than hitherto. North Africa grew in importance as an energy supplier. As well as its natural gas supplies, its abundant renewable energy resources made it a natural exporter of cheap hydrogen. The EU remains dependent on outside energy sources, though less than in the past. First, through its embracing of new technology energy use broadly stabilised at 2000 levels. Exploitation of renewable energy sources has reduced imports. Energy production has become dominated in part by consumer goods manufacturers. Sony-Ballard ventures Play-station 20 combines virtual reality gaming with household management powered from an integrated fuel cell. In southern Europe most of the fuel for such devices in households is generated from roof-integrated PV. In northern Europe natural gas is still important.*

2.5 Back to the present: pathways for emission reduction

What should happen in order to reach an energy system in 2050 corresponding to the biomass intensive image or the solar hydrogen image? This section looks at some of the most strategic issues in implementation trajectories towards these images.

2.5.1 The dynamics of the transition

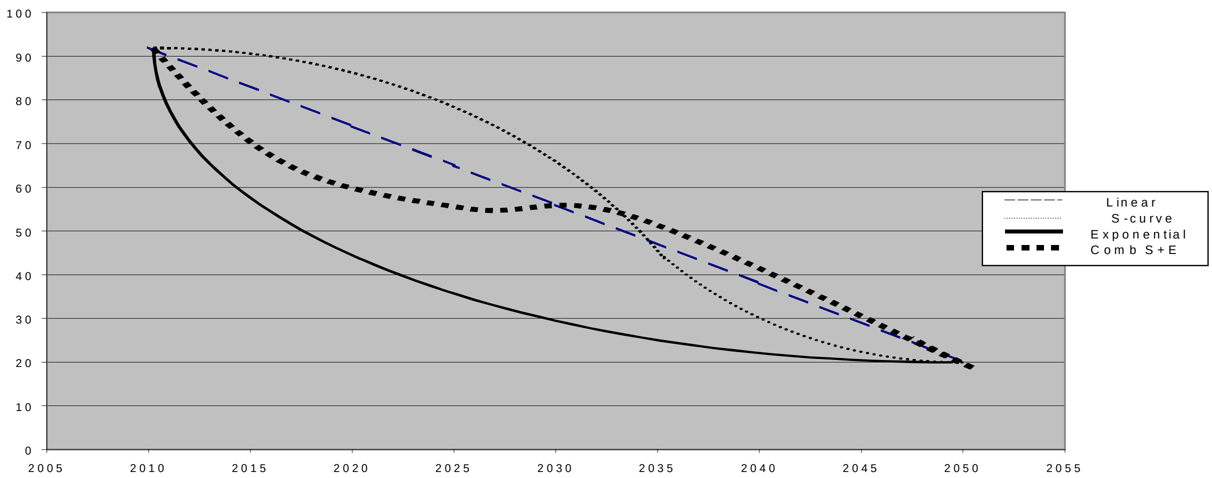
How in quantitative terms would one imagine the transition from the current situation to a situation in 2050 in which the 80 per cent reduction target has been realised? According to the participants in the COOL Europe process there are different possibilities along which this transition can take place: a linear curve, an exponential curve or an S-curve (Figure 2.3).

The linear curve (the one in the middle in Figure 2.3 below) is very demanding towards the end: from 52 per cent emission reduction in 2040 to 80 per cent in 2050. This is almost a 50 per cent reduction in the last decade on top of an already demanding programme till 2040.

The exponential curve is very demanding between 2010 and 2020. By 2020 the emissions are 37 per cent lower than in 1990. One should keep in mind that in this period a lot of old stock still exists.

The S-curve may be a more realistic way to imagine the transition to a new regime. Other curves between the linear and the exponential curves can be envisaged. We think that a combination of the S-curve and the exponential curve would have a lot of merit. In this curve, the first (steep) part implies cost-effective, no-regret policies. The first part can be reached with current policies and a strong focus on investments and policy leapfrogging in transitioning economies in Central and Eastern Europe. These economies are under dynamic changes now establishing new industries, economic structures and consumer cultures, which is a key window of opportunity to channel these changes towards the low-carbon options rather than the business-as-usual ones. After that, other policies are required to reach drastic emission reductions.

Figure 2.3. Possible reduction pathways



2.5.2 Emission reduction options

Emission reduction options can be categorised in several ways. In our exercise we have paid attention to five categories: (1) energy efficiency; (2) development of new structures and patterns; (3) awareness, values and lifestyles; (4) a shift in the mix of fossil fuels; and (5) the development of carbon-free energy sources.

Energy efficiency

The future energy systems described in our images have not increased its total use of primary energy. An annual economic growth of 2 per cent is offset by improved energy efficiency.

Energy efficiency improvement can take place both in the production and distribution of heat and electricity and on the demand side. The current energy efficiency of conversion processes can be improved with improved technologies and utilisation of the potential for combined heat and power production, CHP, on different scales, thereby reducing the amount of primary energy required. Within the economy the efficiency of industrial processes, cars, farm vehicles, houses and offices (in terms of insulation, orientation etc), appliances, etc. can be significantly improved. (For examples of new energy efficient technologies for the petrochemical industry, see Annex 4. For examples of profitable energy efficiency improvements in industry, see Annex 5.)

We have identified a number of kick-off policies and measures for the near term.

- Strict energy performance standards for new buildings. European guidelines are needed here. Mandatory energy performance certificate for existing houses upon sale. This could be coupled with subsidies for retrofit and in a later stage (e.g. 2020) be replaced with minimum performance standards. To help this option take-off, the EU could initiate co-operation with the construction industry and the real estates industry.
- Minimum efficiency standards for all appliances, updated every five years, in which the lowest efficiency classes are eliminated, combined with good labeling for all energy energy-using equipment. EU Member States could establish voluntary agreements with manufactures to make this happen.

Development of new structures and patterns

We think that the following issues should be addressed to speed up the process of industrial transformation. Firstly, information technology can be used in innovative ways to achieve a general reduction in material intensity of products. Secondly, the product chain from raw material to waste product is full of many decisions influencing each other. However this is not reflected in the way policy currently is made. In our view, there is a lack of institutional arrangements – at different levels of policy-making – to deal with the product chain in an integrated way. These institutional gaps should be filled. Thirdly, appropriate monetary signals will be needed. All material and resources should be priced according to their impact on the environment. Fourthly, we encourage international financing institutions to revise their policies to include a strategic vision towards sustainable industry.

Awareness, values and lifestyles

Awareness, values and lifestyles can strongly influence energy consumption. To achieve both the stabilisation in energy use and the shift in energy carriers, energy sources and conversion processes assumed in the two images of 2050, consumers need to be ‘environmentally aware’ to actively stimulate the supply of energy and carbon-extensive options by creating a demand for these options.

A shift away from meat consumption turning to more vegetables in food would have an impact on energy demand. Another lifestyle change may be a re-evaluation of the enjoyment of individual car driving, shifting to more time efficient modes of transport where the traveller can spend his time doing other things than driving the vehicle (see also the COOL Europe strategic vision for the transport sector).

However, people are rather slow in changing their habits and life-styles. For example, in certain European countries the demand for energy efficient lamps is still quite low. A great deal of education is needed here, starting from the kindergarten and school levels. Poor people, who have most to benefit economically from energy conservation and efficiency measures, have been particular difficult to reach.

It has been emphasised many times in our dialogue that a great deal of work still needs to be done to convince individuals at all levels about the possible impacts of global climate change. In order to realise life-style changes, climate friendly alternatives need to become more attractive, more visible and more accessible. An important role of government at all levels of policy-making, of environmental organisations and of private producers is to provide various services to their citizens (information, practical advice, financial aid) which would help them to change their lifestyles. It is very important that the issue of public awareness and life-style changes is linked to specific options and practices.

A new generation of policies for environmental education is urgently needed all over the European continent. Our group encourages EU Member States, European Commission and European Parliament to critically evaluate the effectiveness of existing policies aiming at increased public awareness and life-style changes. A European task force could perhaps be set up to elaborate new and effective strategies aimed at involving the general public in taking measures against climate change.

A shift in the mix of fossil fuels

Our low carbon intensive images of the future assume that there will be a drastic shift in the mix of fossil fuels. Firstly, we assume that coal will be phased out. Secondly, our images posit a sharp reduction in oil use. Thirdly, there will be a sharp increase of natural gas. Natural gas is less carbon-intensive than the other fossil fuels and can be applied in an efficient way, for instance by way of cogeneration of electricity and gas.

The development of carbon-free energy sources

With respect to the development of carbon-free energy sources we concluded very early in the COOL Europe exercise that recent developments have turned wind power into an economically viable energy option. The other renewable sources are likely to follow suit. Most of the discussions on carbon-free energy sources in our group focused on biomass and hydrogen. The key conclusions about these two options follow in the subsequent sections.

2.5.3 Biomass

The unanimous conclusion of our group is that Europe has enough space and agricultural and forestry resources to make biomass a central pillar of the future energy economy of Europe. The potential role of bioenergy is outlined in Box 3 below.

Box 3. Bio-energy – a COOL story

As Andrej Schmidt retires as president of Europower in 2040 he gave a presentation of the history of his company. His main point was that bio-energy had been the key resource in establishing a sustainable energy supply system. At the end of the 20^{th} century it became clear that carbon dioxide emitted from fossil fuel burning was changing the climate. There were a lot of different decisions taken to stimulate new renewable sources of energy. And even if many of the old industries said it was expensive or even impossible we soon proved it was both possible and competitive. Bio-energy fitted well in the competitive market situation because they could be small. As soon as there were economic reasons to avoid fossil fuels there was a growing number of biomass fuelled co-generation plants built. There was a major effort to develop gasification technologies. During the first ten years of this century the first successful biomass gasification plants were built in Europe. The first were for direct cogeneration. Later they were central units refining biomass into a set of different products. By 2010 the use of biomass for energy was expanding rapidly. This was the time when long distance trade in refined biofuels started. Solid bio-pellets, bio-alcohols and gasified biomass were traded all over Europe. As long as bio-energy was only available close to the growth areas the use was small but as soon as you could transport refined fuels consumption increased and prices stabilised. Availability of bioalcohols and gas made small, domestic co-generation technologies attractive. Fuel cells, micro-turbines and sterling engines competed for almost 20 years to win the market. Technologies for biorefineries developed to produce fuels and fibre-materials and heat from biomass. Bioenergy was a perfect solution, giving a lot of people the opportunity to work in the countryside when the demand for food dropped. The technologies of gasification were developing rapidly from 2010-2030.

Short assessments of the bio-energy potentials in Hungary (see Annex 6) and Poland (see Annex 7) carried out in the framework of this project, show that there is a considerable biomass potential in these two countries. The same also holds for other countries in Central and Eastern Europe. EU enlargement is clearly a window of opportunity for the biomass option in Europe as expected productivity developments may make both land and labour available to provide bioenergy. Biomass would provide an additional revenue stream for farmers in declining rural economies in many parts of Europe.

The use of residues from crop and forestry has a great potential for the short term. To stimulate the use of crop and forest residues we think that co-ordination between EU biomass policy on the one hand and EU agricultural, forestry and waste policies on the other hand is required.

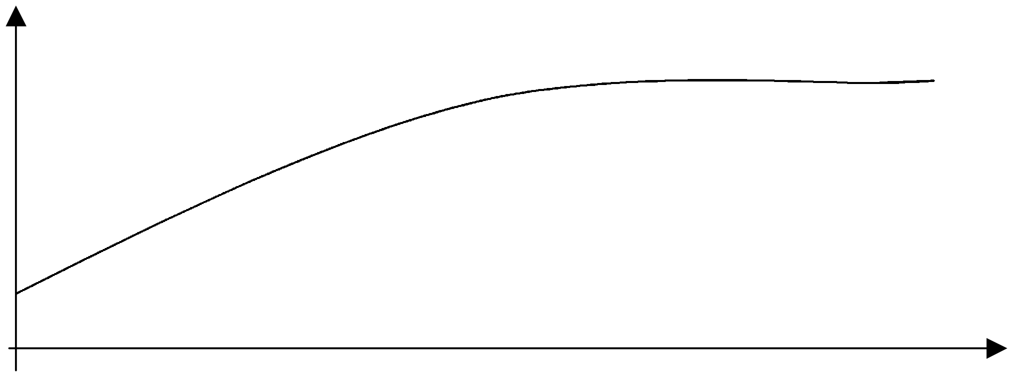
In the longer term the development of new energy crops will be increasingly important. We think biomass can continue to increase its share of the fuel mix until 2030. At this time, competition for land could appear as a constraint for further growth of bioenergy use. Some dialogue participants believe that land availability[3], can be potentially important constraints even before 2030, especially in relation to biodiversity considerations. We assume that improved agricultural productivity can reduce the competition for land. The development of agricultural productivity will set the potential for production of energy crops.

Regarding infrastructure for biofuels, we have noted that biofuel systems can relatively easy be introduced into existing fuel distribution systems using only slightly modified equipment. Still, supply and demand has to be introduced simultaneously requiring concerted action by fuel producers, vehicle producers and distributors of both. Annex 8 contains an example of how concerted action was achieved in Sweden regarding distribution of ethanol cars.

[3] For a discussion about biomass and the availability of land in Europe, see: *Gerlagh, T. (1998). Biomass for greenhouse gas emission reduction – western European land availability. Report ECN/C//98/109 December.*

Figure 2.4 Key issues for the biomass option

Biomass energy consumption



2000 **2030** **2050**

Key issues:
- Co-ordination with EU agricultural policy and forest policy
- Co-ordination with EU waste policy

Key issue: Land availability

Cost considerations

Producing heat, electricity and automotive fuels from renewables may be more costly in the short run. In case of biomass, however, heat and electricity may be produced competitively soon, perhaps within 2-3 doublings of production capacity. As a result, an increase in consumer preferences for green energy and energy tax exemptions for renewable energy may go a long way in reaching the required capacity increase and price reduction.

Investments in biomass-fuelled plants will only take place if biofuel prices can be expected to be low and stable. Even if the real supply will mainly be of local origin it appears to be important that there exists regional and international trade in various solid bio-fuels to assure local price stability. Due to lead times, sometimes in the order of five years, from plantation to harvest of perennial energy plantations long-term contracts between energy companies and local farmers are useful to stimulate stable fuel supply at low and predictable cost.

Production costs of automotive biofuels are currently significantly higher compared to price of the conventional fossil fuels. Fuel taxes covering all environmental costs of fuels would provide incentives for the bioalcohols which make the automotive market reachable if production processes are developed. Research and development efforts will be needed if production processes are to be developed.

Conclusions and recommendations

Our three main conclusions and recommendations regarding European policies for biomass and biofuel are the following:

1) A major short-term challenge for the EU is to improve the co-ordination between the bioenergy ambitions on the one hand and the product/waste as well as agricultural policies (CAP) and forest policies on the other. In the product and waste area it is important to provide economic incentives to keep bioenergy wastes uncontaminated and fit for sustainable combustion using affordable power plants. Opportunities to channel excess biomass production capacity into the energy sector using sustainable agricultural practices could be explored within the framework of EU agricultural policy reform.
2) Allow set-aside subsidies to continue for land used for energy crops. Currently, EU agricultural policy provides a subsidy to farmers that set aside land in order to decrease over-capacity in food production. Farmers lose this subsidy if the set-aside land is used for energy crops. This, in combination with currently low potential prices for the energy crops, forms a barrier for farmers to turn land from food crops to energy crops. In the longer term the development of land-productivity is decisive for the energy potential.
3) The introduction of biofuels on a larger scale in Europe will require concerted action by fuel producers, vehicle producers and distributors of both. In our view the European Commission is in a good position to identify a strategy about how this concerted action indeed could be achieved.

In addition, the following kick-off measures for the biomass option could be considered by European policy-makers:

- Investigate possibilities for combination of land uses. This is a task that could be addressed by DG Agriculture, research organisations, farmers organisations and others.
- Start experiments with biofuels (limited distribution e.g. gas stations from one big oil company along major highways). This is an area where co-operation with the oil industry could be encouraged.

- Subsidies or procurement programmes for the development of biofuel dedicated cars.
- Subsidy gas stations/oil companies to provide biofuel outlets.

2.5.4 Hydrogen

In our view, hydrogen is the best candidate to be the major commercial fuel in the middle of this century. Hydrogen is a clean option. Hydrogen offers flexibility in that it can be produced from several sources such as fossil fuels, biomass, large wind farms and solar PV ranches. The COOL Europe exercise has been particularly interested in exploring the solar hydrogen option.

The development of the hydrogen option will include the following five areas of development: (1) hydrogen production technologies; (2) the establishment of a long-distance pipeline system; (3) the establishment of local hydrogen grids; (4) the development of an infrastructure for refueling of vehicles; and (5) the development of fuel cells cars. Successful implementation will require time and co-ordination.

Needed growth rates for solar PV

To reach the solar hydrogen image solar PV has to grow 22 per cent per year – a rate of growth of the order achieved in recent years. With conventional learning curves, if production capacity grows at the same rate (in terms of number of doublings) for all sources PV electricity would remain the most expensive all the way through 2050.

For PV and solar hydrogen substantial incentives will be needed to bring down costs sufficiently for such systems to play the role foreseen in the future images. It is difficult to imagine the vision to be realised, unless these incentives are introduced early in the period.

Solar PV will need to be forced into the market via regulation and/or subsidies. Major technological breakthroughs, achieved via a large-scale R&D programme, could potentially reduce the costs even more than market stimulation. Within the dialogue some participants have proposed that we may need something like the Manhattan Project or the Apollo Project to bring prices down in some of the renewable energy technology areas. Others have argued that this would be a great exaggeration since renewable energy sources have shown themselves able to come down rapidly in price, even with relatively modest support, once market barriers have been removed. There is a general agreement in our group that solar PV may become economically successful on its own once the threshold of bringing down costs has been overcome.

The present growth in solar PV production is possible due to a combination of profitable niche markets and larger installations relying on subsidies. A major development effort may quickly bring the industry into a position where it can expand and develop the production technologies on a commercial basis.

A recent study by KPMG looked at to what extent large-scale production of solar panels can lower the price of solar energy to make it compete economically with conventional forms of energy. The main conclusion was that scaling up production of solar panels is technologically feasible using current technology. To achieve a reduction in the price to the level of conventional energy, production needs to be scaled up to 500 MWp[4] per year (KPMG 1999: see the list of suggested further reading in Annex 9.)

Box 4. Renewables can boost clean economic growth. *Already when relying on present renewable technologies large emission reductions may be achieved by removing institutional obstacles and making information about opportunities available. With future technologies the economics of sustainable supply may out-compete the unsustainable sources dependent on thermal conversion. Wind generators do not require thermal conversion, solar photo-voltaic systems do not even have any moving parts. In the future, sustainable energy supply may become less costly than conventional sources, boosting economic growth. Such a development may imply more energy use than anticipated in the future image – but the carbon emission reduction target may even be easier to reach.*

Box 5. Costs of the transition. *During COOL Europe workshop 2 in April 2000 the participants were confronted with a calculation about the cost for achieving 75 per cent GHG emission reduction in the Netherlands by the year 2050. Presently the Netherlands spends about 12 per cent of its GDP on the energy system. Without any climate policy measures the cost for the energy system may go down to 8 per cent in 2050 because of ongoing economic growth. With a severe climate policy the expenditures could end up at 10 per cent or so. Source: Energy Policy Platform (2000). Climate change: Solution in Sight. A Dutch Perspective. The report can be downloaded from: www.ce.nl/bg.pdf*
See also Annex 9 for a tentative cost calculation on the -80 per cent target for Europe.

Hydrogen and the transport sector

There is a vicious circle of low demand for hydrogen → no infrastructure development → no availability → no increase in demand. Ways of breaking this vicious circle

[4] P (=peak) indicates how many watt the solar cell can produce when there is maximum sunshine.

are desired. Hydrogen vehicles would create the flexibility of using different possible routes for hydrogen production (produced from renewable electricity, biomass or conventional sources). Alcohol fuels, in particular methanol, may serve as a carrier of hydrogen, fuelling fuel cells after being separated in on board reformers. Methanol can be distributed in the conventional distribution system. Methanol use may be increased by general blending of fossil automotive fuels and by use in internal combustion engines while the fuel cells are increasing in numbers.

Hydrogen and the fossil fuel industry

One important consideration that has been suggested in the COOL Europe process is that geological carbon sequestration, if applied, should be based on the "pre-combustion decarbonisation" model. This involves removing the carbon content of fossil fuels to produce hydrogen before their use for energy conversion. Pre-combustion decarbonisation produces hydrogen. This means that it will still generate demand for the transmission infrastructure and dispersed conversion technologies regarded by this group as essential for long-term sustainable development. Decarbonised fossil fuels would then compete directly with renewable energy sources as sources of hydrogen. This means that the decarbonisation and sequestration process itself will have encouraged, or at least not impeded, the rise of the hydrogen economy. Our view is therefore that a pre-combustion decarbonisation model coupled with geological sequestration could feasibly be made compatible with the long-term vision.

The role of climate policy

Hydrogen technology would benefit from a determined international climate policy with a focus on the realisation of the ultimate goal of the Climate Convention. Demand for hydrogen as an energy storage technology would increase with increased use of wind and solar energy as sources. Demand for hydrogen as an alternative to fossil fuels would increase as carbon emissions become costly. Finally, when a long-term sustainable energy system will become a credible future, hydrogen technology would attract a lot of attention and resources as hydrogen appear the most promising energy carrier in such a future. However, in the absence of such a clear climate policy framework, development may be slow and less efficient.

Conclusions and recommendations

- In order to make the solar hydrogen option viable for the long term, production of solar PV needs to be scaled up. For this purpose, mandatory requirement of installing PV in newly built houses and commercial buildings can be considered. Furthermore, a large-scale R&D programme for solar PV could be required to achieve necessary technological breakthroughs.
- Pre-combustion decarbonisation can be considered since it allows the fossil fuel industry to be a part of the transition toward the hydrogen society.
- Hydrogen vehicles would create the flexibility of using different possible routes for hydrogen production (produced from renewable electricity, biomass or conventional sources).
- It will take time to develop a European pipeline system for hydrogen distribution (see Table 2.1 below). However, local hydrogen grids can play an important role long before there is a European transmission system in place.
- The hydrogen option is a natural task for the European Commission. It has a long-term dimension and will require co-operation between virtually all countries in Europe. The European Commission can play an important role in building a constituency for hydrogen in European countries and key sectors and in initiating a dialogue about possible partnerships and financial arrangements.

Table 2.1 Developing infrastructure for hydrogen distribution

2000–2010	Addressing the “Hindenburg syndrom”: Demonstration and improvement of safety, tests and pilot projects. Discussion about public-private partnerships to share investment costs.
2010	Increased safety performance achieved.
2010–2020	Local hydrogen grids demonstrated for storage and distribution of energy. Hydrogen used as a fuel for trucks in the public sector. Preparatory work for European hydrogen pipeline system: legal work, definition of location, address land use issues, etc.
2030–2050	Standardised European infrastructure for hydrogen distribution in operation.

2.5.5 Carbon dioxide pricing – a critical precondition for the transition

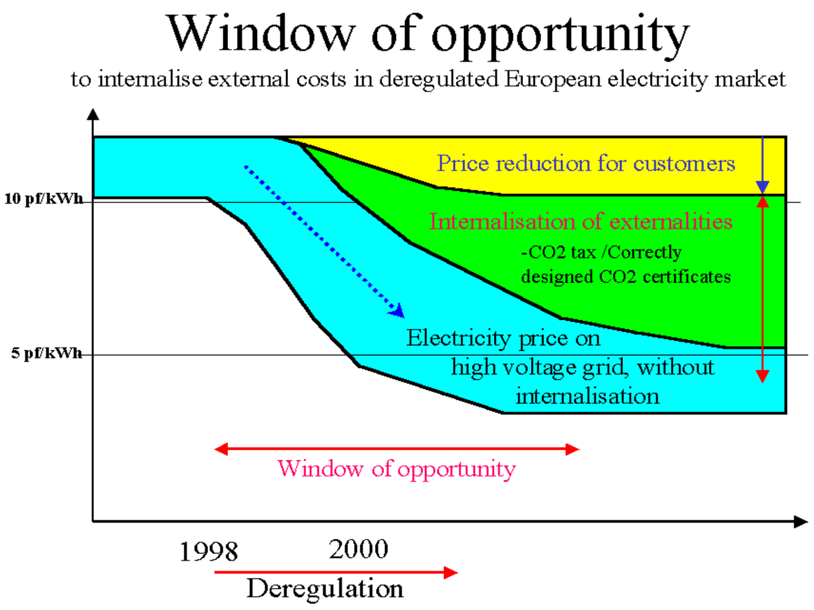
Our group is strongly convinced that pricing of externalities is vital to create a sustainable development of a market economy. Without carbon dioxide pricing it will be difficult to reach the necessary long-term climate policy objectives. In our dialogue it was assumed that different instruments (taxes, emissions trading and project-based instruments like Joint Implementation) can work together in a strategy to achieve carbon dioxide pricing.

There were some ideas brought up during our workshops related to carbon pricing. The first was related to the introduction of competition onto the European electricity market. Increasing competition currently causes decreasing electricity prices. This is a threat to sustainable development as demand usually increases when prices go down. And as the fall in price is due to temporary overcapacity rather than genuinely low production cost the increase in consumption will counteract long-term efficiency. However, the fall in electricity price also creates a window of political opportunity to introduce carbon pricing into the electricity sector.

If carbon taxes are imposed during the increase in competition the net result may by stable or only slightly lowered prices. Income from carbon taxation or auctioning of emission quotas could be relocated to lower labour cost, support introduction of renewable sources of energy, and/or used to support research and development aimed at ecologically modernising European industry.

As prices are not increasing, consumers will not be worse off after the simultaneous introduction of competition and carbon pricing (see Figure 2.5).

Figure 2.5 A window of opportunity for carbon pricing



A second observation we have made is that the enlargement of the European Union has important implications for the introduction of carbon pricing. Union wide carbon pricing has so far been blocked by some Member States. If these cannot be convinced before the enlargement, and the Treaty is not changed to allow majority voting on such issues, it will become very difficult to introduce common carbon pricing after enlargement.

A lot of future EU decision-making will be difficult unless majority voting is accepted. Therefore it is possible that strong interests will favour changes to the Treaty making majority

voting possible also in the field of environmental taxation before enlargement.

With very high carbon prices international competitiveness becomes a relevant issue. Just as there is a need to harmonise economic environmental policy measures with in the European common market, co-ordinated action will be desirable within the WTO if strong measures are to be efficient. If strong measures to reduce greenhouse gas emissions are required, then it will be important to include such measures as a condition to take part in the WTO if the policy is to be efficient. Such environmental conditionalities could of course also be applied to other global regimes, such as those influencing the IMF, the multilateral banks and other international financing institutions.

Box 6. Framework conditions for carbon pricing.

1. *Completion of the re-regulation process introducing competition in the European energy markets, giving rise to complete price transparency and low barriers to entry for new technologies and companies.*
2. *Removal of environmentally damaging subsidies for e.g. coal and nuclear power.*
3. *Internalisation of environmental costs through various forms of carbon dioxide pricing. Window of opportunity: Introduce carbon dioxide tax when electricity prices are falling.*

2.5.6 Social aspects and stranded assets

The issue of stranded assets relates to situations where policy-makers have to deal with existing assets that are undesirable from an environmental point of view and thus should disappear, despite the fact that there still might be an economic rationale for their existence. Currently, the inertia of the historical interest division is predominant for microeconomic decisions. A large number of economic actors have invested to be competitive for the formerly expected market. They now have an interest to secure themselves against the costs of risks undertaken before, which now is out of their direct control. When powerful societal groups are strongly dependent on existing assets, the transformation process is slowed down. It is therefore extremely important to include at an early stage all major players in the energy sector in a learning process about feasible options for the long term and construct possible pathways to reach a desirable future situation. In this way the construction of new assets based on historical criteria can be avoided.

A particular case is the coal mines. The two future images which are the starting-point for our backcasting exercise both assume that in fifty years time there will be no use of coal in Europe. This implies that some coal mines will have to be closed before the end of their economic life time. Structural change may be slowed down if there are no mechanisms to deal with accumulating unemployment. Employment effects related to the two future images and their respective pathways should be carefully investigated.

2.6 Implications for the short term

2.6.1 The role of current stakeholders and the private sector

Current stakeholders that might be threatened by the developments foreseen in the alternative energy futures are large-scale electricity producers, electricity distributors and oil companies. For example, companies in charge of the transmission system are likely to oppose decentralisation. Decentralisation would hurt them because they make money on high voltage power flows.

The discussions in our group showed that many companies are beginning to take an active interest in contributing to the emergence of a sustainable energy system. Oil companies such as Shell and BP Amoco are diversifying into solar technologies. Car manufacturers are investing in hybrid or fuel cell technologies (Toyota, Daimler-Chrysler, Ford). Oil industry and car producers are supplying ethanol vehicles and ethanol fuel (Ford and Q8). Some of the larger electricity producers and distributors are getting involved in the development of the required new capacity (wind parks, CHP plants). With the appropriate institutional framework there is interest also to re-focus into the delivery of 'energy services' instead of mere energy.

Hence, it is becoming clear that an increasing share of companies in the private sector is aware of the fact that constraints on carbon emissions are likely in the future. Pro-active companies have already made efforts beyond legal obligations or short-term economic optima in anticipation of such future restrictions. Many more are preparing themselves to adjust when such restrictions appear. Such voluntary climate protecting measures are made easier by transparency and consistency in public policy development as investment decisions can be made with less uncertainty.

It is critically important that companies taking voluntary early action by reducing their greenhouse gas emissions are not penalised during subsequent rounds of legislation. In order to facilitate such voluntary action, the EU has a role in creating a credible framework of legislation on environmental liability whereby the polluter pays principle is applied.

The proactive parts of industry may contribute by supporting such legislation and changing the habit of many industrial federations operating at the EU level to protect the weakest members against the economic consequences of more stringent legislation or environmental taxes.

Voluntary, private environmental measures in industry are systematically encouraged under EMAS (the European Environmental Management and Audit Scheme). Under this scheme development clusters of mutually supporting companies develop as progressive companies support suppliers who are improving their performance. Mutual support among progressive companies is even more successful when their efforts are clearly rewarded by the attention and possibly even willingness to pay among final customers. Not only private customers are important, a decisive encouragement to progressive industries may come from public bodies acting as customers under public procurement legislation.

The private sector may contribute to this development by actively taking part in clusters of companies supporting each other to improve climate performance. But private industry may also use their consumer marketing to increase awareness of their environmental efforts. Private industry may also contribute to successful development by supporting environmental and greenhouse gas emission criteria being generally applied in public procurement.

Whether these industrial efforts will continue or the companies retreat into defending established supply structures will depend on whether these development efforts are supported by authorities and rewarded by the customers, or not. Clear signals for the long term are required in building confidence among these major investors that the radical transformation will last.

2.6.2 Towards a political framework

In our view it would be desirable for the EU to increase its capacity to deal with the long-term climate policy challenges. For this purpose we propose the following actions. Firstly, the EU could elaborate a vision about how the climate policy regime could develop for the long term to meet the ultimate objectives of the UNFCCC and create a competition advantage for European businesses on global energy related markets. Various stakeholder groups should be invited to participate in this process. Secondly, it is desirable to strengthen the European Commission's capacity to deal with long-term climate policy. For this purpose a cross-DG strategic unit for long-term climate policy might be set up by the European Commission. Thirdly, it is important to establish the institutions in a liberalised energy market which will be responsible for energy efficiency and renewable energy. The opportunities and constraints for renewable energy sources and energy efficiency in the liberalised energy markets in Europe need to be studied more.

Clearly, the recently established European Climate Change Programme is an important forum where these issues could be addressed.[5]

The long-term prospects for climate control actions in Europe are certain to be profoundly influenced by the course of institutional change globally and at the EU level. Important driving forces are, *inter alia*:

- Policy harmonisation between the major trading blocs require new global institutional mechanisms – possibly including an enforcement regime – which could be exploited for environmental purposes, particularly if new rules are agreed defining the scope for differentiation in the interests of environmental protection.
- Improved scientific understanding of global climate change could lead to the formation of a vocal and active constituency comprising existing and potential victims of climate change and popular opinion that accepts the seriousness of the threat.
- An important driving force for institutional change is EU enlargement. It is likely that after the enlargement the EU will have to attach increasing focus to general framework policies at the strategic level. New institutional mechanisms for long-term policy-making could emerge as a result of this.

Lastly, we propose that the EU create mechanisms and a strong policy framework that make it easier for the candidate countries in Central and Eastern Europe to leap-frog in developing their infrastructure, technology mix and consumer cultures. This could involve the creation of a financial mechanism that creates advantages for the long term without causing economic disadvantages for the short term and policies channelling the current dynamic transformation towards low-carbon pathways. This process can be supported via the establishment of Centres for Sustainable Energy Transitions (CSET) in the candidate countries (and perhaps also elsewhere in Europe). These centres could also explore the new business opportunities arising from the necessary carbon constraints.

[5] The European Climate Change Programme was launched by the European Commission in early 2000 to identify and develop strategies that are necessary for the implementation of the Kyoto Protocol. This work, achieved by a co-operative effort of policy-makers and stakeholders, will help the European Commission to propose concrete policy proposal to the Council and the European Parliament. See: www.europa.eu.int/comm/environment/climat/eccp.htm

3. STRATEGIC VISION FOR THE EUROPEAN TRANSPORT SECTOR

The strategic vision on transport has been produced under the responsibility of and with significant contributions of the following participants of the COOL European Dialogue: P.Beeckmans, Community of European Railways (CER), Brussels; A. Kassenberg, Polish Institute for Sustainable Development, Poland; R. Kemp, MERIT, the Netherlands; A. Pastowski, Wuppertal Institute for Climate, Environment and Energy, Germany; Beatrice Quenault MIES, France; Rolf Sartorius, German Federal Environmental Agency, Germany; B. Schell, F. Goodwin, European Federation for Transport and Environment, Brussels; H. Somerville, British Airways, UK; B. Tegethoff, Coalition of German Consumer Unions, Germany; B. Thorborg, Dutch Ministry of Transport and Waterways, the Netherlands; R.Torode, International Union for Public Transport (UITP), Brussels; J. Trouvé, Schenker BTL, Sweden; A. Wijkman, European Parliament, Brussels. The editors of the strategic vision on transport are: G. Bennett and W. Tuinstra.

3.1 Introduction

3.1.1 Creative Thinking in the Transport Sector: a European Dialogue

This document contains the outcomes of a process which involved a wide range of stakeholders (representatives of business, environmental and transport NGOs, consumer unions, research institutes and national and European authorities) of the European transport sector. They met during four dialogue workshops to develop a long-term vision on reducing greenhouse gas emissions in Europe. A similar dialogue took place for the European energy sector. The starting point for the European Dialogue was the assumption that the emissions of CO_2 in Europe will be reduced by 80% within 50 years.

3.1.2 Climate Change: Long-Term Challenges and Short-Term Actions

Climate change is currently a major issue in environmental policy and discussions on economic growth and sustainable development. In order to meet the ultimate objective of the UN Framework Convention on Climate Change, it has been estimated that the global emissions of greenhouse gases need to be reduced by 50-80 per cent by the middle of this century compared to the present, global emission rate. This implies an 80 percent reduction target for the presently richest part of the world.

Is it possible or desirable to try to achieve this at all? Current trends show continuing economic growth and increasing emissions. To change this trend and aim for an 80% reduction in the far future requires creative innovation and effective collaboration between different groups in society in the short term. It also requires a process to create a common long-term vision to identify strategies that relate acceptable current policy measures to a long-term perspective to reach the target. Current policies are often not successful because they focus on the short term. A structural change is needed, and that requires time and co-operation between the different stakeholders.

The four workshops in which the stakeholders in the European dialogue met focused respectively on: (1) images of the future (what are the main characteristics of the sector and society in 2050 assuming a reduction in CO_2 emissions of 80% by that time?), (2) the construction of a pathway connecting these images back to the present (what are the preconditions and strategies that could lead to this state?), (3) short-to-medium term actions needed to reach the long-term goals and (4) the strategic vision itself. It is this strategic vision that is presented in this document.

3.1.3 Strategic Vision

The strategic vision for the transport sector identifies promising long-term options, the key boundary conditions on which these options depend and the actions that are needed in the short term if these options are to be feasible. What would we like to see happen? What are we able to realise? What steps need to be taken to achieve this? How can we best promote partnerships among the stakeholders at the European scale in order to implement these options successfully? Rather than focusing on future technology developments or technical solutions, on which excellent studies exists elsewhere, the group explored issues such as the needs and possibilities for new coalitions between different stakeholders, the role of new institutions and the role of public awareness.

The COOL European Dialogue was devised as a common creative process, not as a planning tool. It was therefore managed as an exercise in which the participants could learn from each other. The resulting strategic vision is therefore intended to serve, not as a policy blueprint, but as a stimulus to further thinking on climate control, as a source of interesting ideas and as a guide to the key issues in developing co-ordinated European action. It is not necessarily complete or fully internally consistent. We hope that this document at least can provide a starting-point for a more structured focus to long-term action.

Box 1: COOL Strategic Vision for the European Transport sector and actual policy developments

The European COOL Dialogue does not stand on its own. Within the European Climate Policy Programme (ECCP) various stakeholders also meet to identify effective policies and measures. However, the focus within the ECCP remains the short term. Furthermore, following the Cardiff process, a transport integration strategy to integrate environmental concerns into transport policy has been developed by European transport ministers. In order to assess the progress of this strategy the European Environment Agency developed a Transport and Environmental Mechanism (TERM). Recently, the OECD has developed guidelines for sustainable transport under the Environmentally Sustainable Transport project (EST). Participants in the COOL Dialogue have participated in the above-mentioned processes. The European COOL Dialogue is unique in the sense that it focuses, in the context of climate change policy, on the long term (that is, 50 years ahead) and on radical emission reductions (a reduction of 80% in CO_2 emissions compared to the year 1990). Furthermore it is ultimately a process in which the role of various stakeholders has been important: exchanging and adding to each others ideas.

(Source: IEEP, 2000)

3.2 Towards a Strategic Vision: Future Image and Path Analysis

3.2.1 Future Image

What does society look like in 2050 when an 80% reduction in CO_2 emissions has been achieved? Trying to imagine such a future helps to think more concretely about the long term. Of course many different futures are possible. In this project the group distinguished four main elements through which the reduction is achieved: 1) improved efficiency, 2) fuel substitution[6], 3) changes in structures and patterns, 4) changes in awareness, values and lifestyles, as illustrated in Figure 3.1.

[6] For reasons of completeness it should be mentioned that for the sake of the discussion and the focus on challenges for the transport sector, the possibility of a sudden availability of carbon-free generated electricity (including nuclear energy) was excluded in the European COOL dialogue from the beginning. Would this assumption not have been made the transport group could have shifted the whole problem to the energy group.

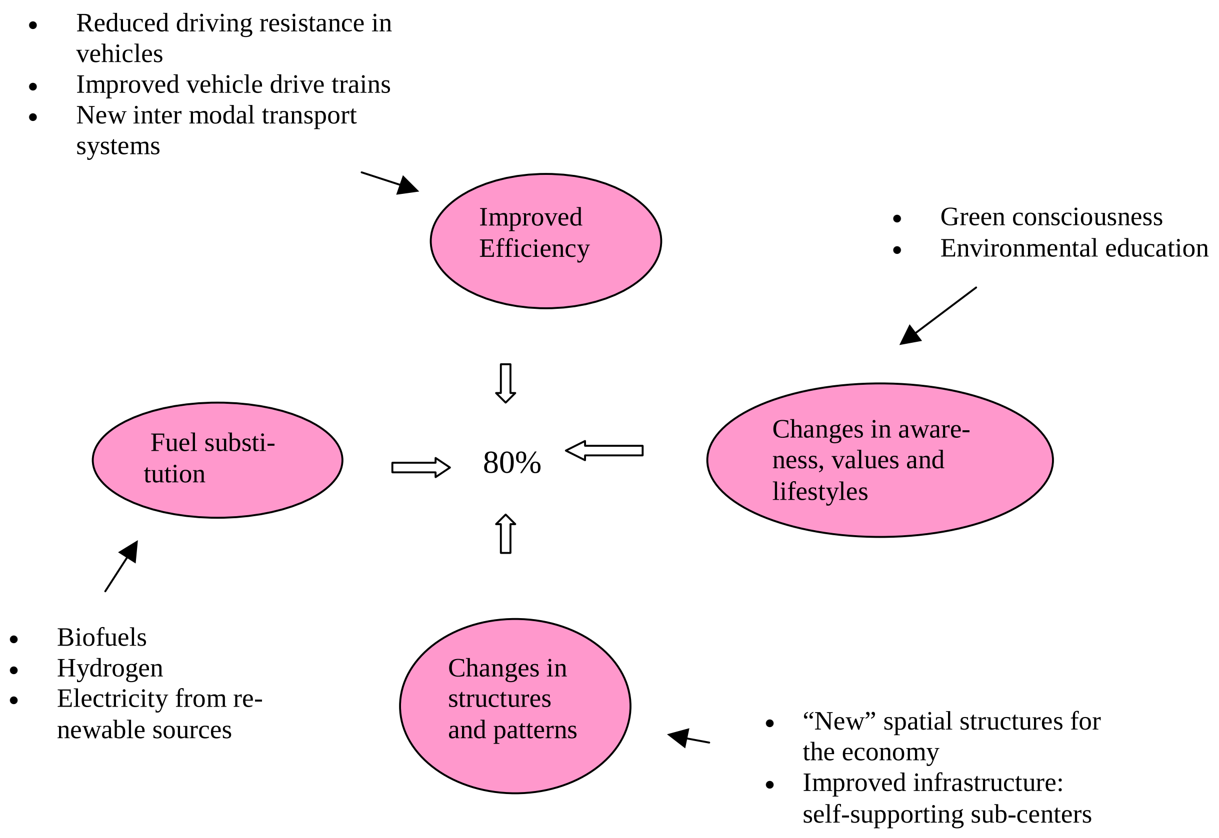


Figure 3.1 The different elements of a future image for the transport sector

Box 2: An overview of the transport system in 2050

The passenger transport system is characterised by a great variety of niche vehicles (for example, small electric city vehicles), all-purpose cars and new systems such as personal electric vehicles that can link to each other and form trains that travel on special tracks. Buses, trams and trains have increased their share somewhat compared to 1995, especially in urban areas There is no single system that dominates the market to the same extent as the private all-round car did at the beginning of the century. Another prominent feature is the spread of inter-modal transport with smooth and short transitions between modes. Organised car sharing also has a market. ICT is being widely used in intelligent traffic control and information systems, and also for flexible road pricing.

The energy efficiency in the transport sector is high The volume of short motorised everyday trips is less than in 1995, due to "decentralised concentration" (urban subcentres are relatively self-supporting) and the use of ICT as a substitute for commuting to work. ICT shopping is also widespread. Long-distance journeys are well above the figures for 1995, especially those by air. All this has resulted in more efficient, flexible and cleaner passenger transport.

In the case of freight transport, inter-modality is widespread, which has led to an increased share for fast trains. Dematerialisation and structural changes in industry have led to a slower growth rate for the tonnage transported, but the increase in average distances continues to be high. More production and service will be done locally using global technology. Ideas on "glocalisation" and decoupling economic development and need for transport have been developed.

It should be noted that within the Transport Group of the European COOL project, there was some doubt whether the above picture really implies a reduction of 80%. Also there was some discussion whether 80% would be feasible for the transport sector on its own. Rather the question was reformulated: what could be the contribution of the transport sector to a reduction of 80%? However, in the course of the dialogue the target of 80% remained the starting point of the discussion to guide the participants towards thinking about real structural changes. A Complete overview of the Future Image which was used by the group as a starting point for discussion can be found in Annex 11.

3.2.2 Path Analysis

Which steps have to be taken to reach such a future society in which CO_2 emissions are reduced by 80% in 2050? What is the appropriate timing, who is involved and what are the necessary boundary conditions? These questions can be addressed by constructing a path from the future image back towards the present.

About the timing and actors with regard to the four elements of the future image the following general observations can be made:

- Many actions intended to improve efficiency can be taken in the short term. They are relatively easy to develop and implement and do not involve many uncertainties. The appropriate actors can also be readily identified.

- Fuel substitution involves more difficult choices, greater uncertainties and more complex coalitions of actors. It is of greater significance in the medium term. However, it also offers more scope for radical change.
- Changes in structures and patterns require a long period to take effect and involve substantial uncertainties. The changes are also dependent to a large extent on appropriate actions by a wide range of actors in other sectors.
- Changes in awareness, values and lifestyles are most difficult to influence since they are dependent on a wide range of factors and complex interactions within society. However, such changes have a huge potential to shape processes that determine the development of the transport sector and CO_2 emissions.

Some actions or measures (such as individual carbon budgets) can only be taken following the implementation of other actions or measures (such as further improvements in ICT and related technologies). A substantial proportion of the measures will have to be initiated in the coming 15 years.

The figure below shows how actions and measures are connected to the Future Image. In Annex 12 those actions and measures are presented in more detail. In order to achieve success, however, it is not enough to consider the actions and measures only in themselves: it is also important to take into account the necessary pre- and boundary conditions for their implementation and to consider opportunities and obstacles. In this document we will refer to those issues as challenges. In the next section we will consider some selected actions and measures, which we will call options, in order to highlight the challenges.

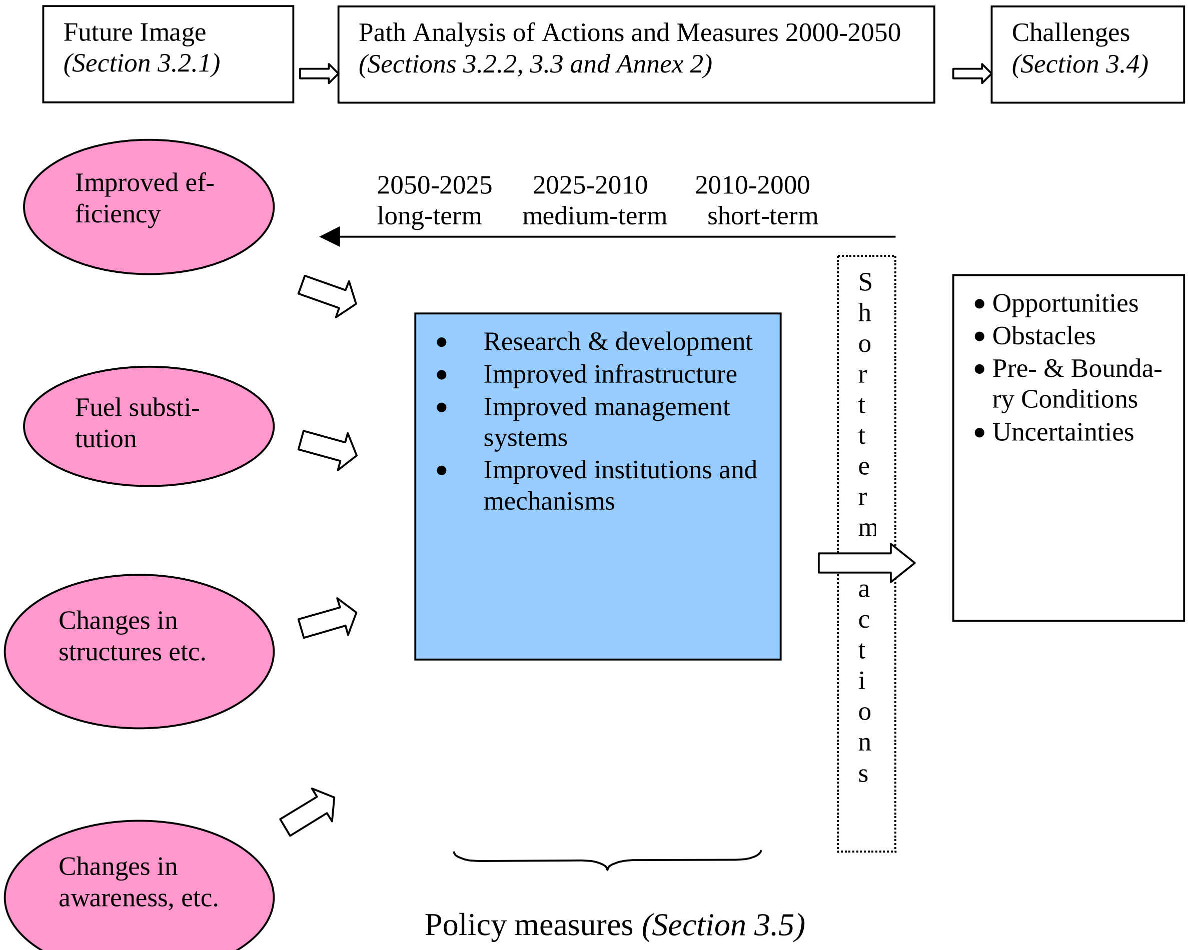


Figure 3.2 The relation between the future image, the path analysis of actions and measures and the challenges

3.3 Promising Options: Examples

Rather than focusing on technology or possible future technological developments, the options sketched below reflect the search for certain choices that have to be made to stimulate developments in the domains of infrastructure, structures for information exchange and co-operation and public involvement.

Option 1. Improved Management Systems and Challenges for Companies: the Example of the Freight Transport Company as Information Broker

Companies will play an important role in giving shape to visionary ideas and in taking action to find intelligent ways to reduce CO_2 emissions. Actions will only be effective and attractive if they enhance business results as well as relations with customers. Taking the freight transport sector as an example, we can discern several “windows of opportunity”:

- Better logistics reduce environmental impacts and transport costs, both for the transport company and the customer.
- A transport company is a services company: it serves its customers in getting goods in the most efficient way from A to B. This includes providing to the customer both the actual transport and information about the most efficient ways of transportation. The transport company thus acts as an information broker providing information about costs, environmental impact, distances, time, modes etc.
- To maintain the highest standards of service, companies will adapt to the wishes of customers. The strongest drive to enhance environmental performance will be the demand for this by customers. On the one hand, companies can anticipate this demand and create a start in the market; on the other hand, transport companies can play a role by guiding their customers concerning the advantages of logistical and environmental efficiency. **Challenge: the potential impact of changing awareness.**

Presently, there are already companies developing this new role as information broker. They operate information systems that include emission reports of complete chains of transport, including all modes. There are many opportunities to extend this kind of systems and connect different companies. **Challenge: transition management as a precondition.**

Option 2. Improved Infrastructure: Decentralised Concentration

In a region characterised by decentralised concentration, the different sub-centres are relatively self-supporting with respect to workplaces, service facilities and shops, entertainment etc., although they are interacting. Furthermore, in a region with a pattern of decentralised concentration, a public transport system will give most inhabitants good access to most nodes in the region. This shift in the organisation and localisation of work will reduce travel as such, but may also revitalise urban sub-centres. When more people stay in the suburb during daytime, the market for local services such as lunch restaurants and shops will grow, making the suburb more attractive to other people. Possible measures to promote decentralised concentration are land-use and city planning, “park-and-ride” schemes, road pricing, restrictions on parking areas in city centres, improved flexible public transport services, bike networks etc. However, the most important policy may be to upgrade the service level of existing sub-centres in order to make them more attractive for both residents and enterprises.

Option 3. Research & Development: Information and Communication Technology[7]

The use of ICT can promote sustainability in the traffic and transport sector in a number of ways:

1. By optimising the use of the infrastructure (including promotion of the “modal split”).
2. By optimising the logistics chain.
3. With intelligent vehicles and monitoring of cargoes.
4. By reducing the pressure on mobility through alternatives (tele-working, tele-shopping, tele-learning).

The interaction between the various aspects is highly complex: optimising logistics chains, for example, could have a negative effect on the modal split, and to a certain extent also on the use of the infrastructure. Energy savings actually achieved are likely to be less than what is technically feasible. When a new technology is introduced, attention should be given to the behaviour of societal actors, new arrangements, infrastructure, organisation and information, and the technology-behaviour interactions. Many of the technical possibilities are not properly exploited because of rebound effects, failure to provide information to the user, divided interests and power positions of actors, so that no one takes the lead in directing the use of ICT technology. Furthermore, it should be noted that ICT applications themselves and the requisite servers and computers increase electricity demand substantially.

What policy actions do we feel should be adopted?

- Stimulate developments in ICT which really contribute to reducing CO_2 emissions.
- Influence technology-behaviour interactions and prevent rebound effects.

[7] Based on input from M. van Lieshout and A. Slob , TNO, the Netherlands.

- Ensure that the infrastructure is adequate.
- Provide information to users; **Challenge: the potential impact of changing awareness.**
- Collaboration is needed between government, companies and civic groups, in which they participate in a dialogue on the measures that have to be taken, and by whom, to supervise the ICT applications in order to gain the maximum benefit from energy-saving effects. **Challenge: transition management as precondition.**

Option 4. Changes in Lifestyles as a Means of Reducing Mobility

Lifestyle changes will be crucial in the process of changing mobility patterns and reductions in CO_2 emissions. New technologies alone will not bring CO_2 reductions about if they are not used optimally but cause significant rebound effects. New technologies might even not be developed if there is no demand to get clean technology to the market. Business reacts to customer pressure. Lifestyle changes are not happening automatically and are difficult to influence. The way people satisfy their needs is closely related to the opportunities and constraints of their culture.
Important for stimulating lifestyle changes is an increased public awareness. Increased awareness on (1) the nature and consequences of the problem, (2) opportunities for alternative behaviour (3) the impact of alternative behaviour. However, increased awareness only is not enough. A paradox is that that consumers often understand the social issues and prefer mobility to be constrained, but as individuals they do not wish to be constrained themselves. Alternatives to daily routines should be available, easily accessible and attractive. **Challenge: the potential impact of changing awareness.**

The pathways to alternatives to change:

- It is important to experiment. The best possibilities for experiments are at the local level. Local debates can be initiated and local partnerships can be built. At the European level, local initiatives and experiences should be exchanged.
- Highlight best practices. Show also the best practices from other countries: habits differ from country to country. Why can cycling to school in some countries be possible and in others not?

- Start information campaigns for the general public and implement these in curricula at schools and universities, acknowledging the various reasons to act "green" or to change behaviour in general.
- Information-and communication technology (ICT) should be widely used to facilitate easy access to information on alternatives, to improve logistics and to reduce needs for travel and transport.
- Different people have a role to play: partnerships should be built, business should set targets as well and should play a role in showing and offering customers alternatives.
- Increase trust by also increasing awareness of politicians. Policy should be consistent, reliable and realistic.

3.4 Challenges

Transforming promising options into feasible actions is the most challenging task of any long-term policy strategy. The realisation of a goal – and particularly such an ambitious goal as the COOL target in such a complex environment as the transport sector – requires a wide range of factors to be understood and shaped. There are uncertainties to be clarified, preconditions to be met, boundary conditions to be created, perceptions to be changed and countervailing reactions to be anticipated.

To take just one example: uncertainties on the future growth in demand for freight transport are enormous. A recent study of the growth in freight transport in the EU-15 and the CEE countries up to 2020 produced minimum and maximum estimates that varied by a magnitude of between 3.5 and 5.5. Such differences have far-reaching implications for the measures that will be necessary to secure emission reductions from the freight transport sector.

This is but one example of an issue that is crucial to the process through which the COOL objective will be met. But there are many others: To what extent is it feasible to secure an increase in investment and government expenditure on R&D and sustainable transport infrastructure? Can the minimum threshold in the market size for sustainable fuels and transport technologies be achieved? How can the potential of ICT be fully exploited in developing sustainable transport systems? Through the backcasting exercise, COOL encountered a wide range of such issues. But four broad challenges emerged that were judged to be of key importance to meeting COOL's long-term target: (1) establishing the necessary preconditions, (2) creating the appropriate institutional boundary conditions, (3) changing awareness and (4) the reactions of vested interests to emission-reduction measures in the transport sector.

Challenge 1. Internalising External Costs and Transition Management as Preconditions for Substantial CO_2 Emission Reductions

COOL is ultimately concerned with identifying the pressures that are necessary to bring about certain changes in societal processes. But to have the desired effect, the pressures require the existence of certain preconditions, such as cultural perceptions, social patterns, economic processes, administrative structures and technology. COOL identified two particularly important preconditions for securing the projected changes: the internalisation of external costs and the development of the capacity for transition management.

A common characteristic of many of the specific measures that were identified through the backcasting process was "getting the prices right": carbon taxes, road pricing, abolishing perverse subsidies, a tax shift from labour to natural resources – all of which aim to influence consumer and corporate behaviour through the price mechanism. And although at first glance these proposals are focused purely on the choice of policy instrument, the emphasis on internalising the environmental costs of transport was so pervasive throughout the COOL process that it infers structural economic change. And the changes will to a large extent have to be European rather than national in scope in order to prevent problems arising through the possible distortion of competition between states or discriminatory national practices.

But change, if it is to move consistently towards long-term targets, must be effectively managed. This requires the ability to manage a wide range of processes, from technological development through to awareness-raising. This in turn requires an effective capability for transition management. Transition management focuses on strengthening the capacity for learning, co-evolution, interactive policy processes and instrumental action through goal definition, experimentation as a means to facilitate learning, and the promotion of interaction between different actors, such as government, business, science and citizens.

Challenge 2. Shaping and Exploiting Institutional Boundary Conditions

Europe has repeatedly demonstrated an enormous capacity for institutional change. Witness the past fifty years, which have seen two institutional revolutions through the development of the European Union and the radical political, economic and social transformations now taking place in Central and Eastern Europe. The capacity for institutional change in Europe therefore cannot be questioned, nor the existence of powerful cultural, political, economic, social and technological forces that are driving further changes. But how will these driving forces shape the institutional boundary conditions that will frame the scope for climate control measures?

One dominant driving force is globalisation, the process through which both the markets for products, services and investments and the operational sphere of companies become increasingly international in character. We are seeing that the capability of transnational companies and investors to take actions that have an impact on the environment is outpacing the capacity of governmental institutions to manage the processes that cause those impacts. An “institutional deficit” is evolving through the combination of the declining capacity of governments to impose national environmental controls on companies and the failure to realise a proportionate increase in the environmental control capacity of international institutions. However, this development is likely to feed two countervailing needs: first, more explicit and more elaborate international rules on the scope for local, national or regional differentiation with respect to trade regulations and instruments where this is necessary in the interests of environmental protection; and, second, more effective international enforcement regimes. Business will certainly be reluctant to accept a significant degree of regulatory differentiation, but in a parallel development companies themselves will appreciate the advantages of launching initiatives that demonstrate a high level of social and environmental responsibility, thereby strengthening consumer trust in particular brand names and, in the words of an executive of a major company, securing a “societal residents permit”.

For the EU, enlargement will in all probability be responsible for the greatest institutional impacts over the next two decades. Enlargement will have three important consequences for EU institutions. First, it will increase even further the already substantial degree of diversity within the EU, with a concomitant decline in Community cohesion. Second, the greater number of actors will complicate even further Community decision-making procedures and the allocation of competencies. Third, the Union will face even greater challenges in ensuring that Community measures are appropriately, consistently and promptly implemented across a greater number and a more diverse family of member states. The greater diversity, institutional complexity and implementation challenges that are the inevitable consequences of enlargement will probably drive EU policy-making towards an emphasis on framework measures that lay down the targets for a particular policy object while allowing the member states a greater degree of discretion in how the objectives are achieved and which instruments are applied for that purpose. This infers a shift towards longer-term policy-making and a greater need to develop policy frameworks, mechanisms and instruments that are effective in establishing and securing long-term goals and objectives – an essential requirement for effective climate control measures. Groups of member states may also establish forms of flexible co-operation, for example with regard to the use of economic instruments for climate policy.

Challenge 3. Opportunities: the Potential Impact of Changing Awareness

Changing awareness is one of the most uncertain but potentially most influential factors in determining the scope for securing substantial reductions in CO_2 emissions. The values of European societies are evolving rapidly in response to economic and communication developments: traditional forms of social organisation are being superseded by common-interest networks which are more specialised, more extensive, more informal, more flexible, more transitory and more consumer-oriented in character. These network interests are being shaped through more direct, focused and flexible means, such as television and the Internet. The longer-term implications will be profound. Some of the greatest impacts could result from the increasing desire by individuals, groups and organisations to exert more direct influence on the actions of public and private institutions that shape their lives. Consumer power in this respect may in certain cases prove to be enormously influential, as the current BSE issue illustrates in its impact on the production and consumption of beef. But an area of potential tension is how the changing perceptions and awareness in western Europe will interact with the widespread preference in the central and eastern European countries for strong political institutions, particularly if and when these countries make up a substantial proportion of the number of EU member states. Also it remains to be seen whether central and eastern European countries will actively promote a sustainable Europe, or whether they will continue to move towards a Western style of consumption.

Broad awareness of the significance and the impacts of climate change and the need to take action will to an important extent be influenced by the results of further climate research. It is certainly possible that in the foreseeable future studies will confirm to an acceptably high level of confidence the current hypotheses on climate change. Associated advances may make it feasible to construct more detailed and confident prognoses of global and regional climate changes and to demonstrate a credible causal link between climate change and specific natural disasters. Even more important will be the role of the media, associating (correctly or incorrectly) pictures of droughts, floods, famine and migration with climate change. The impact of such developments on public, political and corporate perceptions would be profound and probably sufficient to drive a process that could lead to a global climate regime of far greater substance and enforceability than Kyoto.

Challenge 4. Obstacles: Anticipating Reactions by Vested Interests

The measures that will be required to realise an 80% reduction in CO_2 emissions in Europe by 2050 will have far-reaching consequences, not only for transport but for virtually all economic actors. However, the extent to which other sectors can be persuaded to become fully party to such a process is open to question. Many actors, particularly those whose economic interests are most at risk from climate control measures, can be expected to oppose and obstruct such moves. Further, many crucial socio-economic variables – international trade, consumer demand, cultural perceptions, for example – can only to a limited degree be shaped by government and the climate-change coalition. The way in which other actors may respond to climate control proposals and measures is therefore a crucial factor in the COOL process.

The possible response of the oil sector provides an interesting example of the kinds of complications that a climate strategy may need to anticipate. European action to reduce substantially CO_2 emissions coupled with an ambitious global climate regime will have enormous implications for oil consumption and will trigger response measures by the oil industry and the oil-exporting countries. Actions designed to promote a shift to biomass as a source for fuel, for example, will trigger a reaction by the oil sector, not only because of the threat of reduced demand for fossil fuels but also because of the complications that such a shift will cause for oil refineries. Refining oil produces a range of fractions that can be used as the base product for a range of fuels and other products, but refineries have relatively limited scope for changing the relative proportions of these fractions – for instance between diesel and kerosene – unless expensive, sophisticated and energy-intensive processes are employed. It is conceivable in such circumstances that, although several companies in the refinery sector are already proactive in the direction of renewable energy sources, a certain part of the oil sector will attempt to protect its market share by lowering prices, which in turn could lead to the disintegration of OPEC and greater competition between producers for market share.

Such a possible response is but one example of how an attempt to modify the workings of a sector in which a large number of powerful economic actors have a vested interest can trigger counterbalancing reactions elsewhere in the system. Climate control measures should therefore not be conceived as narrow technological or instrumental options that focus on only a single part of a complex system, but as broader strategies that aim to create new system dynamics. Innovative, pro-active companies could also play a crucial role.

3.5 Actions

The special value of COOL is that it provided a forum for experts from business, research institutes, governments and environmental and transport organisations to debate climate control actions, whereby insights can be gained into the specific needs of the transport sector, how climate control actions would impact on the sector's activities and which actions would be most effective and efficient. Priority actions were identified for both governmental actors and the sector itself.

3.5.1 The Transport Sector

Action 1: Clean up your own act. It is the transport sector itself that has the primary responsibility for taking action to reduce its CO_2 emissions. This needs to be recognised by the sector and acted upon. For example, initiatives can be taken to develop sector- or sub-sector-wide voluntary agreements on the reduction of emissions; improved co-operation within certain sub-sectors could lead to improved efficiencies; the sector could co-operate in devising an appropriate emissions-trading scheme; and initiatives could be taken to include transport in the EU EMAS scheme and ISO 14001.

Action 2: Improve customer relations. Low-emission transport systems require for their success special attention and investment in two aspects of customer relations. First, customers – both the public and companies – need to be fully informed of the environmental benefits of such systems. This should be seen as a marketing opportunity for transport operators to create product differentiation and improve product image. Second, customers need to associate climate-friendly transport systems with user-friendly, low-threshold and efficient transport systems. This requires the development of readily accessible user-information systems, short transit times and high levels of service. Again, for the sector itself these requirements should be seen as market opportunities rather than costs.

Action 3: Improve intermodality. A persistent theme throughout the COOL process was the need to improve radically the intermodality of transport systems. This requires in the first instance sector-wide dialogues – that is to say, both public and freight-transport sectors – on the needs and potential for improved intermodality and the related options. Pilot projects, where appropriate developed in co-operation with publicly funded research programmes, will be important in assessing the practical value of the proposals and the boundary conditions necessary for success, such as the availability of sufficient investment resources and efficient user-information systems.

Action 4: Increase R&D. The sector also has a responsibility – in co-operation with government and the research community – to intensify R&D with the objective of reducing CO_2 emissions. A wide range of opportunities for potentially effective technological options can be identified, including the reduction of emissions from the aviation sector through more efficient aeronautical technologies, the use of alternative fuels, novel modes of transport, intermodal systems and improved infrastructures.

3.5.2 Government Actions

Action 5: Develop together with stakeholders a strategic vision for sustainable transport. Most countries lack a clear strategy on what sustainable transport involves and how it should be achieved. This also applies to the EU. Issues such as an integrated approach to meeting and managing mobility needs, the relation between different scales and modes of transport, the interaction between spatial planning and transport infrastructure, the appropriate balance between public investment and market initiatives, measurable and monitorable sustainability criteria, and transition management require analysis and evaluation within a long-term perspective. The OECD-EST study is a valuable contribution in this respect and deserves serious consideration and further action (OECD, 2000).

Action 6: Get the prices right. The COOL participants were unanimous in stressing the importance of ensuring that transport prices fully reflect environmental and social costs. In this way the balance between the financial and fiscal incentives and disincentives that influence transport decisions will be shifted towards less-damaging options. Appropriate instruments that were identified included ecotaxes, road pricing and tradable emission permits.

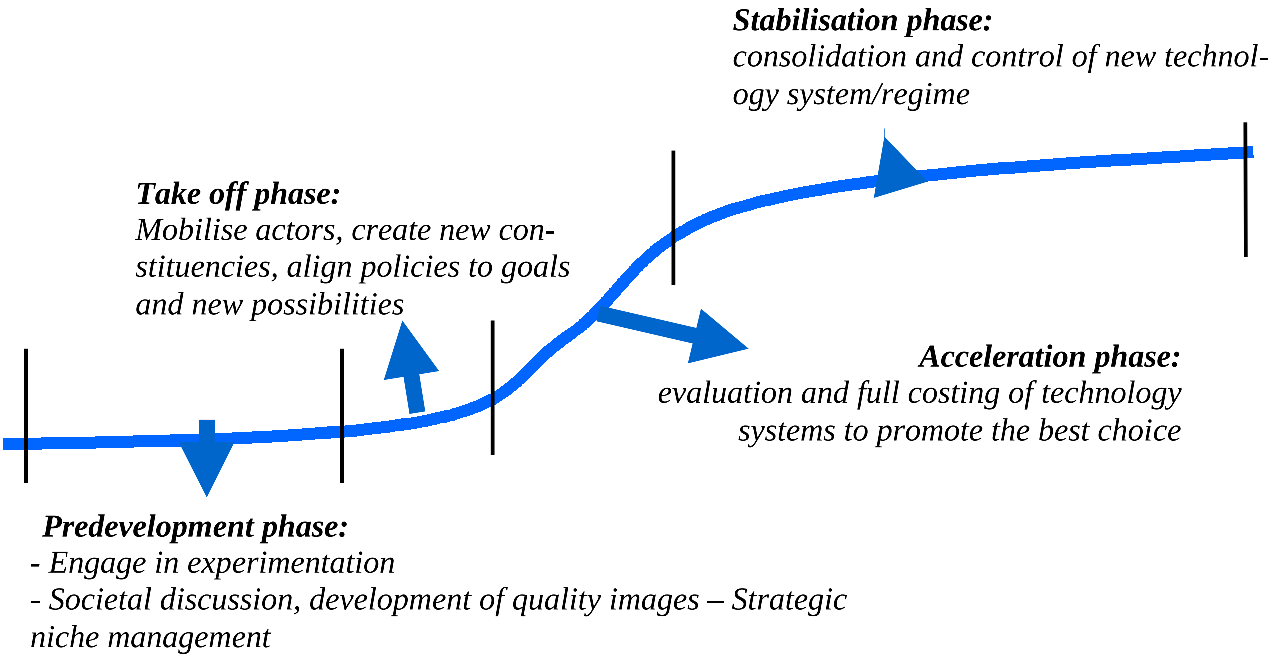
Action 7: Devise effective regulations. Alongside market instruments, regulations will continue to play an important role in encouraging the transition towards a more climate-friendly transport sector. Potentially effective forms of regulation include the establishment of carbon budgets for transport operators or clients (including standardised measurement systems), efficiency standards, the preparation of transportation audits and technology-forcing measures.

Action 8: Promote climate-friendly transport technologies. Government has a clear role to play in promoting new technologies that will lead to reduced CO_2 emissions from the transport sector. In many cases, these technologies will need to be developed at the European level, for example through the EU Framework Programme on Research and Technological Development. Of the various technological options considered during the COOL process, fast and efficient intermodal transport systems were highlighted as of particular importance, particularly for public transportation.

Action 9: Transition management. Policy action should be oriented to long-term goals of sustainability based on images of the future and deal with the transition problems that thwart progress towards sustainable mobility. The latter requires two things: public acceptance of chosen sustainability goals and process management (which builds on transport-relevant developments and utilises policy windows of opportunity). Policies should be aligned to goals and differentiated according to the phase of the transition process: stimulate variation and societal discussions in the predevelopment phase (through experimentation), stimulate investment and the integration of new technologies in existing systems through public planning and system management in the take-off phase and control of side effects of new systems during the later phases. Transition management thus involves policies of support and control, with their timing gauged to the particular circumstances of transition phases and external developments. Transition management is based on a philosophy of “learning by doing” and “doing based on learning”. It emphasises complexity, uncertainty and interdependence, which are made an explicit consideration for policy.

The figure below describes the roles of government during the different phases of a transition towards a new system. It is based on the phase model of transitions and insights from innovation studies such as the technology life cycle model and technical change as a co-evolutionary process. A central element of transition management is that it attempts to achieve long-term structural change through gradual steps. Transition management opts for a gradual transformation of an existing system, instead of the planned creation of a new system. A new element can be added to an existing system, for example, in order to solve a specific problem. The introduction of this new element leads to changes and learning processes within the system. As a result of the changes, new *bottlenecks* will appear which, in the course of time, stimulate the development of new concepts, ideas, insight, methods and techniques. Furthermore, it is possible that the learning processes lead to the discovery of new possibilities. The consecutive improvements, innovations and learning processes, gradually transform the existing system so that finally a new system gets created *out of the existing one*. Transition management thus tries to utilise the opportunities for transformation that are present in an existing system. Joining in with *ongoing dynamics* is often easier than forcing changes. Transition management, therefore, implies refraining from a planning and control approach and from (large-scale) investment in improvement options which only fit into the existing system. Learning about new technologies and institutional change are important elements of transition management.

In general, transition management tries to gradually increase the pressure on the existing system, and, at the same time, to work towards structural change (system innovation) by exploring alternatives and by stimulating processes of co-evolution (Rotmans et al., 2000).



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4. SUMMARY AND CONCLUSIONS

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4.1 Introduction

Our climate is changing. Scientific evidence is getting strong that human activities leading to emissions of greenhouse gases to the atmosphere are, at least partly, the cause of this climatic change. Based on a range of scenarios about developments over the next 100 years, projections show a further increase of global average temperatures, in the range of 1.5-6 degrees C above today's levels. Such changes, that would entail even more significant regional changes in precipitation patterns and temperature, can lead to serious negative effects on human health, the economy and nature.[8]
The United Nations Framework Convention on Climate Change specifies as its objective to stabilise GHG concentrations in the atmosphere at such a level and within such a timeframe that no dangerous interference with the climate system occurs, threatening food supply, natural ecosystems and sustainable development. Scientific consensus exists that for such stabilisation global GHG emissions have to go down to less than 50 per cent of current values. Thus the challenge of controlling the risks of climate change in accordance with international agreements means that drastic emission reductions are inevitable and that they may have to be realised over a relative limited period of time. Is this doable? And what would it require? What does it mean for developing countries trying to combat poverty and improve the living conditions of their people? And what does it mean for industrialised countries that have built their current prosperity on fossil fuels and an energy intensive development pattern? Those are the key questions when looking at ways to control climate change in the long term.

4.1.1 The 80 per cent target

To stabilise atmospheric carbon dioxide levels means that global emissions must not be allowed to exceed the combined absorption capacity of the oceans and the biosphere. In the COOL Europe project it is assumed that this commitment would imply an 80 per cent reduction target, compared to present emissions, for the presently richest part of the world. It is this target that has been the starting-point for this project.

4.1.2 Participation and the process

The European dialogue has focused on two sectors: energy and transport. Distinct features of the COOL Europe project are its focus on the long term and its focus on radical carbon dioxide emission reductions. Most other research activities on climate policy so far have focused on the short term and on incremental changes. Moreover, the dialogue has relied on a broad set of European stakeholders to develop these insights. Participants in the COOL Europe project have been (1) policy-makers at the local, national and international level; (2) representatives of the private sector, (3) representatives of environmental NGOs, and (4) representatives of the scientific community.

Four workshops have formed the core of the COOL European Dialogue. Long-term sector strategies (2000-2050) have been connected with climate policy in a participatory process. The workshops have followed a sequence focussing on elaborating (1) Future Images of 2050, (2) a Path Analysis connecting these Images to the present, (3) Short-term actions needed to reach long-term goals, and (4) Strategic Visions which integrate the former three. Backcasting has been used in the COOL Europe workshops. Backcasting or anticipatory scenarios are backward directed, i.e., they start from some normative final state, and explore the preconditions and strategies that could lead to this state.

The structure of this chapter is the following. Section 2 summarises the main findings from the transport and energy groups with respect to images of the future and path analysis. Section 3 contains an analysis of the main findings. Sector 4 gives some final reflections on how the COOL Europe approach could be taken further.

4.2 Summary of the two dialogues

4.2.1 Introduction

According to both sector groups it is technologically possible to redesign the European energy and transport systems while reducing carbon dioxide emissions by 80 per cent. Calculations carried out in the energy group show that it seems also economi-

[8] IPCC (2001). Third Assessment Report. Summary for Policymakers.

cally feasible to achieve the 80 per cent reduction target, although further economic calculations are needed. Both sector groups argue that European governments should stimulate the move to more sustainable consumption and behaviour patterns in a more active way than hitherto. The countries in Central and Eastern Europe are establishing new industries, economic structures and consumer cultures. It is critically important to channel these dynamic changes towards low-carbon options rather than the business-as-usual ones. EU enlargement is therefore a window of opportunity for EU climate policy.

4.2.2 The energy sector

Two future images have been the starting points for the backcasting exercises in the energy group. Both these images of the European energy system in 2050 meet the criteria of 80 per cent reduction of the carbon dioxide emissions compared to 1990 levels. In the ***biomass-intensive image*** biomass has the largest share of the fuel mix. Besides biomass wastes, energy crops will be grown, which are expected to require 80 Mha, or 17 per cent of total land area in Europe (cropland currently covers 140 Mha, or 30 per cent of total land, with forests and woodlands covering 33 per cent). About 80 per cent of land demand for energy crops can be met using excess croplands, starting with currently set-aside land. This land is assumed to be used for dedicated energy crops with significant net energy yields. The second image relies much less upon biomass. This image is referred to as the ***solar hydrogen image.*** In this image, solar PV generated electricity is used to produce hydrogen. The hydrogen may be used for electricity and heat production, but also as a transport fuel.

It appears that biomass and wind power will be the most important renewable energy sources in the next few decades. Beyond 2030 solar PV will have the greatest potential. Land availability and biodiversity considerations are potentially important constraints for the development of the biomass option.

Hydrogen will be an important energy carrier in the long term, but it would require immediate action to have a hydrogen system established in half a century. Modernisation of the energy and industry sectors in Europe and related sectors like transport will have to include further efficiency improvements in both the supply and demand side. It is important to establish new institutions which will be responsible for energy efficiency in the liberalising markets for energy in Europe. Increased competition and decentralisation in combination with internalisation of external costs can promote the ecological modernisation of the energy system.

Electricity prices will fall dramatically as competition is introduced in the European electricity markets. Lower prices can lead to higher demand for and consumption of electricity. It provides, however, also a potential window of opportunity to internalise the external effects by introducing environmental taxes and removing counterproductive subsidies at the same time. On balance the consumer prices would not have to be increased while the most unsustainable plants and other components would be closed.

The issue of decentralisation

Among some members of the energy group there were strong preferences for decentralised production of electricity, fuel and heat. In such system electricity will be generated by systems such as solar, wind (on-shore and off-shore) and combined generation of heat and power (CHP). Besides CHP, heat can also be supplied by heat pumps.

Recent technological development with conventional technology has supported decentralisation. With conventional technologies the economy of scale is decreasing with technological developments over the last decade. Computer control reduces the cost of monitoring and control, so that reducing the number of plants is not as important as a couple of decades ago. Costs of component failures in big plants are greater than in small. Construction times for large plants have proven much greater than for smaller.

In the electricity system the cost of transmission has become obvious as re-regulation introducing competition has revealed the relation between the cost of electricity production on the one hand and electricity distribution on the other. If distribution costs as much per unit electricity, on site production may be economical even if production at the site costs twice as much as central generation. Thus, the competitive market creates private incentives for local solutions that may be beyond what is economically rational from the systems perspective. The co-generation of electricity and heat is economical if the electricity production is situated close to the heat demand, thereby avoiding long heat transmission pipelines. This has made small electricity production units popular. To many owners of commercial buildings and to industry, the extra supply security of on site electricity generation capacity may appear as an important value, too. The new renewable sources of energy like solar radiation and wind energy are naturally decentralised and require decentralised transformation. The technologies to utilise these resources are becoming commercially viable. To utilise these resources, electricity regulations have to be adapted to decentralised generation thereby opening up also for decentralised solutions using conventional resources and technologies. In the energy dialogue group there have been some important discussions of terminology to describe these systems. Decentralised heat and energy production may be interpreted as meaning that the small distributed units operate independently only to serve local demand. However, economic optimisation of the operation of many distributed units may be very rewarding while relying on relatively inexpensive computer control systems.

Some persons in the energy group preferred to take no position regarding decentralisation versus centralisation. They rather judge all technologies on their own merits regarding emission reduction and resource conservation. In their view, the desirable outcome will probably be a mix of small and large-scale technologies.

4.2.3 The transport sector

Future Image

Unlike the energy group of COOL Europe, the transport group opted for the development of only one future image of 2050, as the basis of further analysis and discussion. In the brainstorm that preceded the construction of the future image, the participants had been rather reluctant to construct two distinct and contrasting possible futures (e.g. a "technical change" one and a "behavioural change" one), arguing that the future would be always a combination of the two. The final future image consisted of four dimensions: 1) improved efficiency; 2) fuel substitution; 3) changes in societal structures and patterns; and 4) changes in awareness, values and lifestyles. Improved energy efficiency and new fuels directly affect emissions (emissions per unit of transport), while new patterns of human activities and values and life-styles mainly have an impact on transport volume. The assumptions regarding energy supply and emission levels correspond with those for the energy sector.

In the future image for 2050 the transport system is characterised by a large variety of niche vehicles (for example, small electric city vehicles), all-purpose cars and new systems such as personal electric vehicles that can link to each other and form trains move via special tracks. There is no single system that dominates the system to the same extent as the private all-round car did at the beginning of the twenty-first century. Another prominent feature is the spread of inter-modal transport with smooth and short transitions between modes. IT is being widely used in intelligent traffic control and information systems, and also for flexible road pricing. The energy efficiency in the transport sector is high.

The future image served very well its purpose: it was a starting point for discussion, to get an idea of the ‘agenda’ for transport in 2050. However, the group was very much aware that this image was only one of many possible futures. There existed wide agreement that the image as such remained ‘conservative’ and contained a rather ‘industrial society’ perspective.

Path Analysis

Subsequently, in the path analysis a range of options was developed for each of the four building blocks, providing a path from the future image to the present. Each of the options in the four categories contained an indicative time-path, advocacy coalitions and supportive conditions.

Many options intended to *improve efficiency* can be taken in the short term. They are relatively easy to develop and implement and do not involve many uncertainties. The appropriate actors can also be readily identified.

Fuel substitution involves more difficult choices, greater uncertainties and more complex coalitions of actors. It is of greater significance in the medium term. However, it also offers more scope for radical change.

Changes in structures and patterns require a long period to take effect and involve substantial uncertainties. The changes are also dependent to a large extent on appropriate actions by a wide range of actors in other sectors and need supportive conditions from the external environment.

*Changes in awareness, values and lif*estyles are on the one hand difficult to influence since they are dependent on a wide range of factors and complex interactions within society. On the other hand lifestyles and value-patterns change constantly, be it not always in a favourable direction from an environmental point of view. Such changes entail a huge potential to contribute – directly and indirectly – to radical changes in the CO2 emissions from the transport sector.

The path analysis explored the options that could enable society to achieve the objective set in the future image. In doing so, the focus was more on the variables themselves, than on the outcome (in terms of emission reductions and actual transformations in the transport system). It was felt that only by identifying the key variables and understanding how they can be (re)shaped that targets can be achieved.

Table 4.1 Overview of the main options and actions advocated by the COOL Europe sector groups.

Energy	**Transport**
Biomass - Co-ordination between CAP/waste polices and biomass policy - Set-aside subsidies for energy crops - Biofuel production requires concerted action by fuel and vehicle producers Hydrogen - Scale up production of solar PV - Precombustion decarbonisation to involve the fossil fuel industry - Development of hydrogen vehicles with fuel cells - Address the "Hindenburg syndrom" - Start preparation for a standardised European infrastructure for hydrogen distribution Energy efficiency - Energy performance standards for new building (European guidelines) - Mandatory energy performance certificates for houses upon sale - Minimum efficiency standards for all appliances, updated every five years **Disagreement:** Degree of decentralisation of the energy supply system	New fuels: biofuels and hydrogen Efficiency of vehicles: improved drive train and reduced driving resistance Improved management systems for transport companies Decentralised concentration: - Land-use and city planning - Park-and-ride schemes - Road pricing - Restricted parking in centres - Flexible public transport - Bike networks - Upgraded service level of existing sub-centres ICT: - Optimised use of infrastructure - Optimised logistics chain - Intelligent vehicles - Tele-working, tele-learning, tele-shopping Awareness/life-style changes: - Local experiments - Highlight best practises - Information campaigns - ICT - Build partnerships - Increase awareness of politicians

4.2.4 *Bridging the gap*

A look into Europe's emission inventories is not encouraging. We see an upward trend of emission, especially in carbon dioxide, from 1994 onwards. According to the most optimistic estimation, existing policies and measures will overall EU GHG missions in 2010 to 1.4 per cent the 1990 level. This would result in an expected gap of –6.6 per cent between the effects of existing policies and measures and the EU's Kyoto target (ECCP 2000). In order to reverse the negative trend urgent action is required with respect to the emissions from the transport sector and the negative effects of the liberalisation of the energy markets together with the process of EU enlargement.

Transport

The fastest increase in emissions is expected in the transport sector. A thorough gap analysis is required regarding the negative trends with respect to the modal split. A case in point is that the EU is closing 600 km of railways per year and at the same time is building 1,200 km of motorways. Furthermore, the TransEuropean Networks (TEN) are arguably giving too little attention to waterways and railways. There is a lack of policies in the field of aviation: lack of internalisation of external costs, lack of a level playing field, and prices which are sometimes going under the railway prices.

Energy

In the energy sector the gap analysis should be focused on the ongoing liberalisation of the European energy markets. It is a process which is currently going against Europe's climate policy goals. The introduction of competition in the electricity markets has led to lower electricity prices in Germany and elsewhere. Demand has increased because the incentives to improve energy efficiency have been reduced. Another effect is that spending on R&D has gone down due to lower profits from electricity production and that co-generation is suffering. The greening of the liberalisation of the energy markets cannot be solved at the national level but requires a European approach.

4.2.5 Emission reduction potentials

In order to reach the desirable situation in 2050, the growth rates for several energy sources need to be high. In the energy sector, natural gas electricity production needs to grow with almost 4 per cent each. Wind energy has to experience an annual growth rate of almost 10 per cent. Solar PV has to grow with 17-22 per cent per year. For biomass production the annual growth rate must be between 2.8% and 3.8 per cent. A high absolute growth occurs in wind and, especially electricity production, but the far largest relative growth occurs in solar electricity (see Table 4.2).

Table 4.2 Required growth rates for various energy sources to meet the amount of energy reflected in the energy images (Source: annex to energy Strategic Vision).

Energy source	**Growth factor (1990-2050)**	**Required annual averaged growth rate**
Wind energy	173	9.9%
Solar PV	5,556 [a] 51,307 [b]	17.0% [a] 21,8% [b]
Biomass	7.5 [a] 4.6 [b]	3.8% [a] 2.8% [b]
Natural Gas	8	3.9%
a = biomass-intensive image b = solar hydrogen image		

For both the energy and the transport sectors it is assumed that energy consumption in 2050 will stabilise at current levels. This is the result of a 2 per cent per year growth in economic activity, a 1.5 per cent per year energy efficiency improvements and a 0.5 per cent per year structural change. Structural change will be realised by shifts towards less energy-intensive products and a higher contribution of energy-extensive sectors such as information technology, services, etc. to GDP. Table 4.3 below brings together the most important elements that can contribute towards target fulfilment, that is, achievement of an 80 per cent emission reduction.

In conclusion, the -80 per cent target is possible and feasible in both sector groups. But it is critically important that all available options are employed within the categories of (1) fuel substitution, (2) energy efficiency, (3) changes in structures and patterns and (4) green lifestyles (see Table 4.3).

Despite this optimistic conclusion many uncertainties remain. It is especially important to address knowledge gaps and uncertainties regarding (1) the rebound effects of ICT, (2) the appropriate relationship between market support vs. large-scale R&D efforts for the development of sustainable energy technologies and (3) the future land availability for biomass. Addressing these and other challenges for the long term will require an ongoing learning process. Stakeholder dialogues, like COOL, are useful tools to confront the challenges, frame problems, elaborate new strategies and increase stakeholders commitment to be involved in the process.

Table 4.3 Most important contributions to target fulfilment (-80 per cent).

Energy	**Transport**
Fuel substitution **I.1 Natural gas** Biomass Solar (in the solar hydrogen image)	Fuel substitution Biofuels Hydrogen (55 % of the market share for passenger transport in 2050)
Energy efficiency Demand side improvements Co-generation	Energy efficiency Modal shift Improved drive train and reduced driving resistance
Structures and patterns Energy-extensive industry and buildings	Structures and patterns Decentralised concentration Structure of industry
Green lifestyles Very important as a precondition for the other elements	Green lifestyles Very important as a precondition for the other elements

4.2.6 From promising options to feasible actions: critical factors for the transition

Transforming promising options into feasible actions is the most challenging task of any long-term policy strategy. The realisation of a goal – and particularly such an ambitious goal as the COOL target in such a complex environment as the energy and transport sector – requires a wide range of factors to be understood and shaped. There are uncertainties to be clarified, preconditions to be met, boundary conditions to be created, perceptions to be changed and countervailing reactions to be anticipated. The most important – but not the only – ones are mentioned below.

Carbon pricing. Both the energy and the transport groups are strongly convinced that pricing of externalities is vital to create a sustainable development of a market economy. Without carbon dioxide pricing it will be difficult to reach the necessary long-term climate policy objectives. In the energy dialogue it was assumed that different instruments (taxes, emissions trading and project-based instruments like Joint Implementation) can work together in a strategy to achieve carbon dioxide pricing. The transport group has highlighted options such as road pricing and a tax shift from labour to natural resources.

Addressing the institutional deficit in supranational environmental management. Globalisation is the process through which both the markets for products, services and investments and the operational sphere of companies become increasingly international in character. We are seeing that the capability of transnational companies and investors to take actions that have an impact on the environment is outpacing the capacity of governmental institutions to manage the processes that cause those impacts. An “institutional deficit” is evolving through the combination of the declining capacity of governments to impose national environmental controls on companies and the failure to realise a proportionate increase in the environmental control capacity of international institutions. However, this development is likely to feed two countervailing needs: first, more explicit and more elaborate international rules on the scope for local, national or regional differentiation with respect to trade regulations and instruments where this is necessary in the interests of environmental protection; and, second, more effective international enforcement regimes. Business will certainly be reluctant to accept a significant degree of regulatory differentiation, but in a parallel development companies themselves will appreciate the advantages of launching initiatives that demonstrate a high level of social and environmental responsibility, thereby strengthening consumer trust in particular brand names and, in the words of an executive of a major company, securing a “societal residents permit”.

The COOL Europe project has identified a number of institutional innovations that could facilitate the transformation towards a decarbonisation of the European energy and transport sectors. These suggestions are presented in Table 4.4 below.

Table 4.4 Possible institutional innovations.

Processes and driving forces	**Possible institutional innovations**
Globalisation	• More elaborate rules on environmental protection. • More effective international enforcement regimes. • A new role for the WTO regarding climate protection. • Consistent and transparent policy framework to help voluntary climate protection measures by private companies.
EU enlargement	• Shift in EU policy-making towards a greater need to develop policy frameworks, mechanisms and instruments that are effective in establishing and securing long-term goals and objectives. • Establishment of Centres for Sustainable Energy Transitions in CEE countries.
The climate agenda: climate science, public awareness, UNFCCC, Kyoto Protocol etc.	• Strengthen the ‘long-term capacity’ of the European Commission. Cross-DG unit on long-term climate change policy. • Develop a European long-term vision of the UNFCCC regime.
Liberalisation of European energy markets	• Establish new institutions to deal with energy efficiency and renewable energy.

EU enlargement. The economic transformation in Central and Eastern Europe can be channeled towards low-carbon options. Biomass and energy efficiency are especially important options in this respect.

EU enlargement will have three important consequences for EU institutions. First, it will increase even further the already substantial degree of diversity within the EU, with a concomitant decline in Community cohesion. Second, the greater number of actors will complicate even further Community decision-making procedures and the allocation of competences. Third, the Union will face even greater challenges in ensuring that Community measures are appropriately, consistently and promptly implemented across a greater number and a more diverse family of member states. The greater diversity, institutional complexity and implementation challenges that are the inevitable consequences of enlargement will drive EU policy-making towards an emphasis on framework measures that lay down the targets for a particular policy object while allowing the member states a greater degree of discretion in how the objectives are achieved and which instruments are applied for that purpose. This infers a shift towards longer-term policy-making and a greater need to develop policy frameworks, mechanisms and instruments that are effective in establishing and securing long-term goals and objectives – an essential requirement for effective climate control measures. Groups of member states may also establish forms of flexible co-operation, for example with regard to the use of economic instruments for climate policy.

Liberalisation of the European energy markets. The European energy sector is in a period of major liberalisation with the purpose of increasing competition and removing national trade barriers. In particular the markets for electricity and gas are changing. This is fundamentally changing the context for climate and energy policies. Increased competition and decentralisation in combination with internalisation of external costs can promote the ecological modernisation of the energy system. As already mentioned, liberalisation of electricity markets in Europe is a window-of-opportunity for introducing carbon taxes *without* increasing consumer prices. It is important to establish new institutions which will be responsible for energy efficiency in the liberalising markets for energy in Europe.

Social aspects and reactions by vested interests. The measures that will be required to realise an 80 per cent reduction in CO_2 emissions in Europe by 2050 will have far-reaching consequences, not only for energy and transport but for virtually all economic actors. However, the extent to which other actors can be persuaded to become fully party to such a process is open to question. Many actors, particularly those whose economic interests are most at risk from climate control measures, can be expected to oppose and obstruct such moves. Further, many crucial socio-economic variables – international trade, consumer demand, cultural perceptions, for example –

can only to a limited degree be shaped by government and the climate-change coalition. The way in which other actors may respond to climate control proposals and measures is therefore a crucial factor in designing long-term climate strategies.

The role of the private sector. The dialogue has shown that an increasing share of companies in the private sector is aware that constraints on carbon dioxide emissions are likely in the future. These companies are now prepared to take a proactive approach to the challenge of climate change and call on the European governments to create fair and more stimulating business conditions for (existing and new) carbon-efficient products and services. Whether these industrial efforts will continue or the companies retreat into defending established supply structures will depend on whether these development efforts are supported by authorities and rewarded by the customers, or not. Clear signals for the long term are required in building confidence among these major investors that the radical transformation will last.

4.3 Analysis and evaluation

The objective of this section is to analyse the strategic visions of the two sector groups, energy and transport, and to bring to the fore some of the most remarkable characteristics. First the COOL Europe dialogue is put in a broader perspective. Then three short sections ensue on the key outcomes of the Dialogues.

4.3.1 The COOL Europe dialogue in perspective

The COOL Europe project has addressed long-term climate policy challenges in Europe by involving stakeholders in a dialogue about feasible options. COOL Europe is not the only stakeholder process addressing European climate change policy. Within the recently established European Climate Policy Programme (ECCP), managed by the European Commission, various policy-makers, scientists and stakeholders meet to identify policies and measures which will help the EU to implement the GHG reduction target set by the Kyoto Protocol (ECCP 2000).[9] This similarity with COOL is paralleled by significant differences. In contrast to COOL the focus of ECCP is on

[9] Furthermore, following the Cardiff Process initiated in 1998, a strategy to integrate environmental concerns into transport and energy policies, and other sectors, has been developed by European Union.

the short term. Moreover, the ECCP is a policy-making exercise, while COOL Europe is primarily a scientific exercise, potentially with policy consequences.

If we compare the COOL Europe exercises with other scientific projects interesting conclusions can be drawn. A comparison between the energy images developed in the COOL Europe energy group and other international sustainable energy scenarios – two IPCC scenarios from the recent IPCC "Special Report on Emission Scenarios" (2000) and a scenario from "Renewable Energy; Sources for Fuels and Electricity" from Johansson et al. (1993) – reveals that the COOL Europe images have a substantially larger share of 'other renewables'. This is especially the case in the solar hydrogen image. The share of biomass in the COOL images lies between the shares envisioned in the IPCC scenarios and the Johansson intervention scenario. This is consistent with the non-intervention character of the IPCC scenarios with regard to climate change, which leads to a lower level of fuel switch towards renewables/biomass. The gas consumption in the images is also in line with the other scenarios. The lower share of oil in the COOL images is explained by the biomass and/or solar hydrogen used for transport in those images. The COOL images foresee no usage of nuclear energy (non-fossil electric), which is similar to the Johansson intervention scenario, and of solid fuels. In the other scenarios some solids still remain, but in one of the IPCC non-intervention scenarios this is limited to only 3 per cent.

Recently, the OECD has developed guidelines for sustainable transport under the environmentally sustainable transport (EST) project. The basic techniques used in the EST project are scenario construction and backcasting. The project examines what kind of policy framework will be necessary to ensure that transport systems are environmentally sustainable in the year 2030 and beyond. By developing a set of essential criteria to be met, and then by using alternative projections to explore different paths forward, this work is helping to show the policies that will be required in the years to come. This approach is both long-sighted and comprehensive, taking local, regional and global effects into account (OECD 2001), and in that sense has parallels with the COOL Europe project. COOL Europe differs in the emphasis on stakeholder dialogues and on climate change issues (rather than overall sustainable development).

In comparison with the studies quoted above and other long term analyses, the path analyses conducted within the framework of the COOL Europe project have been less focused on technical aspects and more emphasised institutional aspects. Furthermore, they were more focused on the identification of necessary boundary conditions for various actors to take action and on barriers for these actions. This is even more true for the European transport Dialogue than for the energy Dialogue. In this respect the VISIONS project (Rotmans et al., 2001) is probably one of the most closest to COOL Europe, as the former also focused on Europe and on the social and institutional changes, rather than the technical ones. The VISIONS project forecasted scenarios with a focus on sustainable development in general. One of the scenarios focused on the impact of globalisation on European integration: The nation state would fade away as a protective force for its inhabitants and European politics might consist predominantly of corporate strategies. Another scenario involved fundamental social change caused by dramatic technological developments in information and communication technology and biotechnology. A second project that needs mentioning is the ULYSSES project (Urban Lifestyles, Sustainability and Integrated Environmental Assessment; De Marchi et al., 1998). It shares with COOL Europe its dialogue characteristics, a pre-occupation with social and institutional issues and a focus on climate change issues (in a sustainability context) in Europe. But it differs from COOL Europe in its more local orientation, taking lay-actors in major European cities as the main participants in dialogue processes to develop local GHG reduction strategies and options.

4.3.2 Between European Union and local level action

Creating a European platform for long-term climate policy

It is clear that the EU has leadership ambitions in the process towards entry into force of the Kyoto Protocol. However, thus far, relatively little is known about its strategy for the second and third commitment periods and beyond. The question then arises: how could the EU develop a fruitful climate policy platform for discussion and developing the medium and longer term?

COOL Europe took the desirability to develop a long-term climate policy vision for Europe as a starting point. In order for such a vision to have value and to mobilise stakeholders and policy-makers it has to relate long term ideas via pathways to immediate actions by stakeholders. If the outcomes of COOL Europe are analysed the truly European dimension is not all-dominating. Although European integration, European institutions and European actors are mentioned, their position is not as prominent as one would have expected in a European Dialogue. Private actors, local and national governmental authorities, and social movements and organisations seem to have at least an equal important position in contributing to the development and implementation of radical GHG reduction strategies. It is, however, hard to envision the emergence of a hydrogen economy in Europe without a joint European vision and coordinated European investment strategies. Some of the central questions 'behind' the COOL Europe long-term climate strategy documents are the following: which policies and measures have to be taken at Community level? What options at the national level are most dependent on EU policies? Who should take the lead? What is the specific role for European institutions?

In developing radical European climate mitigation strategies the COOL-Europe Dialogue groups have identified ancillary benefits of climate change policies, by connecting climate change with other policy domains. Obviously, a move to hydrogen or biomass economies will lead to improved urban air quality, improved human health, lower congestion problems, fewer traffic accidents and respiratory diseases in the cities. There would also be regional environment benefits such as less pollution of soils, improved agricultural output, and better forest systems. The work of the OECD indicates huge benefits, potentially 30-100 per cent offset of the cost of direct mitigation. Local communities are in a particularly good position to value ancillary environmental benefits (OECD, 1999: 47), linking a European strategy with bottom-up interests.

Perhaps somewhat surprisingly, the COOL Europe dialogue did not bring up the European Energy Charter for discussion. For the longer term, this initiative could be highly relevant for European climate policy. It could be mentioned that Ruud Lubbers, the former Prime Minister of the Netherlands, has already proposed to expand the Energy Charter Treaty to include carbon dioxide policy (Lubbers et al., 1999).

EU enlargement

According to the European Commission (1999) the enlargement of the EU represents an opportunity to enhance the institutional and technical capacity in the candidate countries, to raise the profile of climate change with stakeholders and the public in general in Central and Eastern European countries, and to ensure sustainable growth with controlled greenhouse gas emissions. Enlargement has also played a significant role in the European Dialogue of COOL, as it affects not only the possibilities and challenges of the accession countries, but it also reflects opportunities and challenges of the EU, within and beyond the domain of climate and energy policies.

First of all there is an economic dimension. If all the candidate countries from Central and Eastern became members of the EU, the EU's population would increase by 29 per cent, but its GDP by only 5 per cent (Economist, 2001a). Secondly, as has been pointed out in the European COOL dialogue enlargement will necessitate a process towards more effective decision-making rules in the Council of Ministers. The Council of Ministers would need to reform its voting procedure. The need to go away from unanimous voting would become increasingly apparent. It is already today almost impossible within 15 Member States, it will be even more difficult with 25 or 27 members.

The EU financial instruments to support environment protection and transport infrastructure among accession countries in Central and Eastern Europe (for example, ISPA – Instrument for Structural Policies for Pre-Accession – and European Investment Bank) are important tools to promote a development towards climate friendly options in the energy and transport sectors. However, the COOL Europe process has revealed that ISPA, EIB and other instruments of the enlargement process sometimes tend to promote investments that are not fully compatible with the requirements of a sustainable development. This problem is linked to the policy preferences of *both* sides involved in the enlargement process. As one representative of the European Commission put it during a COOL Europe workshop:

> "If there is not a sufficiently strong political will and demand from the various players in Central and Eastern Europe then it will be very difficult for our side to come forward with the sustainability criteria. The accession countries need to make a much bigger claim what they really want in their policies, in their political statements, in their own countries. They have to tell the Commission what do they want and what do they feel is necessary. Only then will there be pressure for the Commission to reconsider and rethink some of the concepts which are currently being transferred to the transition economies."

Action at the local level

Although being a Dialogue at the level of Europe, the COOL Europe project has strongly pointed to the importance and relevance of actions at the local levels, decentralisation of the energy supply system and the role of the citizen-consumers being the most outspoken examples.

Decentralisation. Due to technological developments in the past decade decentralised options on the supply side are increasingly becoming important in the European energy sector. In that sense the call for decentralisation in the European Dialogue reflects the state-of-the-art. There is currently also an economic driving force for decentralisation: “It is micropower, not megapower, that the market favours, thanks to the far smaller financial risk involved” (Economist, 2001b: 31). Hence, decentralisation is clearly an autonomous trend, and as such emphasised by the COOL Dialogue (be it stronger in the energy than in the transport group). If this trend is to be stimulated it is important to address the following questions: what instruments and approaches are needed to achieve a far-reaching decentralisation of the European energy system? What institutional framework will be required? Can the EU achieve a far-reaching decentralisation without an energy chapter within the Treaty on the European Union? Where, how and to what extent do decentralised options link to centralised energy infrastructures?

Citizens and consumers. The COOL Europe process has also emphasised the crucial role of public awareness, citizen-consumers and life-style changes. By voting green with their wallets consumers can support the introduction of climate friendly options; by political involvement citizens can influence the formal and informal political decisions. However, there is a risk involved in relying too much on voluntary behavioural change as a consequence of ‘green’ attitudes of individuals. Nevertheless, it is clear – and stressed by the COOL Europe Dialogue – that policies for *radical* emission reductions may be possible only if they have the political support of a large number of citizens. And technological innovations may also be only possible if market demand of consumer and customers is available.

These European and local level actions come together in a new role for the EU at the local level. The EU could become active in facilitating and supporting various initiatives, mediating and building coalitions inside and between cities. The fact that DG Transport and Energy recently has become involved in promoting clean urban transport is a good illustration of this. The question is to what extent will this new role of the EU be compatible or in conflict with the subsidiarity principle that is endorsed by the EU.

4.3.3 The role of the private sector

Globalisation is a robust trend which the EU has to learn to work with in looking for long-term strategies to address global climate change. Both sector groups in COOL Europe have recognised the fact that in a globalising world, cross-border climate policy is a necessity. It is extremely encouraging that representatives of multinational companies have participated actively in the European dialogue, in both sectors groups, to discuss far-reaching emission reductions.

But under what precise conditions would these companies commit themselves to undertake radical emission reductions? Among other things, this is likely to depend upon the structure of the future investment regimes, especially in supra-national perspective. This issue is a point which hitherto has been largely overlooked in the climate policy debate. In an input paper to the COOL Europe process, Konrad von Moltke (2000) argues that the climate regime is essentially an investment regime. In his view, virtually all strategies for emission reduction, whether undertaken by individuals, households, corporations or public agencies have the character of investments. To promote a consistent transition from more greenhouse gas emitting technologies to less-emitting technologies requires that the risk/return ratio for the latter must be notably better than for the former. A central issue for any international investment regime is its ability to balance the interests of private actors against public goods in a manner that is equitable and non-discriminatory. That is a goal that is currently beyond the reach of most international regimes, with the possible exception of the EU. This unique characteristic of the EU makes this institution so interesting as an experiment in creating a supra-national investment regime. The international community can perhaps learn from this experiment in creating institutions capable of achieving a balance between the interest of private actors and the public goods.

A second point the European Dialogue draws our attention to, are those ideas that have become known in the scientific literature as “subpolitical arrangements” (Beck, 1994): the increasing role of non-state actors in radical environmental reforms. Enterprises, but also non-governmental environmental organisations, utility sectors, and consumers are seen by the COOL Europe Dialogue as important actors. COOL Europe has moved beyond a state-centered strategy towards GHG emission reduction. The potential in the ongoing co-operation between many European and US companies in climate change emission mitigation is a current process that reflects these COOL

Europe ideas. The feasibility of and conditions for voluntary agreements involving US and European companies and sectors could be investigated.[10]

4.3.4 Technologies and markets

Creating a market for the solutions

In evaluating the strategic visions of both European Dialogue groups, a major technology optimism can be identified. Both sector groups in COOL Europe have been quite optimistic regarding the future availability of sustainable energy and transport technologies.[11] In their view the key challenge lies less in designing the options for the long term than in putting them into practice. Governments have a role to play in creating favourable conditions – that is, a market – for climate friendly options in the energy and transport sectors. Both sector groups identify major difficulties and barriers in developing markets for desirable technologies, making them competitive, fitting them into social and institutional characteristics of European society, and penetrating these technologies in the everyday live of consumers, citizens, enterprises and farmers. In the case of renewable energy technologies this implies that governments could (1) provide a guaranteed market with favourable prices and/or premium prices for renewable electricity; (2) provide a guaranteed market share for renewable electricity with competition among all suppliers; (3) mandate electricity purchase for a certain time period at fixed cost levels and (4) provide capital subsidies for renewable energy systems (OECD 1999). The COOL Europe dialogue has emphasised that policy initiatives of this type are of crucial importance for embarking on sustainable emission trajectories.

Carbon pricing has been identified as an outstanding issue in the COOL Europe process to help market creation. Without carbon taxes, it has been argued, it will be very difficult to reach the necessary long-term climate policy objectives. However, so far it has been very difficult for the EU to move on this issue and one wonders if the Euro-

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[10] In the past two decades large segments of the international business community has moved from an initial position of denying the climate change problem to take an open and sometimes proactive approach. In the past few years companies such as BP, Shell, Ford and Daimler Chrysler have all left the US based Global Climate Coalition,, a stronghold for the opponents of Kyoto Protocol.

[11] This thinking is in line with the message coming from a recent study commissioned by the Department on Energy, Transport and the Regions in the UK on the role of technology in emissions abatement for the medium to long term. It concludes that reductions in world fossil carbon emissions of 50-60 per cent by 2050 and 70-90 per cent by 2100 are technically attainable. The study argues that it is important to focus on the economic, social, political, and institutional barriers (AEA Technology 2001).

pean Dialogue is not too optimistic in this. Efforts to introduce a common hybride carbon/energy tax has failed due to strong opposition from some member states, mainly Spain and the UK. Four countries in the EU (Denmark, Finland, the Netherlands and Sweden) have introduced carbon and/or energy taxes specifically to address climate change. The environmental effectiveness of the specific carbon-related taxes has been limited because tax rates have been set relatively low and exemptions are often provided to energy-intensive firms (OECD, 1999: 51). More far-reaching and European wide carbon taxes will indeed be an issue for a *long* term strategy.

Carbon pricing will certainly help renewable energy sources to penetrate but may have its limitations as an incentive for the radical changes that are needed for the long term. It is not likely that the hydrogen economy will emerge as a result of carbon pricing only. In such situations carbon pricing can be combined with other policies, such as standard setting and information campaigns.

In carbon pricing the pre-conditions to be met are of course essential, as identified by the COOL Europe Dialogue. The competitiveness of European industry may decrease if it will face far-reaching carbon pricing that is absent in countries such and the United States and Japan. Clearly, such options and agreements with potentially substantial economic consequences will have to be co-ordinated at the international level. Perhaps it would be useful to explore the idea whether the WTO could play a role in promoting a global regime on carbon pricing.

European technology policy

The European dialogue has devoted relatively little attention to the role of European programmes devoted to research and technological development. Nevertheless, when the easiest and cheapest measures will have been taken to address climate change, the EU will need new solutions behind the traditional policies and measures. New technologies will be necessary in virtually all sectors. In designing a long-term R&D strategy for the EU the following aspects could be taken into consideration. Firstly, it is essential that the EU gives enough financial resources to research and technological development. In relation to the GDP, the EU currently spends less on this matter than the USA and Japan. The EU is far behind the USA in the development of the fuel cell that is considered to be one of the most promising technological options for the long term for both the energy and transport sectors.[12] Secondly, the priorities of existing R&D programmes should be revised. Historically, energy R&D in the EU has been heavily weighted to fission and fusion[13]. None of these options are in line with the preferences of the energy group of COOL Europe. Thirdly, the future role of existing the R&D centres in the accession countries in Central and Eastern Europe should be defined precisely and the possibility to establish new centres of this kind should be explored. (The energy group in COOL Europe has proposed the establishment of Centres for Sustainable Energy Transitions in this region.) Lastly, the desirability and feasibility of a “Manhattan project” or an “Apollo Project”, to force breakthroughs in some crucial technology areas should be assessed.

4.4 Concluding remarks: moving on

The major contribution that the COOL Europe Dialogue has made to climate change policy and mitigation strategies is not to be found so much in innovative and new ideas which open the eyes of the reader of the strategic visions on energy and transport. It is especially the fact that two broad and diverse groups of stakeholders have together worked upon and concluded strategic visions for radical GHG emission reduction over a period of 50 years.

The preparations of the long term strategies in Europe cannot but be done in broad consultation with stakeholders. Such a process is especially useful to identify barriers and to define and re-define solution strategies. As Senge et al. (1999: 567) puts it: “The real work of strategy is less about setting ‘the strategy’ than creating forums, both formal and informal, for addressing deep strategic issues that otherwise would become indiscussable, and for cultivating the collective capacity to rethink and recreate.”

[12] The distinction between the electricity and transport sectors will be reduced with the large-scale introduction of the fuel cells.

[13] For example, in the 5th RTD Framework Programme covering the period 1998-2002 (“Energy, Environment and Sustainable Development Programme”), more than 1 billion Euro is dedicated to non nuclear energy (renewables and energy efficiency) and in the Euratom Framework Programme about 1 billion Euro is expected for nuclear energy (fusion and fission).

The proof of the pudding of these kind of participatory policy analyses and designs are of course not to be found in rather ‘protected’ experiments such as the COOL project. The proof will be when moving from such a scientific experiment in participatory policy analysis to designing actual policy strategies on the long term. Especially if these strategies involve a radical departure of existing trend a common frame of reference, a common vision of the future, among the most relevant stakeholders is required. In that COOL Europe forms a starting point.

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Annex 1

LONG TERM ENERGY FUTURES; TOWARDS A LOW CARBON WORLD

Input for the European COOL Dialogue process

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Prof. Dr. K. Blok

[TWe1]

INTRODUCTION

The present report has been prepared as input into the European COOL Dialogue process. This process is part of the Dutch COOL (Climate OptiOns on the Long term) project, financed by the Dutch National Programme on Global Air Pollution and Climate Change. In the COOL project, stakeholders, policy-makers, and scientists of the energy and other economic sectors discussed long-term (2050) options for substantial CO_2 emission reductions at three tiers (the national – Dutch – tier, the European tier and the global tier). The European part of the COOL project was organised by Wageningen University in the Netherlands, with the scientific input for the energy sector being provided by Ecofys.

In the dialogue process the connection between short-term climate change policy in Europe and long-term sector strategies is assessed through a back-casting approach: First, alternative long-term energy futures were explored through the development of ‘energy images’. Precondition was that the energy image should result in an emission reduction of about 80% compared to 1990 levels. Second, implementation trajectories connecting these images to the present were developed in the ‘path analysis’. The barriers identified in the path analysis provide an overview of short-term actions needed to reach the long-term goals.

Chapter 2 discusses the general approach used in preparing the energy futures, regarding energy drivers in the energy images, potential competition between various energy demands and the different type of emission reduction measures. In Chapter 3 two alternative energy images are presented, one representing a biomass-intensive energy system, the other with an emphasis on solar hydrogen. The path analysis described in Chapter 4 shows the developments necessary to realise the energy situation pictured in the energy image. Chapter 5 identifies major barriers to reaching the projected energy futures and suggests short-term actions that may enhance the transition towards such a low-carbon future.

1 GENERAL APPROACH

In this section the general approach and main assumptions underlying the COOL energy images are described. We briefly describe the drivers that determine energy consumption. We also present an overview of the energy supply & demand system and the energy carriers that can be used, which can be helpful in determining the competition between various energy demands on the different type of energy carriers.

1.1 THE ENERGY SUPPLY AND DEMAND SYSTEM

Figure 1 shows an overview of the economy, divided in its subsectors: industry, buildings (including both residential and commercial/tertiary sector buildings), transport and agriculture. For each subsector a number of important drivers are listed. Section 2.1.1 provides a short description of the drivers and how they influence energy consumption.

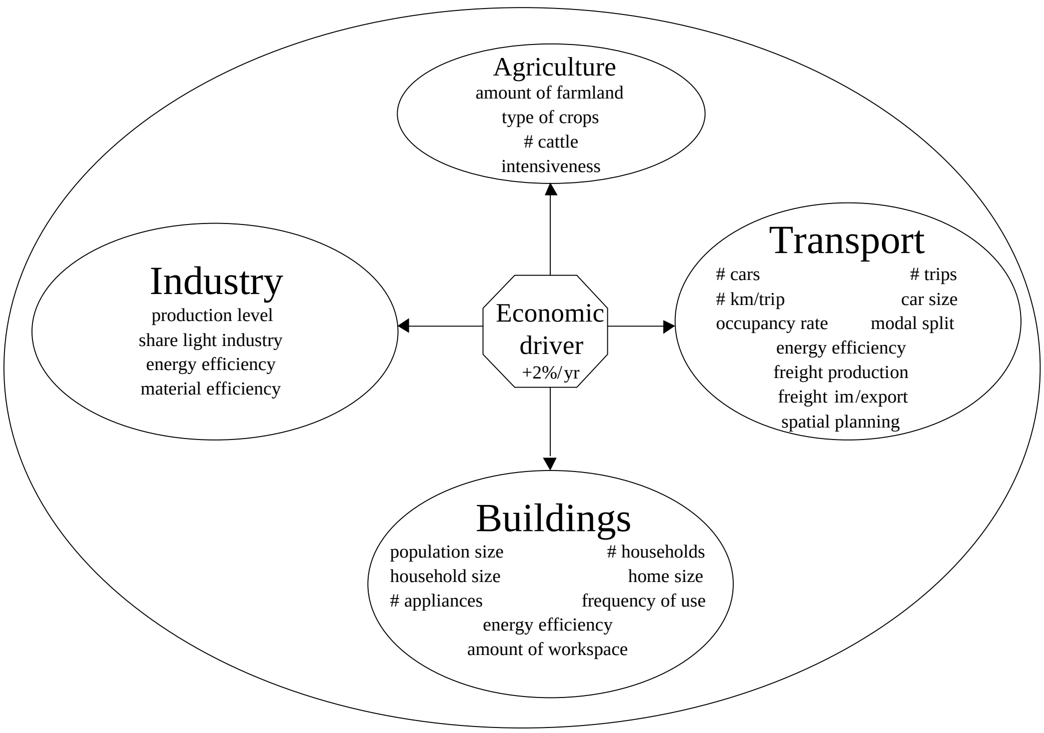

Figure 1: A schematic representation of the economy by sector and important drivers of energy consumption.

1.1.1 Energy drivers

For the industry sector important drivers are:

- Production level
  The more products (such as steel, electric appliances, bread, etc.) are manufactured, the higher the energy consumption will be.
- Share of light industry/economic structure
  Light industry consumes less industry per unit of production than heavy industry. Also within the light and heavy subsectors differences in economic structure can occur that influence energy consumption. Examples are the share of the cement industry versus the share of the (more energy-intensive) aluminium industry, or in the chemical industry the share of the petrochemical industry versus the share of the pharmaceutical industry.
- Energy efficiency
  The higher the efficiency, the lower the energy consumption per unit of production will be.
- Material efficiency
  By reducing the amount of new material used in the manufacturing of a product energy can be saved. Examples are bottles out of thinner glass or garbage bags out of recycled plastics. Energy consumption can also be influenced by substituting one material for another (plastic bottles instead of glass bottles or wooden chairs instead of plastic chairs). A third option to influence energy consumption is by extending the lifetime of products, either by increasing product quality and repairability or by producing re-usable/refillable products. Note that part of these changes also require adjustments on the consumer side of the economy.

Important drivers for the transport sector are:

- The number of trips in both passenger transport and freight transport
  The number of trips is determined by the amount of people and freight to be transported and the occupancy rate. Occupancy rate tends to drop when the number of cars increases.
- The distance travelled per trip;
- Modal split
  The share of road transport versus rail transport versus maritime transport versus air transport.
- Vehicle size and type
  Larger (i.e. heavier) and more luxurious cars will require more energy without necessarily increasing occupancy rate.
- Energy efficiency
  The lower the energy consumption per km per type of vehicle the lower the energy consumption will be.
- Spatial planning
  Spatial planning partly determines the demand for transport services. An infrastructure mainly based on large malls on the outskirts of town will lead to a higher energy consumption than when local shops provide goods and services to residents.

For the buildings sector important drivers are:

- Population size
  A larger population size means more energy consumption for cooking, washing, showering, etc.
- Household size
  Larger households use less energy per capita than smaller households (less living rooms to be heated, a higher capacity load for washing machines, etc.)
- Home size
  Larger homes require more energy for space heating, lighting, cleaning.
- Amount of workspace
  More workspace results in a higher energy consumption for heating, ventilation, air conditioning, lighting, cleaning.
- Number of appliances
  Together with the frequency of use, the number of appliances in both homes and workspace is an important factor in electricity consumption in buildings.
- Energy efficiency
  The lower the energy consumption to heat or light a certain area or use an appliance, the lower building energy consumption will be.

Important drivers of agricultural energy consumption are:

- Farmland area
  The larger the farmland area the higher the energy consumption for farm vehicles and machinery will be.
- Type of crops
  The type of crops will determine the number of operations necessary for processing.
- Number and type of livestock
  The amount and type of livestock will determine energy consumption for heating stables, milking, etc.
- Intensiveness
  Energy consumption will also be determined by the characteristics of farming (greenhouses vs. conventional farming, free-ranging animals vs. stables).

Almost all of these drivers can be subject to policies in order to reduce energy consumption, although some may be less socially acceptable (e.g. population size). Based on expectations on technical, economic as well as social developments (autonomous or policy-driven) we estimated how the consumption of different types of energy carriers in each sector would develop.

1.1.2 Energy carriers

Within the energy supply system various sources (e.g. wind, biomass, coal) basically deliver a limited number of energy functions or energy carriers. In Figure 2 we distinguish electricity, heat (low temperature, high temperature and steam) and fuels. With fuels we mean the use of fuels for other purposes than providing heat or steam, such as automotive power. Not all sources can be used to provide all carriers. Nuclear power, wind power and hydropower only deliver electricity. CHP (Combined Heat and Power generation), solar energy and biomass can deliver both electricity and heat. On top of that biomass can also provide fuels. Natural gas, oil and coal can provide all three carriers (in Figure 2 coal is not included and oil is only used to produce fuels as we envision their use to be limited in our future energy image). Of course the electricity from electricity-only sources can subsequently be used to produce fuels through electrolyses (hydrogen out of water). This can also be used as a storage system, i.e. to limit fluctuations in supply or in case more electricity can be generated from renewable sources than required. It must be noted that there can be competition between different energy demands. For example, if a large amount of biomass is used for bio-fuel production there is only a limited potential for biomass-based electricity generation.

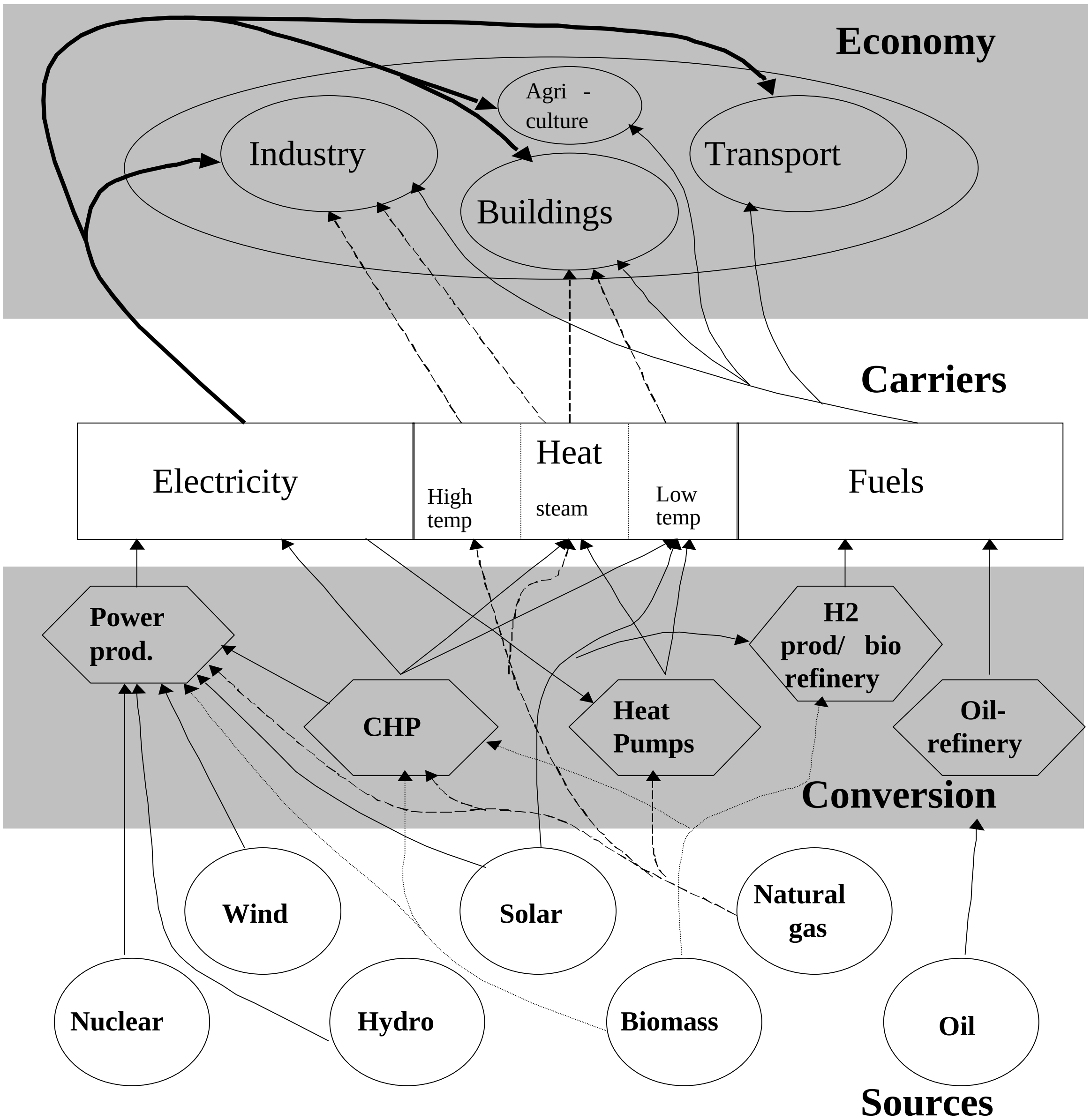

Figure 2: The future image of the energy supply and demand system in 2050.

1.2 Categorisation of energy savings and emission reduction options

Energy savings options and emission reduction options can be categorised in many different ways. A categorisation, which indicates where decisions on the implementation of such options are taken, is useful in identifying implementation barriers and targeting of policy measures. Here the following categories are distinguished:

- Fuel switch
- Energy efficiency
- Structure and patterns
- Awareness, values and lifestyles

Here we will discuss how Figure 2 is connected to these four categories.

- Fuel switch
  Decisions on fuel switching are made in the conversion sector (the bottom half of Figure 2) on the basis of the expected demand for fuels, electricity and heat, the expected prices and considerations regarding the security of supply, regulations, resource availability (i.e. land), import dependency, PR, etc. Of course the consumer can influence this decision-making by demanding certain types of energy (e.g. green electricity, see also bullet 4). In a more decentralised future these decisions will to a larger extent be made by the end-user (PV panels or solar boilers on homes, CHP in industry).
- Energy efficiency
  Energy efficiency improvement can take place both on the supply side and on the demand side. The current energy efficiency of conversion processes, such as electricity plants, CHP plants, heat pumps and refineries can be improved, thereby reducing the amount of primary energy carriers required to fulfil final energy demand. Within the economy the efficiency of industrial processes, cars, farm vehicles, houses and offices (in terms of insulation, orientation etc), appliances, etc. can be improved.
- Structure and patterns
  A shift in structure and patterns can result in either an increase or a decrease in energy consumption. Shifts that reduce energy consumption can, for instance, be an increased railroad capacity (for passenger or freight transport), a shift towards less energy-intensive products (e.g. from aluminium soda cans to glass or plastic bottles), towards more recycling, towards a more service-oriented economy or a shift away from intensive farming. Also spatial planning can influence energy consumption, i.e. large malls on the outskirts of town vs. local shops.
- Awareness, values and lifestyles
  Behaviour and awareness can strongly influence energy consumption, but is relatively difficult to quantify. In order to realise the full potential of emission reductions that can be obtained through fuel switch, energy efficiency improvement and a shift in structure & patterns a change in behaviour and awareness is required. This holds for car drivers (are they willing to carpool, to switch to public transport, or to move closer to their work?), for buyers of appliances (are they willing to pay a higher initial price for reduced operation costs?), for electricity consumers (are they willing to pay extra for green electricity?). for

manufacturers (are they willing to accept higher pay-back periods on their energy efficiency investments), etc. Also the awareness of policy makers plays a role: Are they willing to use policy instruments such as carbon taxes and regulation? Values of ‘the society’ as a whole are of influence: Do we accept a higher energy import dependency? How do we value biodiversity (monocultures in biomass production)?

Basic assumptions in our future images:

- Total energy consumption will stabilise at current levels. This is the result of a 2%/yr growth in activity, a 1.5%/yr energy efficiency improvement and a 0.5%/yr structural change. Structural change will be realised by shifts towards less energy-intensive products, and a higher contribution of energy-extensive sectors such as information technology, services, etc. to GDP.
- In accordance with the preferences of the stakeholders the energy supply system will become more decentralised. This means electricity will be generated by decentralised systems, such as solar, (on-shore) wind and CHP (Combined Heat and Power generation. Besides CHP, heat will also be supplied by heat pumps. It must be noted that a decentralised supply system, with largely small-scale generation capacity limits the potential for CO_2 removal and disposal.
- To achieve both the stabilisation in energy consumption and the shift in energy carriers and conversion processes consumers need to be ‘environmentally aware’ and actively stimulate the supply of energy and carbon-extensive options by creating a demand for these options.

2 ENERGY IMAGES FOR 2050

In this chapter two alternative energy images are presented for a low carbon society in Europe in 2050. Differences between the images arise mainly on the supply side. One image represents a future with a heavy reliance on biomass for energy. The second image has an emphasis on solar hydrogen. Both images result in similar CO_2 emissions in the year 2050, corresponding to about 20% of 1990 levels. In this chapter first the developments on the demand side are described. Second, the supply side for both energy images is quantified. Then a number of general remarks valid for both images regarding energy efficiency, fuel switch, structure and patterns and awareness, behaviour and lifestyle are made. Finally, an example is given of how such a carbon-extensive world could look like in day-to-day life is given. In the Image Profiles the main characteristics of the images are summarised.

2.1 THE ENERGY DEMAND SIDE

The development of the consumption of different types of energy carriers in each sector is based on expectations on technical, economic as well as social developments (autonomous or policy-driven). Table 1 shows the expected annual change rates for different energy carriers by sector included in the energy images. The demand side assumptions are the same for both of the images.

Additional assumptions for 2050:

- About 55% of industrial heat demand is high temperature heat, 40% is steam and 5% is low-temperature heat. In the other sectors only low temperature heat is used.
- 25% of transport fuels is aviation fuel and cannot be delivered by biomass.
- Gas-based CHP has an electric efficiency of 60% and a heat-efficiency of 30% (conventional gas-based electricity generation – not in our current image – has an electric efficiency of 70%). Biomass-based efficiencies are 50% for electricity and 30% for heat.
- Electrical heat pumps have a coefficient of performance of six.

Table 1: Rate of change in final energy consumption between 1990 and 2050 by carrier and by sector and total final energy consumption. A negative change indicates a reduction in energy consumption. Note that the change rates listed here are the result of combined changes in activity level (e.g. more transport), structure (e.g. different products in industry) and energy efficiency.

Carrier	Sector	Category	Rate of change (%/yr)	Final energy consumption in 2050 (EJ)
Heat	industry	Low temperature	-0.5%	0.2
		High temperature	-0.5%	1.5
		Steam	-0.5%	2.0
	Residential	Low temperature	-1.5%	3.0
	Tertiary + agriculture	Low temperature	-1.5%	1.1
	Total			**7.9**
Electricity	Industry		0.8%	4.7
	Residential		0.8%	3.0
	Tertiary + agriculture		1.0%	2.9
	Total			**10.7**
Fuels	Industry		0.0%	2.7
	Residential		-1.0%	0.2
	Tertiary + agriculture		-1.0%	0.2
	Transport		0.4%	9.3
	Total			**12.4**
Total				**30.9**

2.2 THE ENERGY SUPPLY SIDE

The energy images are constructed on the basis of the potentials for the various sources, the estimated requirements for each type of carriers (see section 3.1) and the relative growth paths for the different sectors. These potentials are shown in Appendix I.

Two energy images are presented, the first with a heavy reliance on biomass for energy. This image poses a high demand on the available space in Europe because of the high biomass demand for energy purposes. Large-scale PV plants could be a less land-intensive route for energy production. Therefore, a second, alternative image has been developed, which is less biomass-intensive. We have assumed that the amount of land area used for energy crops in this alternative image is limited to 75% of the excess farmland (about 50 Mha, compared to 80 Mha in the biomass-intensive image). This leaves room for other land uses, such as recreation, extensive farming, etc. Since the majority of the biomass in image I is used to produce transport fuel, the PV-generated electricity in image II will be used to produce hydrogen, that can also be used as a transport fuel. The efficiency of solar hydrogen production is assumed to be 85% (current efficiencies in small-scale plants are 70-75%) [Johansson et al., 1993].

2.2.1 THE BIOMASS-INTENSIVE IMAGE

In this section the developments in the biomass-intensive image are discussed. First the overall image is presented and quantified (Figure 3). Next, the fuel switch occurring in the image compared to 1990 levels is described (Figure 4).

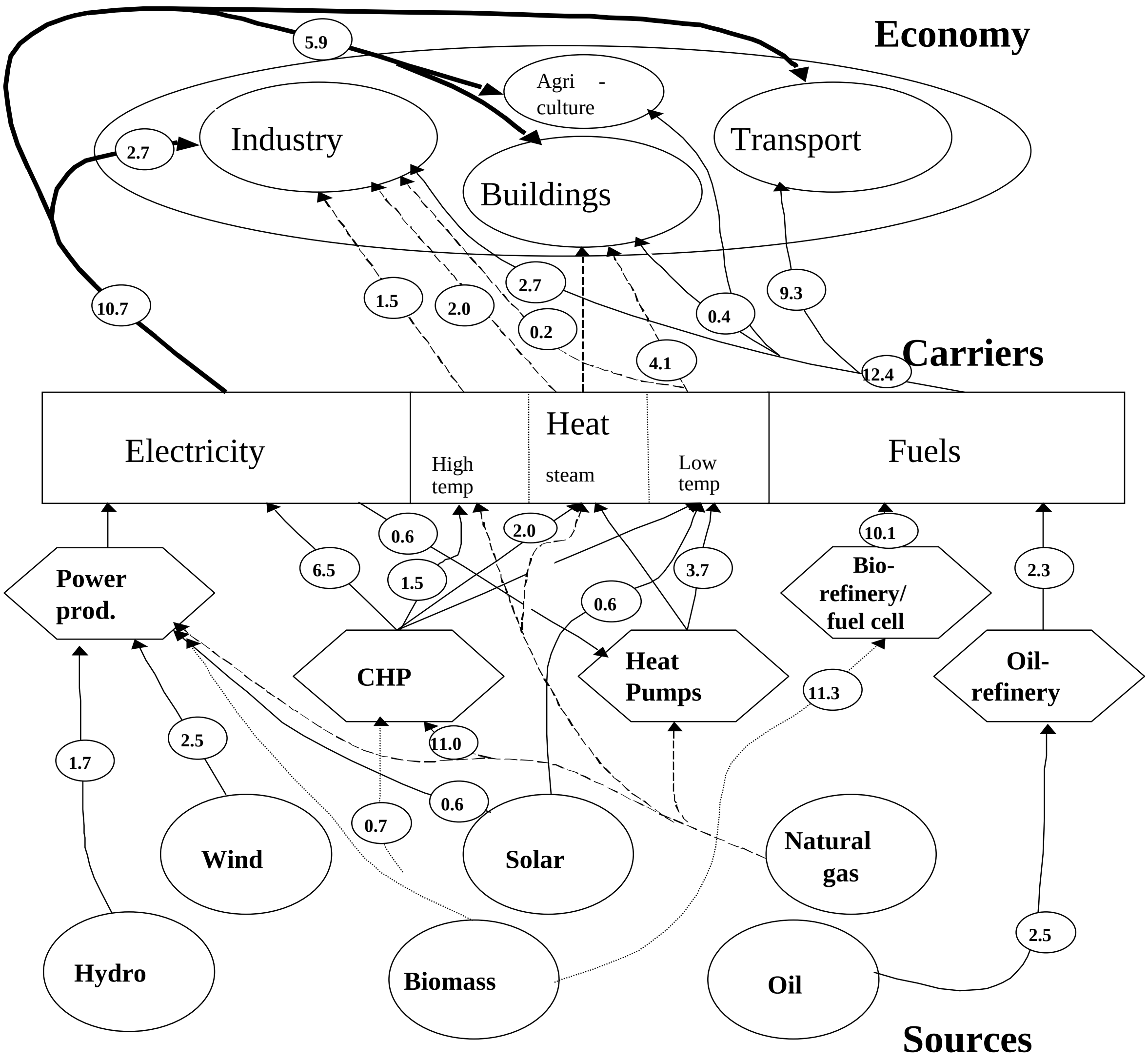

Figure 3: The biomass-intensive energy image quantified for 2050. Shown are sources, the energy carriers to which they are converted to and the economic sectors they are used in. The numbers represent energy consumption in EJ. Note that on the supply side (sources), numbers represent the demand of primary energy carriers. On the demand side, numbers represent final energy consumption. The difference between input and output in the conversion sector represents conversion losses. Note that the energy image shown leads to a CO_2 emission reduction of 75%.

Fuel switch

Figure 4 shows the fuel mix in Europe in 1990 and 2050. The graphs show a large shift from oil to biomass for fuels and a shift from coal to natural gas and renewables. Total potentials for fuel switching are shown in Table A3 in the Appendix.

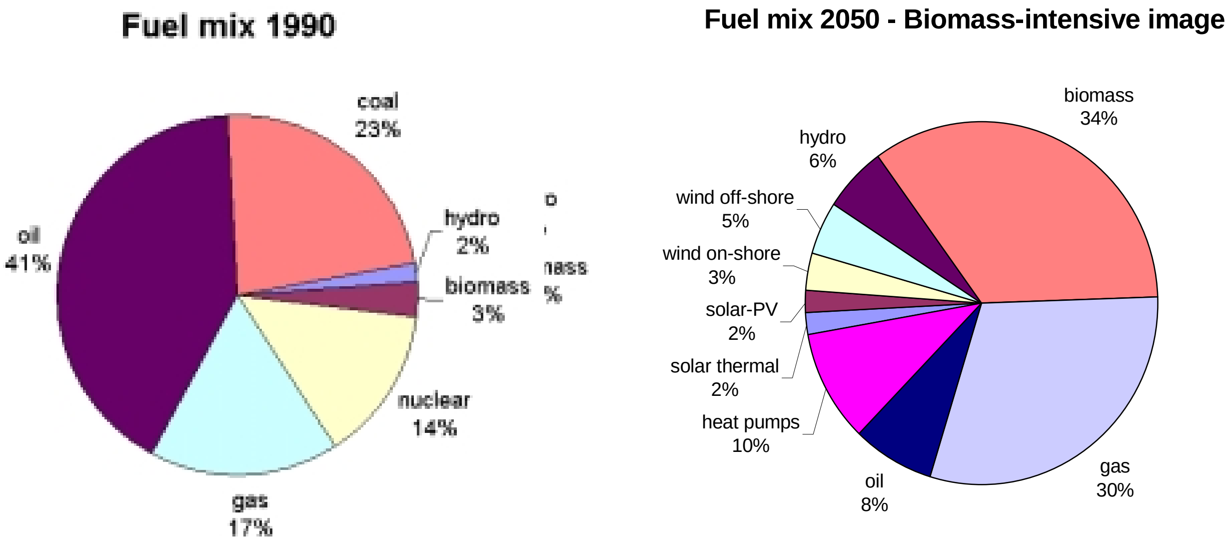

Figure 4: Fuel mix in Europe in 1990 and 2050 in the biomass-intensive future.

2.2.2 The solar hydrogen image

In this section the developments in the solar hydrogen image are discussed. First the overall image is presented and quantified (Figure 5). Also, the fuel switch occurring in the image is described in Figure 6)

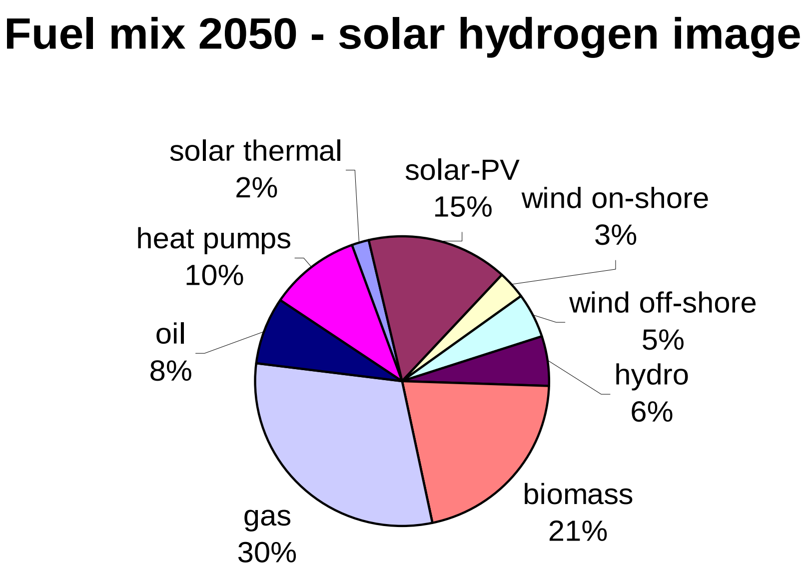

Figure 6: Fuel mix in Europe in 2050 in the solar hydrogen future.

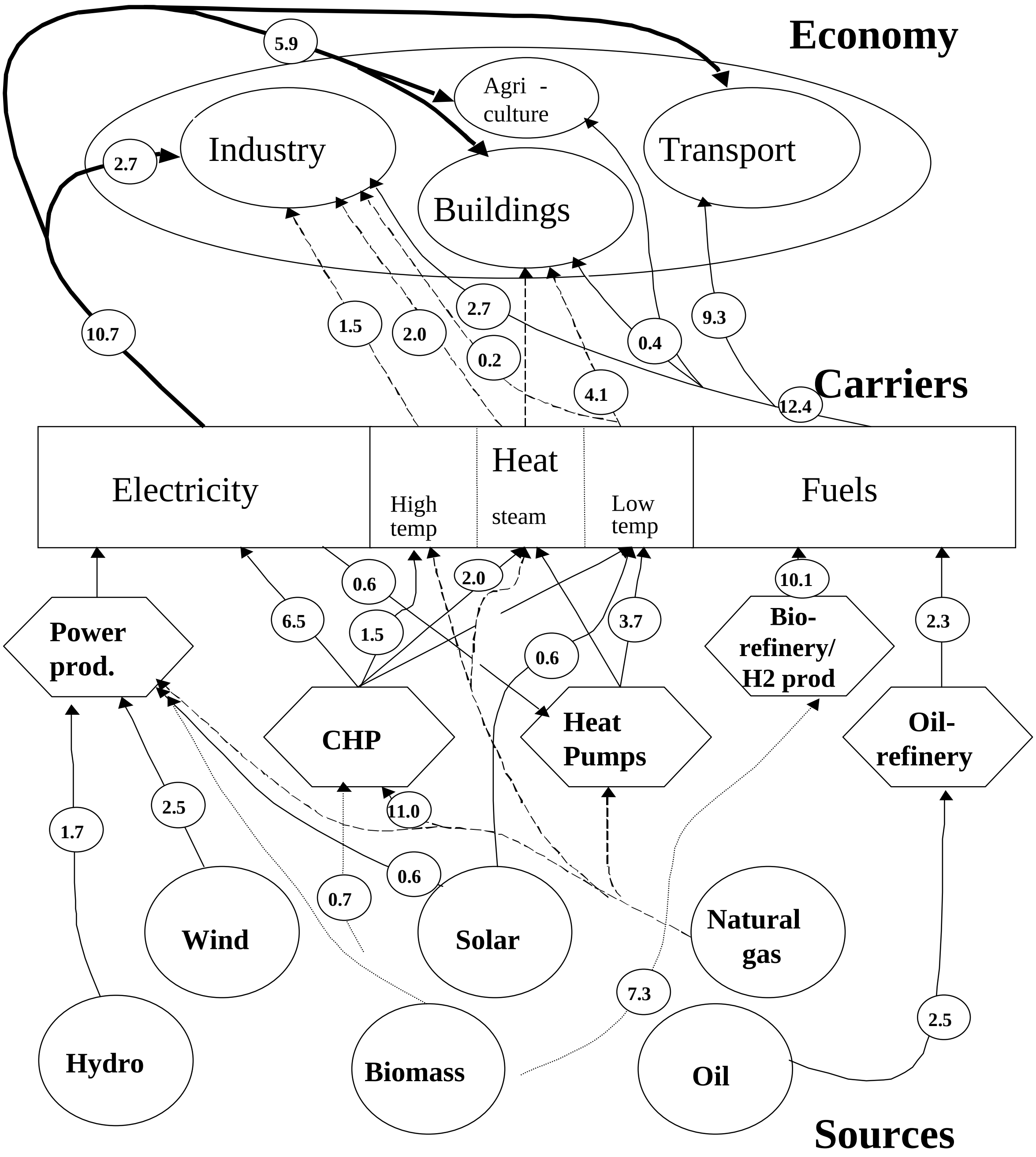

Figure 5: The solar hydrogen energy image quantified for 2050. Shown are sources, the energy carriers to which they are converted to and the economic sectors they are used in. The numbers represent energy consumption in EJ. Note that on the supply side (sources), numbers represent the demand of primary energy carriers. On the demand side, numbers represent final energy consumption. The difference between input and output in the conversion sector represents conversion losses. Note that the energy image shown leads to a CO_2 emission reduction of 75%.

2.3 General remarks

Energy efficiency

The energy efficiency of the economy as a whole is improving by 1.5%/yr. The efficiency of the energy supply system increases too. While final energy consumption stays at current levels, primary energy consumption decreases with about 35% compared to 1990. Table 1 (Section 3.1) shows the annual change rates by energy carrier by sector. Note that these change rates are the combined result of a change in energy efficiency, changes in structure and changes in activity level. Table A.2 in Appendix I shows potential improvements in specific conversion processes.

Structure and patterns

Shifts in structure and patterns are responsible for a 0.5%/yr reduction in final energy consumption. See Table 1 in Section 3.1 for a more detailed breakdown of changes by carrier and by sector (for a combination of energy efficiency effects, structural effects and activity effects). Section 3.2.4 shows what type of structural shifts may occur in the transition to a low carbon future.

Awareness, behaviour and lifestyle

Changes in behaviour will be one of the vehicles to implement the expected energy savings and emission reductions through fuel switch, energy efficiency improvement and structural change (see also Section 1.3).

Awareness, values and lifestyles can also negatively influence energy consumption and emissions. Negative effects related to awareness, values and lifestyles could arise from:

- resistance to change
- threatened interests (e.g. fossil fuel industry)
- risk perception (security of supply, safety risks, economic risks)
- biodiversity (biomass energy)/bird safety (wind power)/protected area and loss of habitat (hydro power)
- visual impact (wind power)

Changes in values and lifestyles cannot be enforced, but education, information and opinion-forming campaigns may help. There are tendencies today towards environmentally aware lifestyles, but there are also contradicting tendencies. Conditions that would strengthen the inclination towards ‘greener’ lifestyles, for example, are a clearly recognisable greenhouse effect, strong scientific evidence for the role of CO_2 in this context and a responsible and co-operative attitude among world leaders.

How could such a world look like?

In this Text box a picture is painted of how such a world as described here could look like in day-to-day life.

Imagine a world in which…..

…the environment has emerged as the most important political issue in all European countries. Because of a number of serious natural disasters, which have been attributed to the effects of climate change, public pressure in Europe has forced governments at all levels to apply strictly the precautionary principle. Europe is pressing other political regions to do the same.

…all municipalities in Europe have approved their own local Agenda 21+50. The local policy makers rely on partnerships with citizen groups in implementing schemes for, for example, energy efficiency and renewable energy. At many places environmental consultancy shops are operating. Many activities at the local level are supported by the regional and local branches of the European Bank for Sustainable Development.

…education and public-awareness policies play an essential role in international greenhouse gas mitigation strategies. Green attitudes among a majority of the consumers have increased the speed of uptake of climate-friendly products and technologies throughout European countries. More than half of the consumers buys green electricity via green power schemes. One-third of citizens save their money in green equity funds which, due to green fiscal policies, provide a relatively high return on investment and invest in sustainable projects all over the world.

…sustainable development has become an obligatory subject in all primary and secondary schools in Europe. The subject addresses issues such as the global environmental situation, global development, intra- and intergenerational equity and the history of sustainable development. It also offers practical skills such as civic participation.

…a widespread application of ICT enhances efficiency of movements, fiscal policies promote environmentally friendly transport systems, road pricing and other measures in order to internalise externalities are generally accepted and tele-shopping or e-commerce are a part of every-day life.

…material usage has become much more environmentally friendly by the use of renewable (plant-derived) materials, increased recycling, a more extensive use of reusable packaging , improved product design and repairability.

2.4 PROFILE OF THE IMAGE

Table 2 gives an overview of the main elements of the two energy images in terms of the importance in fulfilling the target (of a 80% emission reduction), possible facilitating measures and forces against the various elements. In addition, the text boxes present the main characteristics and the main consequences of both images.

Table 2: Overview of the main elements of the energy image. In case the importance differs per image this is indicated in brackets.

Elements	Contribution to target fulfilment	Facilitating measures	Forces against this element
1.Fuel substitution			Conventional energy suppliers
• Natural gas	very important	carbon tax, environmental regulation (sulphur, particulates)	utilities (import dependency)
• Biomass	important (Image II) to very important (image I)	Non-Fossil Fuel Obligation (NFFO), the use of set-aside agricultural subsidies	utilities, competition with other uses (food, materials, sinks), environmentalists (loss of biodiversity)
• Hydro	some importance	carbon tax, NFFO	local residents, environmentalists (loss of habitat)
• Wind	important	carbon tax, NFFO, subsidies	utilities (security of supply), local residents (visual impact), environmentalists (bird safety)
• Solar	Some importance (image I) to very important (image II)	carbon tax, NFFO, subsidies	utilities (security of supply), architects, building corporations
• Electric heat pumps	Important	subsidies, agreements with architects, building corporations	suppliers of conventional heating systems, building corporations

2.Energy efficiency • supply side • demand side	 important very important	 efficiency standards, energy tax efficiency standards, energy tax	 liberalised energy market
3. Structures and patterns • energy-extensive industry • increased recycling refillable packaging • increasing lifetime (higher quality and reparability	 important	 tax base reform	 energy-intensive industry, ministry of economic affairs shop keepers producers of short-lived products
4. Awareness, values and lifestyles	very important as a prerequisite for the other elements	information campaigns green labelling	suppliers of less environmentally friendly, but more convenient alternatives

Basic assumptions:

- Stabilisation of total energy consumption will occur in 2050 at current levels;
- The energy supply system will be largely decentralised;
- No coal consumption is envisioned;
- No nuclear energy is envisioned;
- The transport system will be based on biomass-derived fuels (Image I) or solar hydrogen (Image II);
- Electricity will largely be supplied by Combined Heat and Power generation and renewable energy sources;
- Low temperature heat will be supplied by heat pumps and solar hot water systems;

Consequences of the energy images:

- Large renewable input can result in a reduced security of supply, unless storage capacity can be developed.
- Biomass consumption in the biomass-intensive image requires 80 Mha land (or 17% of total land area in Europe, the estimated long-term excess cropland in Europe is estimated at 65 Mha). In the solar hydrogen image land requirements are limited to 75% of excess croplands.
- Loss of biodiversity could result from monoculture biomass plantations.
- It is unclear whether water availability is a limiting factor.
- PV electricity production requires PV panels to be installed on 42 million houses (roughly one fifth of total number of houses) with a panel size of 20 m^2.
- An increasing import dependency for gas might become an issue.
- Infrastructure will need to be developed for biomass-based CHP, but especially for the distribution of transport fuels (either biofuels or biomass-based or solar hydrogen)

3 PATH ANALYSIS

In this chapter the developments in energy supply and demand patterns are quantified, which are required to arrive at the low carbon future. First we discuss the developments on the demand side. Second, the supply side developments are presented, for the biomass-intensive energy and the solar hydrogen image are discussed, including the costs of energy supply in both alternative low-carbon futures. Barriers to the realisation of the low carbon futures are discussed in Chapter 5.

3.1 DEMAND SIDE DEVELOPMENTS

Besides changes in the supply side, also energy demand patterns need to be changed to achieve the energy image in 2050. Table 1 in Section 3.1 shows the development of energy demand leading up to the energy demand included in both energy images.

Compared to 'business as usual' developments, the developments shown in Table 1 are ambitious. This becomes clear if the energy image developments are compared to those included in various short-term scenarios, as shown in Table 3.

Table 3. Demand-side developments in short-term scenarios [Capros, 1999]. Shown are average annual changes over the period 1995-2020.

Carrier	Sector	Rate of change (%/yr)
Steam	Industry	1.2%
	Residential	1.4%
	Tertiary and agriculture	3.3%
Electricity	Industry	1.1%
	Residential	1.6%
	Tertiary and agriculture	2.8%
Fuel	Industry	0.1%
	Residential	0.3%
	Tertiary and agriculture	0.1%
	Transport	1.0%

Note that the fuel listed in this Table is also partly used to supply heat. No distinction on the basis of energy service (heat, electricity, fuel for other purposes than heat as done in Table 1) could be made.

For electricity, growth rates foreseen in the image are lower than in most short-term scenarios. This requires a substantial increase in the efficiency of domestic and office appliances, industrial motors and drives and lighting systems. In addition, also new buildings have to be designed in such a way that they make optimal use of daylight and passive solar energy. Also the implementation of heat/cold storage systems could lead to lower growth rates e.g. for air conditioning. Behavioural changes such as switching appliance off stand-by or fully loading (dish) washers and will be important. Behaviour, however, will play a bigger role in purchasing equipment and the choice for insulation, etc.

The decrease in low-temperature heat consumption foreseen in the image will have to be met through increased insulation in buildings (including walls, roofs and windows) and a better use of passive solar energy. An increased efficiency of heat generation (high-efficiency boilers, heat pumps and district heating) will lead to a lower fuel demand for heat production. The reduction in high-temperature heat and steam demand in industry can be achieved through an increased integration of processes, a shift to different processes (e.g. using membranes for separation instead of distillation) and products (e.g. less energy-intensive industry and more knowledge-intensive industries and services). An already occurring example is the emergence of internet publishing as an alternative to ‘regular’ printing, using paper.
A shift to electricity could also contribute to the decrease in heat (e.g. by using electric compressors instead of steam-driven compressors).

For transport, the growth in fuel demand in the image is much lower than is assumed in short-term scenarios. A large part of this difference can be achieved by the introduction of hydrogen or methanol-fuelled vehicles. Such vehicles have a fuel intensity that is typically three times (for hydrogen) that of gasoline cars. In addition, behavioural changes, such as tele-working, car pooling, increased use of public transport and the use of bikes for short-distance travel can play an important role.

3.2 The biomass-intensive image

In this section we will first quantify the developments that are required on the supply side to arrive at the desired image. We will discuss required growth rates for the various energy sources, the required development of electricity supply costs and the issue of security of supply.

3.2.1 Required growth rates in supply

Table 4 shows that to reach the desired image, the growth rates for all sources except hydropower need to be high. For biomass and natural gas the electricity production needs to grow with almost 4% each year, for 60 years in a row. Solar thermal and wind energy have to experience an annual growth rate of 8-10%, while PV (solar electricity) even has to grow with 17% per year over this 60-year period. Note that with such high growth rates the rate with which production capacity for e.g. PV modules can be constructed can be a limiting factor. Figures 7 and 8 show the absolute and relative growth in production for the various energy sources. They show that a high absolute growth occurs in wind and, especially, gas-based electricity production, but by far the largest relative growth occurs in solar electricity.

Table 4. Required growth rates for various energy sources to deliver the amount of energy reflected in the energy image[1]

Energy source	Final energy (EJ)		growth factor	required annual averaged growth rate
	1990	2050		
Wind energy	0.014	2.5	173	9.9%
Hydropower	1.1	1.8	1.6	0.9%
Photovoltaics	0.0001	0.6	5556	17.0%
Biomass	1.6	12.0	7.5	3.8%[1]
Geothermal	0.03	0.0 3	1	0%
Solar thermal	0.017	0.6	55	7.5%
Natural gas	1.2	9.4	8	3.9%

Notes: 1 The biomass used in 1990 was almost entirely used for electricity and heat, not for transport fuels. The majority of the biomass energy consumption in 2050 is foreseen to be used for transport purposes. The growth rate for biofuels will therefore be larger than shown here.

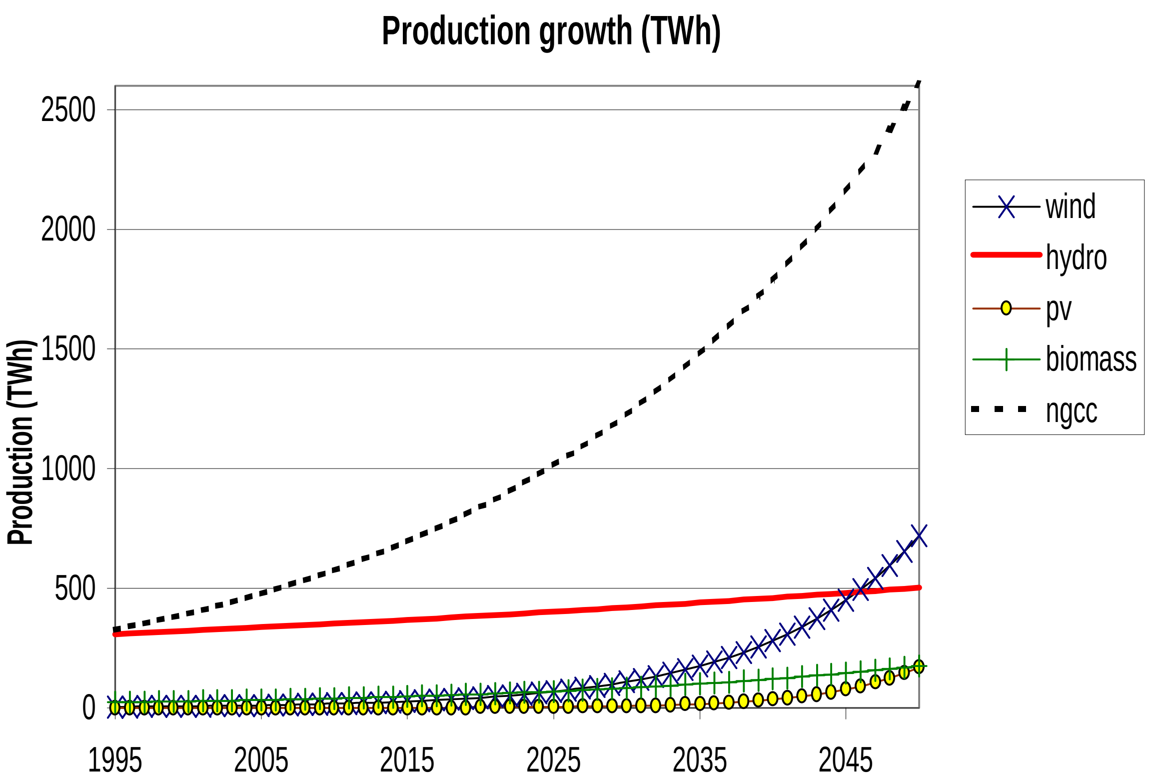

Figure 7 Production growth of electricity by source required to meet the contribution of each energy sources foreseen in the energy image (based on an annual average growth rate). NGCC refers to Natural Gas Combined Cycle electricity generation.

[1] Note that the image has been changed following the comments of the participants at the second workshop. Nuclear energy has been omitted from the image. The resulting electricity gap was filled by increasing the amount of wind and solar electricity.

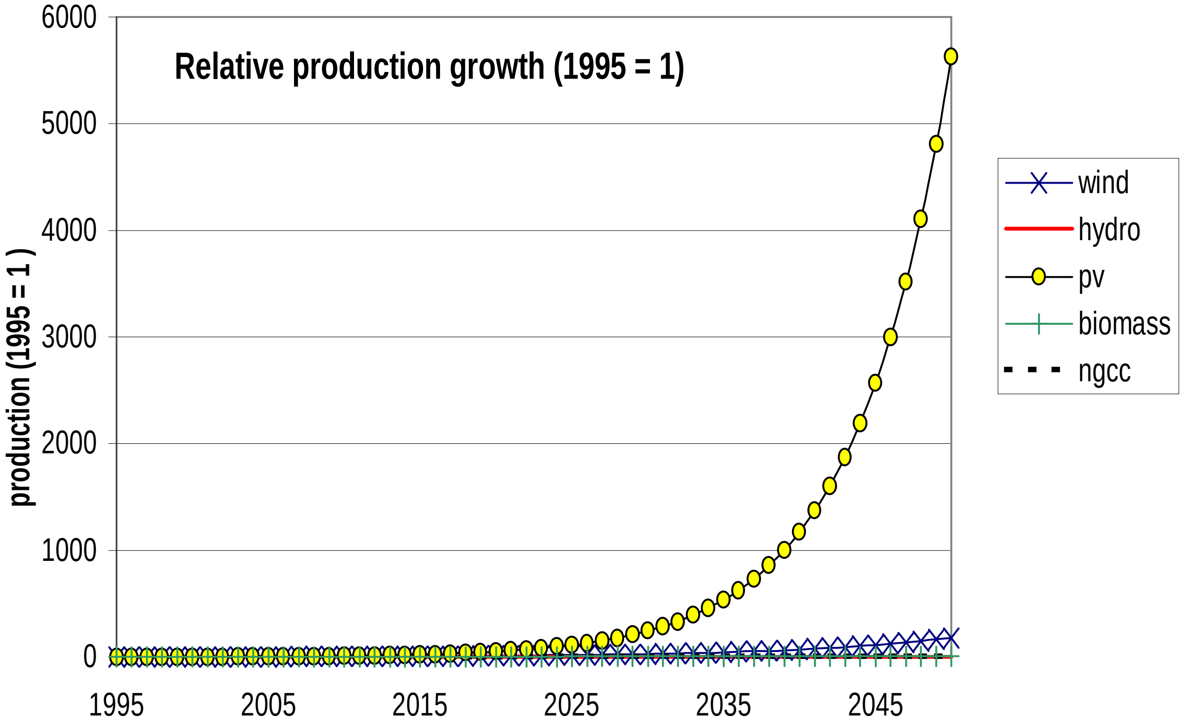

Figure 8. Relative electricity production growth by source required to meet the contribution of each source, foreseen in the energy image.

3.2.2 Energy production costs

Table 4 shows the current costs of producing electricity and transport fuels [Neij, 1999, Faaij et al., 2000]. Also shown are the progress ratios for various energy supply options, reflecting the reduction in production costs achieved with each doubling of production [IEA, 1998]. For example, a progress ratio of 85% means that a doubling of production capacity leads to a decrease in production costs of 15%.

Figure 9 shows the development of electricity production costs with each doubling of production capacity for various electricity supply options according to the progress ratios shown in Table 4. Figure 10 shows the cost development over time based on the average annual growth rates shown in Table 3. The Figures show that if production capacity grows at the same rate (in terms of number of doublings) for all sources PV electricity will remain the most expensive all the way through 2050. The market share of PV can therefore not be enlarged on the basis of production costs. However, the energy image assumes PV electricity production to grow by 17% per year, on average, while other sources ‘only’ experience 1-9% per year in production. From this it is obvious that PV can only play the role foreseen in the energy image if PV is forced into the market (e.g. through regulation or heavy subsidies) or in case major breakthroughs in costs are achieved (i.e. even larger than already required to follow the learning curve).

Table 4. Current energy costs and progress ratios for electricity production

Energy source	progress rates [IEA, 1999]	Current costs range		unit	Remarks [source for cost data]
Electricity					
Wind	81%	6,6		1995 $ct/kwh	[Neij]
PV modules	82%	32	40	1995 $ct/kwh	[Neij]
Biomass	70%	8	14	1995 $ct/kwh	[Faaij et al., 2000]
Hydro		7,8		1995 ct/kwh	[Neij]
NGCC	90%	2,8	7,3	1995 ct/kwh	[Neij] fuel price 2.2-5-5 US$/GJ high figure includes CO2 capture
Coal	95%	4,6	7,7	1995 ct/kwh	[Neij], fuel price 1.2-2-5 US$/GJ high figure includes CO2 capture
Nuclear		4	7,7	1995 ct/kwh	[Neij], including waste disposal and decommissioning
Transport fuel					
Biomass transport fuel		14	43	US$/GJ	[Faaij et al, 2000] at the car low figure refers to H_2/alcohol-based systems. High figure refers to biodiesel
Gasoline		8		US$/GJ	[Faaij et al., 2000] at the car excluding taxes

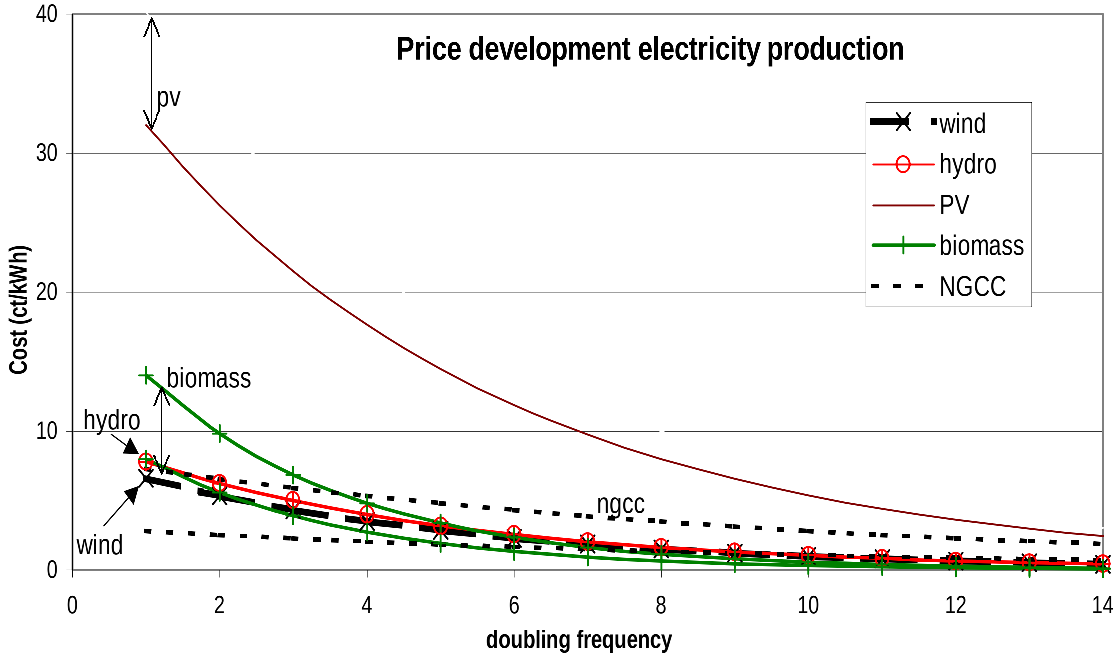

Figure 9. Cost development for electricity production by renewable energy source with each doubling of production capacity (according to the progress ratio's shown in Table 1. For the gas-fired plants (NGCC) the high estimate reflects a plant with CO_2 removal and storage, while the lower figure does not include the removal and storage option. In the current image no CO_2 removal and storage is assumed.

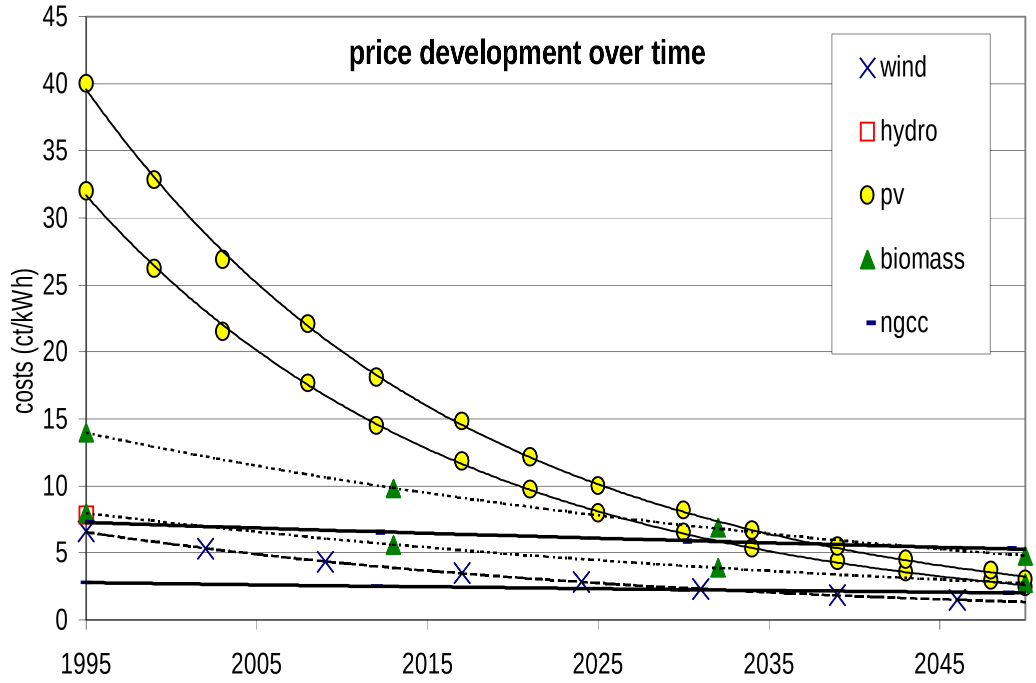

Figure 10. The development of electricity costs by source over time ($ct/kWh). For the gas-fired plants (NGCC) the high estimate reflects a plant with CO_2 removal and storage, while the lower figure does not include the removal and storage option. In the current image no CO_2 removal and storage is assumed.

Table 5 shows the long-term production costs for biofuels for transport for various options [Faaij et al., 2000]. Together with the cost estimates for electricity production from Figure 1.4 and the total consumption of fuel and electricity by source, total energy supply costs in 2050 for the biomass-intensive image can be calculated. These are shown in Figure 11. Figure 12 shows the relative contribution of each source to the total costs.

Table 5. Long term costs for transport fuels from biomass [Faaij et al., 2000]

Source	Costs (US$/GJ delivered at the car)
Compressed hydrogen	9
Liquid hydrogen	11
Methanol	10
Ethanol from wood	6
Ethanol from sugar	24
Biodiesel	23-28

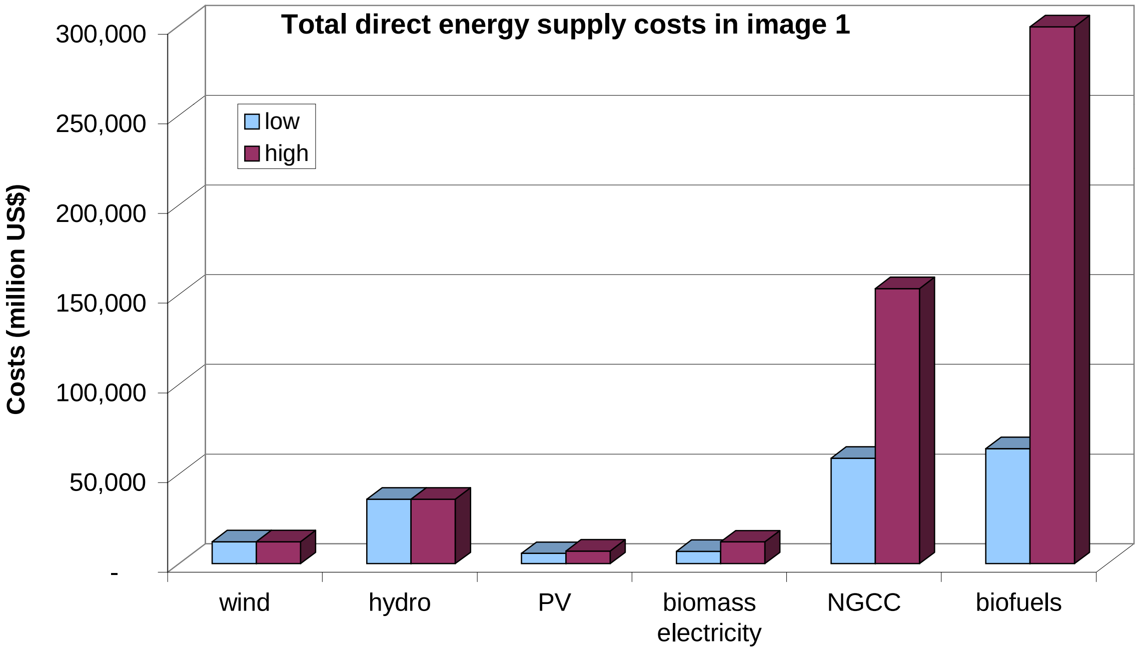

Figure 11. Total costs of energy supply in 2050 in the solar hydrogen image. For the gas-fired plants (NGCC) the high estimate reflects a plant with CO_2 removal and storage, while the lower figure does not include the removal and storage option. In the current image no CO_2 removal and storage is assumed. For biofuels, the low estimate refers to ethanol from wood, the high estimate refers to biodiesel. Note that no indirect costs or benefits are included (e.g. employment effects, etc).

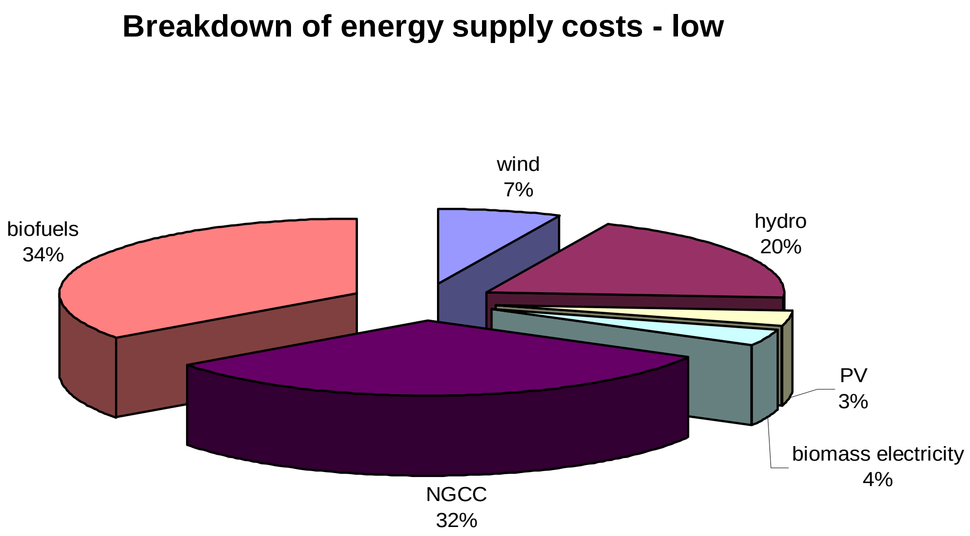

Figure 12. Breakdown of energy supply costs (low estimates) by energy source in 2050 in the biomass-intensive path.

3.2.3 Security of supply

When using substantial amounts of intermittent energy sources, security of supply deserves attention. Especially solar and wind energy sources can show great variability depending on weather conditions, the time of day (for solar) and the season. But also hydropower and biomass are, on a seasonal basis, depending on weather conditions. Table 6 shows the share of intermittent source in electricity generation in the energy image. It shows that intermittent sources in 2050 contribute for almost 50% to electricity generation, which the highly fluctuating PV and wind sources combined contribute 29%. PV can typically show a variation of 0-50% of the load curve. Wind can even vary between 0-100% of the load curve, posing a larger problem. . As a consequence, security of supply cannot be guaranteed without either a substantial over-capacity or a storage system. In addition, all the available electricity production capacity needs to be able to come on/off line quickly.

Table 6. Share of intermittent sources in electricity generation in the biomass-intensive energy image in 2050

Source	Share (%)
Hourly fluctuation	
PV	6%
Wind	23%
Seasonal fluctuation	
Hydro	17%
Biomass	3%
Total	49%

3.3 SOLAR HYDROGEN IMAGE

In this section we will first quantify the developments that are required on the supply side to arrive at the desired image. We will discuss required growth rates for the various energy sources, the required development of electricity supply costs and the issue of security of supply.

3.3.1 REQUIRED GROWTH RATES IN SUPPLY

Table 7 shows that to reach the desired image, the growth rates for all sources except hydropower need to be high. For biomass and natural gas the electricity production needs to grow with almost 3-4% each year, for 60 years in a row. Solar thermal and wind energy have to experience an annual growth rate of 8-10%, while PV (solar electricity) even has to grow with almost 22% per year over this 60-year period. biofuels. It must be clear that with such high growth rates the rate with which production capacity for e.g. PV modules can be constructed can be a limiting factor. Figures 13 and 14 show the absolute and relative growth in production for the various energy sources. They show that a high absolute growth occurs in wind and, especially, gas-based electricity production, but by far the largest relative growth occurs in solar electricity.

Table 7. Required growth rates for various energy sources to deliver the amount of energy reflected in the energy image[2]

Energy source	Final energy EJ		Growth factor	required annual averaged growth rate
	1990	2050		
Wind energy	0.014	2.5	173	9.9%
Hydropower	1.1	1.8	1.6	0.9%
Photovoltaics	0.0001	4.8	51307	21.8%
Biomass	1.6	6.5	4.6	2.8%[1]
Geothermal	0.03	0.03	1	0%
Solar thermal	0.017	0.6	55	7.5%
Natural gas	1.2	9.4	8	3.9%

Notes: 1 The biomass used in 1990 was almost entirely used for electricity and heat, not for transport fuels. The majority of the biomass energy consumption in 2050 is foreseen to be used for transport purposes. The growth rate for biofuels will therefore be much larger than shown here.

[2] Note that the image has been changed following the comments of the participants at the second workshop. Nuclear energy has been omitted from the image. The resulting electricity gap was filled by increasing the amount of wind and solar electricity.

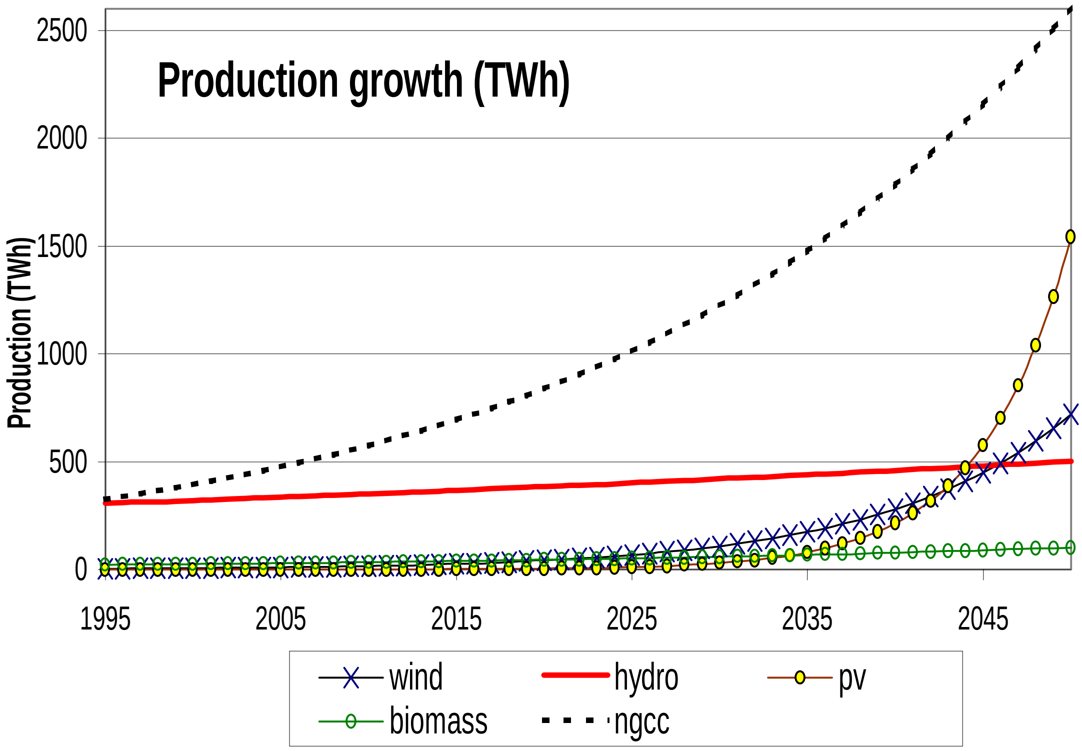

Figure 13. Production growth of electricity by source required to meet the contribution of the various energy sources foreseen in the energy image (based on an annual average growth rate).

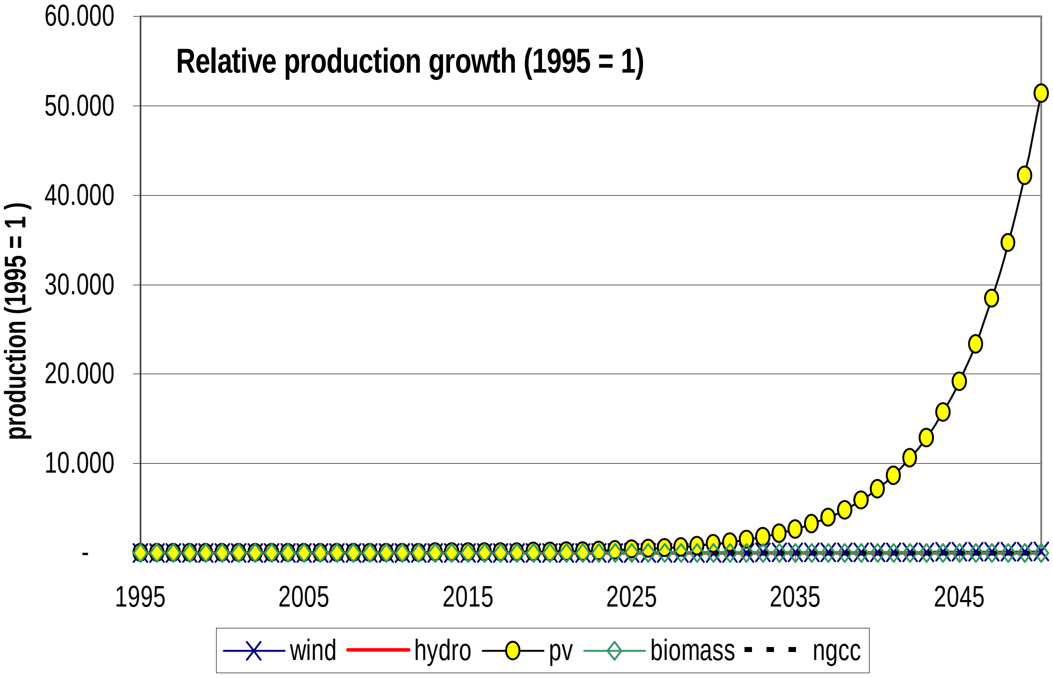

Figure 14. Relative production growth by source required to meet the contribution of each source, foreseen in the energy image.

3.3.2 Energy production costs

In the second image the same data on the current costs of producing electricity and transport fuels and progress ratios are used as in the first image [Neij, 1999, Faaij et al., 2000; IEA, 1998].

Figure 15 shows the development of electricity production costs with each doubling of production capacity for various electricity supply options according to the progress ratios. Figure 16 shows the cost development over time based on the average annual growth rates shown in Table 7. The Figure shows that if production capacity grows at the same rate (in terms of number of doublings) for all sources PV electricity will remain the most expensive all the way through 2050. The market share of PV can therefore not be enlarged on the basis of production costs. However, the energy image assumes PV electricity production to grow by 22% per year, on average, while other sources 'only' experience 1-10% per year in production. From this it is obvious that PV can only play the role foreseen in the energy image if PV is forced into the market (e.g. through regulation or heavy subsidies) or in case major breakthroughs in costs are achieved.

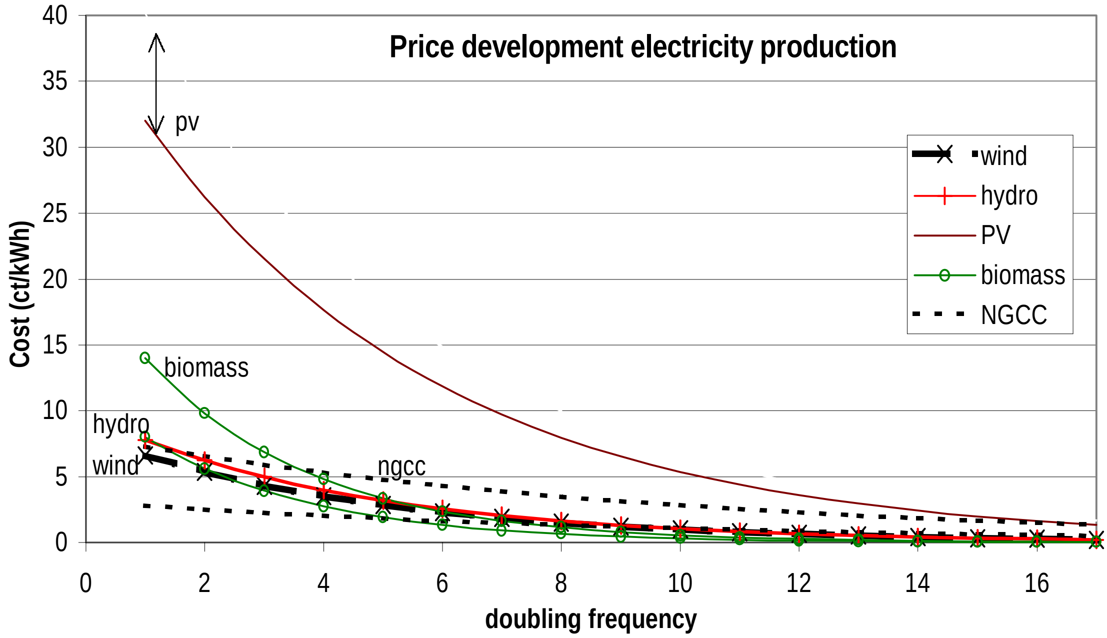

Figure 15. Cost development for electricity production by renewable energy source with each doubling of production capacity (according to the progress ratio's shown in Table 4. For the gas-fired plants (NGCC) the high estimate reflects a plant with CO_2 removal and storage, while the lower figure does not include the removal and storage option. In the current image no CO_2 removal and storage is assumed

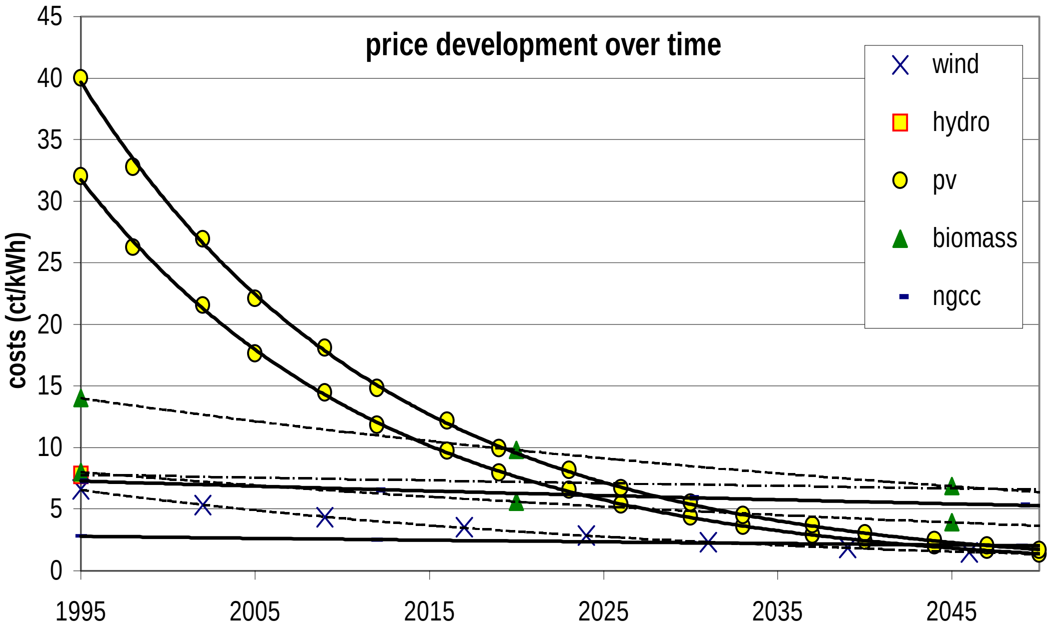

Figure 16. The development of electricity costs by source over time ($ct/kWh). For the gas-fired plants (NGCC) the high estimate reflects a plant with CO_2 removal and storage, while the lower figure does not include the removal and storage option. In the current image no CO_2 removal and storage is assumed

In image II, the same long term costs for biofuels for transport are used as in image I [Faaij et al., 2000]. For solar hydrogen a cost range of 25-30 US$/GJ delivered at the car is used. Note that these costs are based on production on sites in Europe. In case the hydrogen is produced in the African desserts, prices will increase with an additional 10-15US$/GJ [Johansson et al., 1993]. Together with the cost estimates for electricity production from Figure 16 and the total consumption of fuel and electricity by source, total energy supply costs in 2050 for the solar hydrogen image can be calculated. These are shown in Figure 17. Figure 18 shows the relative contribution of each source to the total costs.

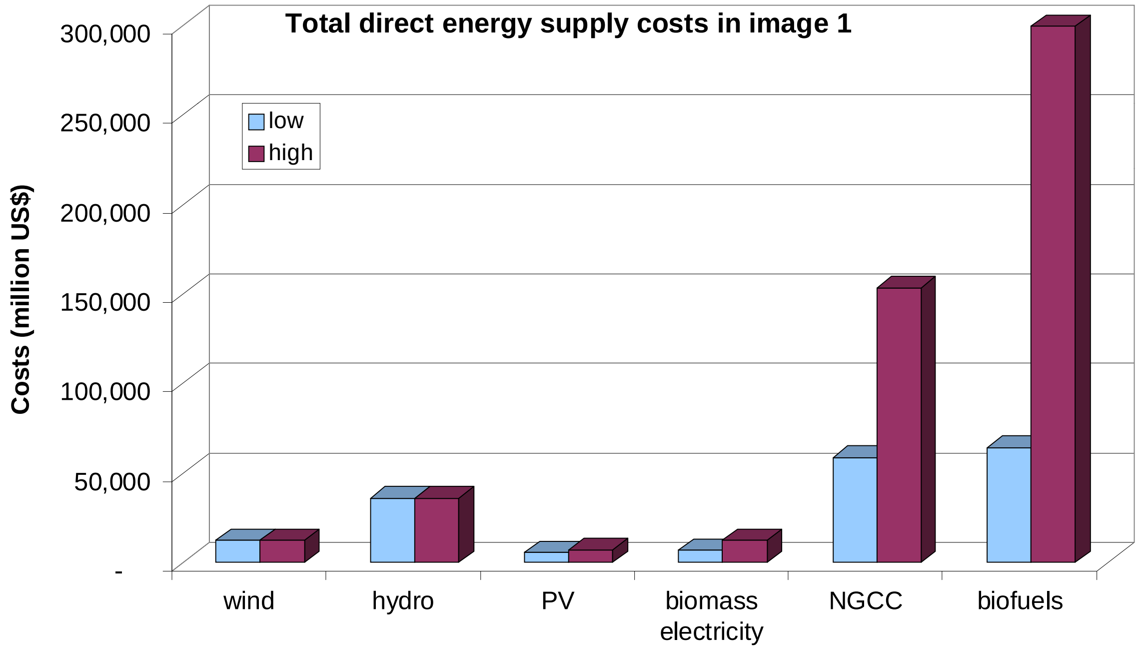

Figure 17. Total costs of energy supply in 2050 in the solar hydrogen image. For the gas-fired plants (NGCC) the high estimate reflects a plant with CO_2 removal and storage, while the lower figure does not include the removal and storage option. In the current image no CO_2 removal and storage is assumed. For biofuels, the low estimate refers to ethanol from wood, the high estimate refers to biodiesel. Note that the costs for solar hydrogen are included in 'fuels', not in 'PV'. From the fuel costs, about 60-70% is for solar hydrogen.

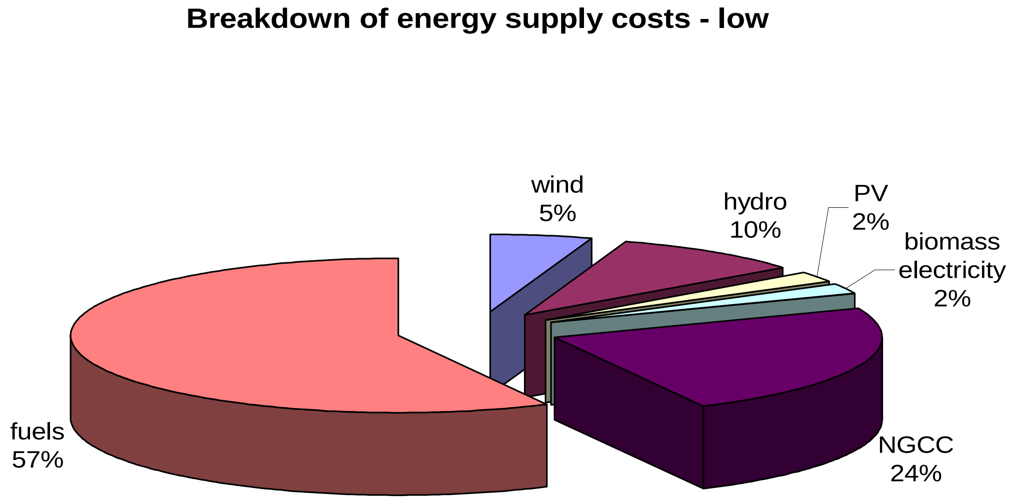

Figure 18. Breakdown of energy supply costs (low estimates) by energy source in 2050 in the solar hydrogen image.

3.3.3 Security of supply

The share of intermittent source in electricity generation in the solar hydrogen image are the same as in the biomass-intensive image (almost 50% of electricity generation in 2050 is covered by intermittent sources, of which 3/5th is from highly fluctuating PV and wind sources). As a consequence, security of supply cannot be guaranteed without either a substantial overcapacity or a storage system. In addition, the solar hydrogen image is also depending on highly fluctuating solar energy sources for 1/3rd of its fuel demand. This means a substantial amount of fuel must be kept in storage to secure the supply of transport fuels e.g. during winter.

3.4 Comparing both images - production costs

Figure 19 shows a comparison of the total direct energy supply cost between the two images, showing the big difference in costs, related to solar hydrogen production. The figure shows that the lower land requirements in the solar hydrogen image result in the penalty of higher energy supply costs.

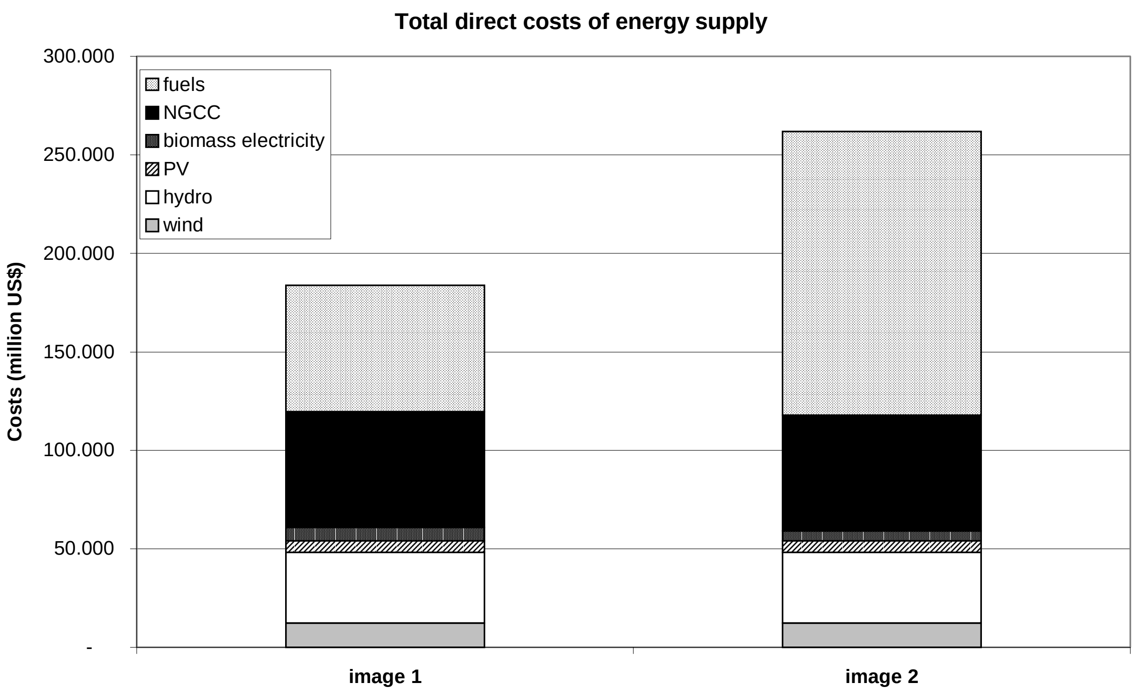

Figure 19. Comparing total direct energy supply costs between 1. the biomass-intensive image and 2. the solar hydrogen image (low estimate). Note that solar hydrogen costs are included under ‘fuels’, not with ‘PV’.

4 BARRIERS AND INTERMEDIATE STEPS

In this chapter barriers towards the realisation of the low carbon futures are discussed and intermediate steps to overcome these barriers are suggested.

4.1 BARRIERS

4.1.1 COSTS

As shown in the previous section, currently costs of renewable energy production are usually higher that that of conventional sources. Figures 9 and 13 have shown that the cost of wind and biomass electricity may become competitive on the relatively short term, perhaps even within 2-3 doublings of production capacity. This means that an increase in consumer preferences for green energy and energy tax exemptions for renewable energy may go a long way in reaching the required capacity increase and price reduction. For PV, however, cost differences are so large that much stronger incentives will be needed if it is to play the role foreseen in the image. This is also valid for solar hydrogen produced as transport fuels.

Biofuels are currently not competitive, when production costs are compared to those of gasoline. However, taxes can increase the gasoline price paid by the consumer by a factor of 2-3 in a number of Member States. Exempting biofuels (partly) from those taxes would make them competitive on a relatively short term (not taking into account the infrastructural side of the problem).

In addition to PV and, to a lesser extent, biofuel production processes, other technologies that need further development are for example heat pumps, underground storage systems for heat/cold, hydrogen storage systems (both for vehicles and for electricity production).

4.1.2 SECURITY OF ELECTRICITY SUPPLY

The large share of intermittent renewables foreseen in the energy image will result in a decreased security of supply. To absorb the variation in supply from hour to hour (for wind and solar), day and night (mostly solar) and season to season (all sources) a safeguard needs to be built in the system. This could be done either through the availability of back-up capacity or by means of storage capacity. In case back-up capacity is used, a distinction can be made between peak capacity (for short-term fluctuations) and medium or base-load capacity (for seasonal variations). In case storage systems are used, one can choose for (a combination of) pumped storage (hydro), hydrogen (from the electrolysis of water) or batteries.

4.1.3 Biomass supply and required land area

The first energy image heavily depends on biomass. Besides biomass wastes, energy crops are expected to require 17% of total land area in Europe (for comparison: cropland currently covers 140 Mha, or 30% of total crop land, with forests and woodlands covering another 33%). About 80% of the land demand for energy crops can be met using excess croplands, starting with currently set-aside land. In the second image land area required for biomass production for energy is limited to a part of the excess cropland. In both cases an adjustment of agricultural policies is required. Currently, EU agricultural policy provides a subsidy to farmers that set aside land in order to decrease over-capacity in food production. Farmers loose this subsidy if the set-aside land is used for energy crops. This, in combination with currently low potential prices for the energy crops, forms a barrier for farmers to (partly) switch from food crops to energy crops. The remainder of the land required in the biomass-intensive image (almost 20% of 17%, i.e. 3% of total land area in Europe) needs to be found elsewhere, e.g. through energy plantation forests. This may lead to competition for land, e.g. with more extensive ('biological') farming, recreation, etc. A solution might be the combination of different activities, e.g. energy plantation forests and recreation, in the same area. On the other hand, biomass-fuelled plants will have difficulties starting up if the supply of fuels is not sufficiently large and stable. Insecurity in the supply of biomass will lead to lower plant utilisation or higher fuel prices. Closing a deal with surrounding farmers for guaranteed supply/demand of biomass at fixed prices may benefit both parties involved.

4.1.4 Infrastructure

New infrastructure will need to be developed for the distribution of biofuels and hydrogen and for a potential storage system. Currently no biofuelled or hydrogen-fuelled cars can be introduced, because no infrastructure is in place to supply the vehicles with the necessary fuels. On the other hand, no biofuel or hydrogen infrastructure will be developed, because there is no demand for such alternative fuels yet. This seemingly vicious circle needs to be broken in order to achieve a substantial vehicle fleet to be driven by alternative fuels.

One additional problem regarding infrastructure are the competing options for biofuels (see Table 5) and other alternative fuels. Building up infrastructure for different types of alternative fuels will be too expensive. This means a choice for a specific type of alternative fuel has to be made, without knowing up front which type will develop into the best and cheapest option. In this respect, hydrogen has an advantage, since it can be made from e.g. fossil fuels (in the transition phase for example), from biomass or from electricity (fossil or renewable). Considering biomass-derived hydrogen, a distinction could be made between on-board production of hydrogen, in which the vehicle is fuelled with biofuels and an on-board reformer transforms the biofuel into hydrogen, and direct fuelling with hydrogen at the pump. The former option has the flexibility to start with mixing biofuels with regular gasoline in the transition phase and to switch to on-board reforming vehicles when sufficient infrastructure is in place. The latter option has the flexibility of using possible routes for hydrogen production, but it does not offer a solution for the transition phase (although DaimlerBenz has experimented with dual fuel hydrogen/gasoline cars).

4.1.5 CURRENT STAKEHOLDERS

Current stakeholders that might be threatened by the developments foreseen in the alternative energy futures are large-scale electricity producers, electricity distributors and oil companies. Other stakeholders that need to play an important role are farmers, car manufacturers, architects and building contractors

In achieving the situation sketched in the energy image it is important to involve the potential opponents in the solution to the problem. Part of the players is already doing this, e.g. oil refineries diversifying into solar technologies such as Shell and BP, or car manufacturers investing in hybrid or fuel cell technologies (Toyota, DaimlerChrysler, Ford). Large-scale electricity producers and distributors could be involved in the development of the required new capacity (wind parks, CHP plants) but they could also refocus on the delivery of 'energy services' instead of mere electricity. This could include advising on managing back-up capacity and/or storage systems, demand-side management, offer integrated concepts for heating/cooling systems, etc.

4.2 COMPARING BOTH IMAGES - BARRIERS

The bottlenecks and required intermediate steps towards both alternative low carbon futures will to a large extent be similar. Here we will discuss the most important differences.

The amount of land required in the solar hydrogen image is smaller than the biomass-intensive image. Since the land demand is limited to 75% to expected excess croplands, there will also be room left for other activities with a demand for land. Land demand is therefore not expected to be a problem in the solar hydrogen image. Biomass will, however, still contribute a substantial part to the energy supply in 2050. Therefore, the intermediate steps discussed in section 1 will still be needed.

The introduction of PV has to be much larger in the solar hydrogen image than in the biomass-intensive image. Therefore, technological breakthroughs, substantial cost reductions and strong policy actions have to be attained to an even larger extent than in the biomass-intensive image.

Security of supply is a bigger issue in the solar hydrogen image, since the contribution of intermittent sources is larger than in the biomass-intensive image. However, large part of the PV capacity will be used for fuel production, which is, in a way, a storage system. A sufficiently large amount of fuel would need to be kept in storage to be able to act as a buffer for transport purposes alone (to make sure fuel demand can be met at times with less sunshine). To flatten out fluctuations in electricity supply (e.g. from wind), additional storage capacity and quickly adjustable capacity (coming on/off lone quickly) will still be needed.

With regard to transport fuel infrastructure, the same vicious circle (low demand -> so no infrastructure is developed -> so no demand can develop) needs to be broken as with the biomass-intensive image. Hydrogen vehicles would create the flexibility of using different possible routes for hydrogen production (produced from renewable electricity, biomass or fossil fuels). It does not, however, offer a solution for the transition phase in which the switch from conventional to alternative fuels take place (such as with biofuels, that can be mixed with gasoline).

4.3 POSSIBLE INTERMEDIATE STEPS

Here a number of short-term intermediate steps are suggested that can facilitate in the transition towards one of the alternative low carbon futures. A distinction is made between actions aiming at the demand side and options aiming at the supply side.

Demand-side

- Strict energy performance standards for new buildings
- Mandatory energy performance certificate for existing houses upon sale. This could be coupled with subsidies for retrofit and in a later stage (e.g. 2020) be replaced with minimum performance standard.
- Minimum efficiency standards for all appliances, updated every five years, in which the lowest efficiency classes are eliminated.
- Provide tax incentives for public transport users, car poolers (e.g. through tax rules for lease/company cars) and bike-riders.
- Provide tax incentives for tele-working.
- Improve public transport systems (capacity, frequency, reliability, coverage) and bicycle infrastructure (bike paths, guarded bicycle sheds, service stations)
- Limit parking possibilities in city centres and with companies (coupled with providing parking space at train/bus stations).

Supply-side

- Stimulate consumer preference for green electricity with publicity campaigns
- Energy/CO_2 tax with tax exemption for renewable energy
- Large scale R&D programme for PV
- Mandatory requirement of installing PV in newly built houses, commercial buildings, sound barriers, etc.
- R&D on the most efficient, cost-effective storage system
- Allow set-aside subsidies to continue for land used for energy crops
- Close guaranteed supply contracts between farmers and biomass-fuelled plants
- Investigate possibilities for combination of land uses
- Start experiments with biofuels (limited distribution e.g. gas stations from one big oil company along major highways)
- (Partial) exemption from gasoline tax for biofuels
- Subsidise gas stations/oil companies to provide biofuel outlets (could be done by using part of the gasoline tax)
- Subsidise the development of biofuel (or hydrogen) dedicated cars.

It must be noted that both images are based on the assumption that a 75-80% emission reduction is reached in 2050. Probably the most important bottleneck in achieving the energy image foreseen for 2050 is convincing all stakeholders (including consumers and politicians) that climate change is sufficiently urgent to warrant the ambitious changes described in this path.

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[TWe2][TWe3]

APPENDIX I

Table A.1: Fuel switching potentials in electricity production (potential effect of switching TO the listed fuel). As far as available, cost estimates are also shown, as well as additional remarks regarding potential consequences.

Category	Potential	Costs	Remarks
Fossil fuels Gas	Technical potential: about 270 Mt CO_2 (replacing all current coal capacity)		Current CO_2 emissions from coal-based electricity about 670 Mt CO_2 World gas reserves (proven) 5000 EJ, in Western Europe about 250 EJ. Current EU gas consumption 10 EJ/yr. Increasing import dependency
Nuclear	Technical potential 1 Gt CO_2 (replacing all fossil fuel-based capacity)		Current emissions from fossil fuel-based electricity about 1 Gt CO_2 Liberalised electricity market poses barrier Public acceptability Risk of non-proliferation
Hydro Large-scale Small-scale	Techn.pot: 910-1280TWh (32-48% in use) Economic pot.: 640 TWh (63% in use) Economic pot. 75-85 TWh (20% in use)	?	Loss of habitat Risks of earthquakes Part of potential may be protected area (e.g. in Scandinavia)
Wind	Gross Electrical Potential 9000TWh/yr 1st order potential (GEP minus physical constraints) 555 TWh/yr (on shore) 2nd order pot (GEP minus social/environm. Constraints) 180 TWh (on shore)	Current cost: 0.05 ECU/kWh	Fluctuation in supply Bird safety Noise

	Off shore: 2800 TWh	Probably higher	Includes potential at more expensive locations.
Solar[1] PV Thermal-electric	Techn.potential >total energy consumption 240 TWh/yr in 2050 > 100GWe in Mediterranean	 Expected costs <0.10 ECU/kWh	Fluctuation in supply Requires about 55 million houses (1/4th total number) to have a 4 kW (20 m^2) PV panel
Biomass[2] Waste Energy crops	30% of primary energy cons. in 2050 for EU: 300 Mtoe (12 EJ) for EU 1/3rd of total biomass used (4 EJ for EU) 2/3rd of total biomass used (8 EJ for EU)	Biomass for electricity 5-10 $-cents	Land requirements (competition with food and material supplies) 15% of land now in use in forests (now 157 Mha) 40% of land now in use in crop land (now 140 Mha) total: 80 Mha (17% of total land) estimated long term excess crop land: up to 65 Mha Loss of biodiversity Water requirements
Other Tidal Geothermal	 Techn.pot. 60 TWh/yr Techn.pot >>primary energy demand Realistic pot. 0.5 EJ	 0.05-0.15 ECU/ kWh ?	 Conflicts with shipping/navigation

Notes: [1] Not included is solar thermal energy (solar boilers). The potential for this is estimated at 0.6 EJ; [2] Biomass figures for electricity and fuel combined, except when otherwise noted. Cost figures for bio-fuels are 0.14 ECU/l bio-oil (current prices) from waste and 0.5 ECU/l bio-ethanol from energy crops (regular gasoline-diesel 0.07 ECU/l before taxation).

Table A.2: Energy efficiency of conversion processes and potential future developments

Energy resource	Process	Energy carrier	Current efficiency	Potential efficiency 2050
Fossil fuels				
Coal	Combustion	Electricity	45%	
		Steam		
		Warm water		
	Gasification	Methanol	50%	
		Hydrogen		
Oil	Combustion			
Gas	Combustion	Electricity	55%	
		Warm water		
		Steam		
		Methanol	60%	
		Hydrogen		
Biomass	Extraction from oil-rich plants	Bio-oil		
	Biochemical conversion	Ethanol		
	Thermochemical conversion	Methanol	40-54%	
		Hydrogen		
	Pyrolysis	Biocrude		
	Anaerobic digestion	Biogas Electricity		
	Combustion	Warm water	14-18% (steam turbine)	34%
		Steam		
		Electricity		
	Gasification	Steam	est. 33-43%	
		Cogen-mode	est. 29-34%	55%
			est. 29-38%	50-60/30%

Electricity Nuclear Renewables	Electrochemical conversion	Hydrogen	70-75%	90-95%

Table A.3: Potential for emission reductions from changes in structure & patterns

Category	**Application**	**Remarks**
Change in Economic structure	Stimulating higher value-added industries, more knowledge-intensive or service-oriented economy	Dislocation of heavy industries
CO_2 removal And disposal	Large plants	Often transport from production site to storage site is required. CO_2 stored in oceans may influence ocean/atmosphere equilibrium. Estimated capacity in Western Europe 50-2600 Gt CO_2

ANNEX 2

SCENARIO COMPARISON

by G.J.M. Phylipsen

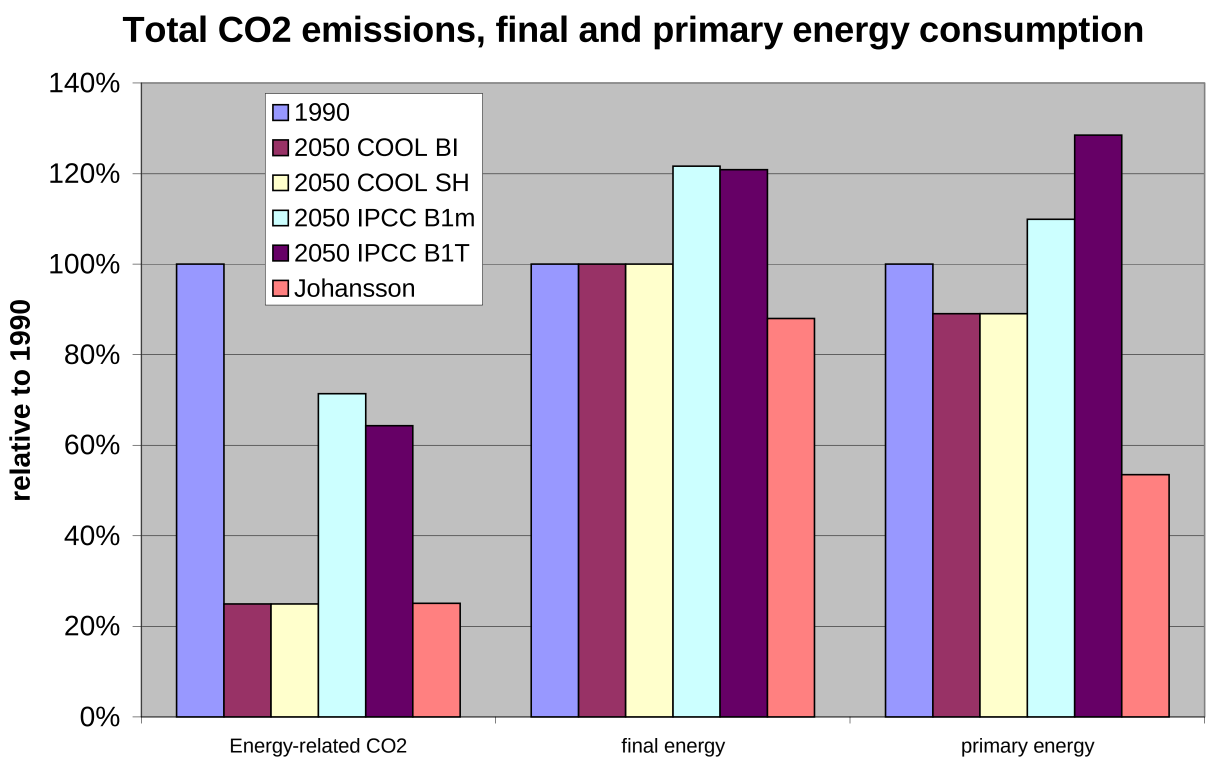
In this annex a comparison will be made between the energy images developed in the COOL Europe dialogue process and other international scenarios.

<u>The scenarios</u>

Shown are two IPCC scenarios from the recent IPCC "Special Report on Emission Scenarios" (2000) and a scenario from "Renewable Energy; sources for Fuels and Electricity" from Johansson et al. (1993). The two IPCC scenarios shown are both scenarios from the so-called B1 family, meaning that they both describe a globalised world with converging standards of living and increased awareness of sustainability and equity. The scenarios, however, do not include specific climate policies (note that part of the policies taken to enhance sustainability, such as better air quality and safety, will also have an effect on greenhouse gas emissions). They are therefore qualified as non-intervention scenarios. The Johansson scenario, on the contrary, is clearly a (climate) intervention scenario.

<u>Total energy consumption</u>

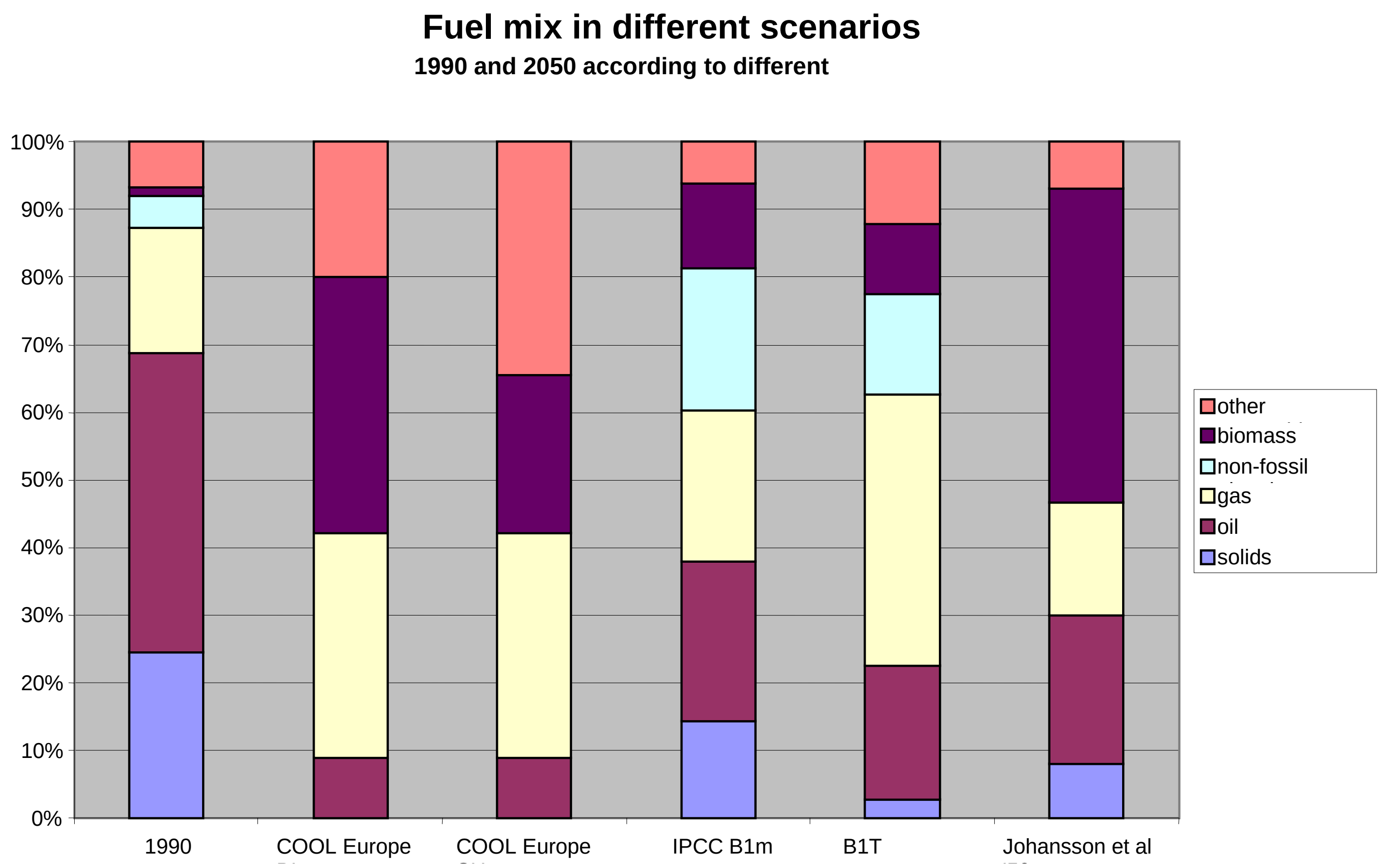
Figure 1 shows total energy consumption and CO_2 emissions in the various scenarios relative to 1990 levels. The figure shows that in terms of final and primary energy consumption the COOL images lie in between the IPCC non-intervention scenarios and the Johansson intervention scenario. The Johansson scenario has a lower final and primary energy consumption than foreseen in the energy images (derived from 1991 IPCC inter-



vention scenario called ‘Accelerated Policies’). The 2050 emission levels are comparable in the two cases, because of a somewhat different fuel mix, as can be seen in the next section.

<u>Fuel mix</u>

Figure 2 shows the 2050 fuel mix according to the developed images, compared to that in the other scenarios. The most remarkable differences between the COOL images and the other scenarios are a substantially larger share of ‘other renewables’ in the COOL images[3], especially in the solar hydrogen image. The share of biomass in the COOL images lies between the shares envisioned in the IPCC scenarios and the Johansson intervention scenario. This is consistent with the non-intervention character of the IPCC scenarios with regard to climate change, which leads to a lower level of fuel switch towards renewables/biomass. The gas consumption in the COOL images is also in line with the other scenarios. The lower share of oil in the COOL images is explained by the biomass and/or solar hydrogen used for transport in those images. The COOL images foresee no usage of nuclear energy (non-fossil electric), which is similar to the Johansson intervention scenario, and of solid fuels. In the other scenarios some solids still remain, but in one of the IPCC (non-intervention scenarios this is limited to only 3%.



[3] Explicitely done at the request of the COOL Europe participants

Page: 1

[TWe1]Namen van de auteurs. Vergeet niet co-auteurs op te nemen (name, affiliation). Geen tab na de titel.

2633737. Page: 38

[TWe2]Conclusies puntsgewijs opzetten;

2633737. Maak heldere structuur, bijvoorbeeld indeling naar onderdeel van installatie of naar groep (fabrikant, exploitant, overheid);

2633737. Elke conclusie/aanbeveling dient zelfstandig leesbaar te zijn.

2633737. Gebruik positieve bewoordingen: niet 'installatie x doet het slecht', maar 'installatie x kan verbeterd worden via …'. Ga niet onnodig in op wat we niet gehaald hebben, maar op wat we wel gehaald hebben.

2633737. Elke conclusie dient in een eerder hoofdstuk te zijn onderbouwd.

2633737. Neem ALLE in eerdere hoofdstukken getrokken conclusies op.

2633737. De conclusies en aanbevelingen moeten onderling consistent zijn.

2633737. Verbreed je blik naar het vervolgtraject: leg een basis voor vervolgwerk bij deze of andere opdrachtgevers.

Page: 38

[TWe3]Gebruik in het rapport [Achternaam Auteur, jaartal]. Zet de referenties hieronder in alfabetische volgorde. Zorg voor volledigheid van de referentie (auteur(s), titel, uitgever, tijdschrift, pagina’s, plaats, jaartal).

ANNEX 3

DECENTRALISATION VERSUS CENTRALISATION

Kornelis Blok, Ecofys

In the seventies and eighties there were two conflicting paradigms regarding the development of the energy system: on the one hand large scale power generation with ever increasing plant size and on the other hand a diversity of options in the area of renewables and CHP that had much smaller unit sizes. This conflict was phrased in terms of central versus decentral. Regarding the technology this was certainly the case, although it was more the outcome: by that time most small-scale options were environmentally more benign and less resource intensive then large-scale options. The conflict central versus decentral was even more visible in terms of "market" power: big monopolies versus a variety of suppliers.

We are now in a different situation. If we look at the development of technology, we see that there has been a tremendous step forward in gas turbine technology, which has led to very high efficiencies in the range, say from 50 - 500 MW. Fairly low emissions can be reached in stand-alone power generation and use of this technology in CHP mode (applications then are industrial CHP and district heating) – if well designed – even makes environmental performance better. For many other CHP options it is difficult to compete with these technologies in terms of environmental performance. This is certainly the case for the present generation of so-called micro-CHP: small engines (<10 kW) with electric efficiencies of 10 - 20%. Specific emissions generally will be higher than in the case of the gas turbine based technology.

For the somewhat longer term, it is even questionable whether PEM fuel-cell technology will be able to compete with gas turbine based options. Evaluating the options requires a full system approach, but based on our present knowledge I expect that the optimum (= low emissions) system for electricity and heat generation will consist of industrial CHP, combined cycle district heating in areas with high heat demand densities and heat pumps and solar technology for areas with low heat demand densities.

Most renewable energy technologies will be inherently more small-scale than conventional technologies. However, a full renewable energy system in Europe probably will also contain large-scale elements, like off-shore wind parks, biofuel production facilities, high voltage DC transmission and (in case of high penetration) large-scale storage systems.

One specific comment that is used to defend decentralised systems is that grid losses will be smaller. Even if this would be the case the difference in grid losses in electricity systems generally will make up a few percent, which will not compensate for inherent disadvantages of specific technologies, like micro-CHP. The only technology that shows high losses is district heating CHP (heat losses of about 20%). However, in this case the heat losses are more than compensated by the good performance of the combined cycle technology that is uses as a heat source.

Hence, my position is to take no position regarding decentralisation versus centralisation, but rather judge all technologies on their own merits regarding emission reduction and resource conservation. The outcome will probably be a mix of small and large scale technologies.

ANNEX 4

NEW TECHNOLOGIES FOR THE PETROCHEMICAL INDUSTRY

Dian Phylipsen, Ecofys

In relation to climate change targets and policies and measures, it is often said that industry has more or less reached the limits of its energy savings potential. And although it cannot be denied that many industries have already made an effort, still a substantial energy saving potential exists. This is also confirmed by many independent studies. It is also shown in the Netherlands, a country with a relatively efficient industry (see e.g. [Phylipsen, 2000]), where annual efficiency improvements are achieved of 2% per year in the context of the Long Term Agreements on Energy Efficiency. In addition, technology improves over time, decreasing best practice energy consumption and increasing the potential for energy saving again.
In general, technology improves gradually, but with a time horizon in 2050 and under a very ambitious climate target, improvements may be larger because completely different technologies are developed and employed. Here an example is given for the petrochemical industry, based on technologies in an early stage of development that are very different than the currently employed technologies.

Current production process
The production of the most important petrochemicals such as currently predominantly takes place through the steam cracking process. In this process the feedstock (e.g. naphtha) is cracked under high temperature (about 850° C) and high pressure into smaller unsaturated compounds, which are subsequently separated in partly cryogenic (very low temperature) distillation units. Due to the extreme process conditions this is a very energy-intensive process. Current best practice energy consumption is about 17 GJ/t of ethylene. Actual energy consumption varies from 17 GJ/t in an occasional plant to over 40 GJ/t of ethylene (30-35 GJ/t on average).

New technologies

- Membranes instead of distillation in separation

Membranes are already being used in many separation processes, such as the recovery of hydrogen in refineries. Currently, membranes are also being developed as an alternative to the cryogenic distillation now used to separate different products and by-products of the cracking process (e.g. ethane/ethylene and propane/propylene). Separation energy requirements are estimated to drop with 80% and compression energy requirements with 50%, at investment costs of only 50% of a conventional design [Smit et al., 1994]. Together they can account to 50% of total energy consumption for ethylene production. Membranes have been successfully applied in two BP demonstration projects to separate ethane and propane from mixtures [Worrell et al., 1997].

- New production processes

  An even more radical change might occur if a switch is made to completely different types of production processes. At least three can be mentioned:

- *Oxidative coupling of methane*

  The oxidative coupling of methane to form ethylene and small amounts of higher olefins using catalysts is being developed by ARCO [Badoni et al., 1996]. The technology is not ready for commercialisation yet, because of the lack of appropriate catalysts with good selectivity.

- *Methanol-To-Olefin (MTO)*

  A MTO process has been developed by UOP and Norsk Hydro (Norway), with a pilot plant coming online in June 1995 [Badoni et al., 1996]. The process is developed as the second step in the production process of ethylene and propylene out of natural gas [HP, 1996]. It uses selective catalysts to produce olefins.

- *Electrochemical conversion of natural gas*

  In this process methane is converted to ethylene while generating electricity in a solid electrolytic fuel cell [DOE, 1995]. The materials developed by Eltron Research Inc. circumvent many of the material limitations associated with higher operating temperatures in Solid Oxide Fuel Cells.

The above-mentioned processes are not commercially operational yet, and no clear indication of the energy saving potentials can be given yet. But the long time horizon leaves sufficient room for further development, and the use of catalysts instead of high temperature processes promises large energy savings.

ANNEX 5

PROFITABLE ENERGY EFFICIENCY IMPROVEMENTS IN INDUSTRY

Tomas Kaberger, Ecotraffic, Sweden

If the economy had been in equilibrium there would be no opportunities to improve energy efficiency and earn money at the same time. But there is.

Technological development continues to open up new opportunities for profitable efficiency improvements. Many old opportunities have remained un-exploited for different reasons.

The Louisiana Division of Dow Chemical Co initiated an "energy contest" in 1981 to find efficiency investments costing less than 200,000 USD with payback times less than one year. In the first year 1.7 million USD was invested with an average return on investment of 173%. During the following years investments increased. After seven years the investment was 7.5 million USD and the average return on investment a record high 470%. After ten years the investments were totalling 6.4 million and the rate of return on investment was on average 305%.

Recently, an investigation comparing electricity costs of producing Volvo cars at a factory in Sweden and Belgium showed significant differences due to historical differences in electricity prices.

Profitable opportunities to reduce electricity consumption were discovered at Volvo in Sweden. Electric resistance heating of test tracks could be switched of when not needed, 80 saunas previously continuously switched on got a timer and counteracting cooling and heating systems where switched of when the factory was empty. These measures saved more than a million Euros per year with negligible investment costs.

The investigation describe potential improvements using a combination of efficiency measures and structural measures reducing electricity consumption to less than half the present.

Once carbon-pricing spur interest in improving energy efficiency, potentials of this kind may become utilised.

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ANNEX 6

BIOENERGY POTENTIALS IN THE HUNGARIAN AGRICULTURE

Diana Ürge-Vorsatz
Central European University
Budapest, Hungary

<u>Input paper to COOL Europe workshop 3</u>

Hungary used to be considered as an agricultural economy during the Soviet era; the country has traditionally supplied the majority of the Soviet Union with a wide spectrum of agricultural products, including canned fruits and vegetables, vegetable juices, etc. Given Hungary's geographic, climatic and mineral resources, agriculture clearly has a high potential in contributing to the Hungarian economy. In 1997, agriculture has contributed app. 10% to the Hungarian GDP (KSH 1999). The future of this economic orientation, however, is controversial in the light of EU accession and the problems of EU agriculture. Thus, there is an increasing pressure towards the utilisation of agricultural lands for renewable biomass energy production to replace fossil fuels, and other utilisation of biomass energy sources from agriculture. However, as in many other OECD countries, this mainly remains still on the rhetorical level, or at best at the planning stage. There is currently a frequently attacked biodiesel programme supported by the Ministry of Agriculture and Regional Planning.
The International Energy Agency (1995) estimates that the exploitation of agricultural and forestry byproducts and waste material and production of specialised pland and tree crops on surplus farmland could be capable of providing more than 1.1 Mtoe of energy annually, comparing to the app. 25 Mtoe TPES in 1999 (IEA 1999). However, the report also admits that information is very limited in this area. The most comprehensive study on biomass energy potentials from agriculture was carried out by the Hungarian Academy of Sciences in the early 1980s, as a response to the oil crises (which had limited direct impact on Soviet-system economies due exclusively Soviet imports, and the "Bucharest formula" for calculating fuel prices). While Hungary's economy has changed since 1985, experts consider the figures in this study (Lang 1985) still largely valid ballpark figures for estimating biomass potentials.

Lang et al. (1985) estimated that Hungary's primary (plant) biomass production in agriculture and forestry was app. 53.4 million tons. More recent studies (Kocsis 1995) found that this figure has not changed significantly: app. 55 – 58 Mt, out of which 26 – 28 Mt are by-products. The same study estimated that app. 3.5 Mt of this can be used for energy production. Unfortunately I have not seen the assumptions, but this figure to me seems as a very conservative estimate. Since the Lang study is the most detailed and thoroughly researched, now we go back to the detailed findings in that report.
When the biomass is translated into energy figures, 369.3 PJ are by-products out of the 941 PJ agricultural plant biomass production. This is constituted as follows:

	PJ
Corn residues	188.7
Straw	136.5
Other	44.1

Total	*369.3*

Out of the 369 PJ, app. 13 PJ was used for energy production in the 1980s, and app. 284 PJ remained as stalk residues after subtracting other uses. Since total agricultural production has decreased since the 1980s, I estimate that this amount is app. 20 – 30% smaller today.

In animal husbandry, there was app. 5,650 Mt of byproducts in the early 1980s, with 92 PJ energy equivalent of manure. Unfortunately the Hungarian livestock numbers have close to halved since 1980 (KSH 2000), thus this figure can now be estimated to be around 46 PJ. 59% of manure originates from cows, and 20% from pigs.

In summary, Hungary has a significant potential for producing biomass energy in agriculture. The potential is largest in the burning of crop residues (corn and cereals, but also fruit tree and vine cuttings), and in the production of biogas from animal manure. As Hungary is waiting to access to the EU, it may also be desirable to convert some agricultural land into biomass plantations.

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ANNEX 7

THE BIOMASS POTENTIAL IN POLAND

Ewaryst Hille

Polish Foundation for Energy Efficiency

Input paper for COOL Europe workshop 3

To assess the biomass potential in Poland two strategic approaches have been used:

A. Passive approach
B. Active approach

The passive approach assumes that biomass potential is being a function of time and micro-economic phenomena. This means that a majority of the processes are dominated or even determined by the existing, only slowly changing, market situation and its actors. Under these assumptions biomass is a risky endeavour and its economic potential is strongly limited by historical circumstances like existing assets, lobbies, and interests division. New actors, with investment and market entrance costs, have to struggle with a number of existing matured actors without such costs.

The active approach assumes that the biomass potential in Poland is effected by a macroeconomic strategy of a sustainable development of the society and its economy. It means that macroeconomic and political risks for the biomass market development is compensated by public institutions on the basis of the demand for expected public values. Valuation is done on the basis of the defined public values witch in the moment due to number of reasons is no yet "privatised" goods to the market regulations. It could be, for example, the following categories: (1) transformation of the rural sector of the economy and creation of plenty of new labour demand, (2) improvement of the energy security of the economy, and (3) local, country-wide and global environmental effects.

It is expected that those different approaches create different allocation of risk and interest and result in synergetic effects (or not) at the microeconomic level. The main assumed syner-

getic effect is the decision to use less or more of the available land for biomass production against other rural and non-rural activities.
The following resources have been qualified as potential primary energy biomass resources:

1. Solid biomass:
- forest, garden and city wood and wooden waste,
- wood and paper industry waste,
- food industry waste,
- straw and other agricultural waste,
- special energy plants:
- one season plants e.g.: crops, hemp, rape, cane,
- trees and the like e.g.: poplar, willow, aspen,
- many seasons plants grass and the like e.g.: Miscanthus spp., Arundo spp. Spartina spp.
- communal – city waste;

2. Gaseous biomass:
- waste treatment biogas
- sewerage treatment station biogas.

3. Liquid or semi-liquid biomass:
- sedimentation rest of the sewerage treatment station,
- animals droppings.

The number of the above-mentioned resources is currently recognized as a difficult residue and its energy potential is not taken in to account. Eligible part of these resources which are used for energy supply are used only to cover the producer's own demand which benefit then producer's and consumer's surplus together. When biomass is not standard market commodity yet it effect that:

- there is no market for biomass itself and no market price for it,
- there is limited information about the biomass potential in Poland for a majority of the biomass categories, and

- for the biomass potential assessment it is necessary to analyse biomass resources and technical circumstances for its utilisation for the final services together.

The appraisal of the economical biomass potential is extremely difficult because of:

- the market for the facilities of biomass utilisation is on the very preliminary stage of development,
- there are plenty of energy efficiency improvement opportunities and the market for related services will develop itself, and
- traditional energy systems possess eligible over capacity from long distance; conventional sources and energy market liberalisation is ongoing.

The all above-mentioned circumstances are strong microeconomic barriers for the market entrance of biomass in the near future. From the another side there are strong macroeconomic and social arguments for a reduction of hose barriers and a promotion of biomass at the strategic level.
Due to above-mentioned reasons, the below presented biomass potential in Poland can only be a qualitative estimation. According to the European Center for Renewable Energy (EC BREC) [Warsaw 2000] the technical potential of the primary biomass in Poland is:

a. straw and other agricultural waste 533 PJ/a
b. forest and garden wood and waste 481 PJ/a
c. communal – city waste 130 PJ/a
d. animals droppings 38 PJ/a
e. special energy plants 44 PJ/a

Total 1226 PJ/a

According to J. Hauff, the total biomass potential for Poland is 810 PJ/a [World Bank, Warsaw 1996]. Both of these estimations are based on a passive approach.
Below I present my estimation of the primary biomass potential for Poland, based on active approach

1. Solid biomass:

■ forest, garden and city wood and wooden waste	500 PJ/a
■ wood and paper industry waste	40 PJ/a
■ food industry waste	15 PJ/a
■ straw and other agricultural waste	553 PJ/a
■ special energy plants	1,000-1,400 PJ/a
■ communal – city waste	130 PJ/a

2. Gaseous biomass:

■ waste treatment biogas	10 PJ/a
■ sewerage treatment station biogas	55 PJ/a

3. Liquid or semi-liquid biomass:

■ sedimentation rest of the sewerage treatment station	100 PJ/a
■ animals droppings	38 PJ/a

Grand total: 2441-2841 PJ/a

According to the Polish government, the energy demand for 2020 year will oscillate around 5,000 PJ/a (the presented range is c. 4,700-5,100 PJ/a). It means that actively shaped biomass potential if used, for example, for 30% in the year 2020, is able supply over 15% of the estimated demand.

<u>Additional comments:</u>

Land use structure changes are inevitable. It is due to the necessity to increase of the agriculture productivity of food 2-3 times during coming years. Simultaneously there is an over supply of food for the European market. It means that the eligible part of the land has to be free from conventional, commercial food production. This available land only to some extent will be used for reforestation, extensive "ecological" (unconventional) food production and so-called civilisation demands (trends for decentralisation and dispersion of living) etc.

When biomass technology-related markets will be developed to same stage and related prices will be much lower then today's number of additional and commercially available opportunities appear for biomass e.g. related to specific land areas not used today.

ANNEX 8

ESTABLISHING DISTRIBUTION OF ETHANOL CARS IN SWEDEN

Tomas Kaberger, Ecotraffic, Sweden

Ethanol, produced using residues from a pulp mill, was first used in local public busses in Örnsköldsvik, close to the mill. The municipal buss company had Scania deliver buses that used ethanol. In 1994 Per Carstedt, a local car dealer, brought in flexible fuel vehicles from the US that could run on any mixture of petrol an ethanol. Some consumer owned local petrol stations distributed the ethanol. Later, the national federation of consumer owned petrol stations (OK) offered to distribute ethanol to any city where there were at least ten ethanol cars.

An additional force in extending the distribution network was a condition offered by some companies and local authorities using ethanol cars; they would buy all their fuel from a fuel distributor who could deliver the ethanol they needed.

During 1997-98 another 300 Ford Taurus FFV-vehicles were imported. In total, there is now more than 50 fuel stations throughout Sweden where ethanol (E85) is available. In addition there are more than 300 ethanol-fuelled busses operating in several cities, most of them in Stockholm.

In the next step some 4,000 Ford Focus FFV will be distributed during the latter part of 2001. A new ethanol production plant is just starting to produce fuel ethanol from grain in the city of Norrköping. Ethanol from this plant will be used to blend all petrol in the Stockholm region.

For further information: www.baff.nu

ANNEX 9

COST CALCULATION FOR THE 80 PER CENT REDUCTION TARGET

A major conclusion emerging from the discussions in the energy group at the third COOL Europe workshop in September 2000 was that 80 per cent emission reduction is feasible from a macro-economic perspective. Calculations were presented at the workshop that showed that 80 per cent reduction would not entail excessive burden on the economy. Assuming annual growth in GDP at 2-2.5 per cent and greenhouse gas emissions growing half of that (1 per cent per year) with no particular policy action (business as usual scenario) one arrives at the numbers presented in table below.

	2000	**2010**	**2030**	**2050**	
GDP, bn EURO	7,000	9,000	14,000	22,000	(1)
GHG emission, M ton CO_2 eq.	4,000	4,600	5,800	7,200	(2)
80% reduction, S-shape	0	92	50	20	(3)
Actual emissions	4,000	3,700	2,000	800	(4)
(2) - (4)	0	900	3,800	6,400	(5)
Assumed compliance costs EURO/ton		10	50	100	(6)
Compliance cost (5) x (6) bn EURO		9	180	640	(7)
GDP increase since 2000		2,000	7,000	15,000	(8)
% of increase		0.45	2.7	4.3	(9)

Hence the conclusion can be drawn that the cost of achieving a drastic reduction in GHG emissions over a 50-year period is insignificant compared to the anticipated growth in GDP. One participant noted that if economic growth continues in the same rate as presently the costs for the energy system would go down from 6-7 per cent of GDP to 2-3 per cent of GDP.

The two future images elaborated by the energy group of COOL Europe (the biomass-intensive image and the solar hydrogen image) both assume a deep change in the way energy is produced and distributed. The calculation above is based on the price of carbon dioxide and hence does not reflect the costs for changes in technologies. The technological choices will affect the cost.

Therefore, the calculation made above need further investigation and qualification. The COOL Europe project did not have the time and the means to go deeper into this aspect.

ANNEX 10

SUGGESTED FURTHER READING

For scenario studies:

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Future Images for 2050
Transport

Climate OptiOns for the Long term

COOL Europe

Input paper for the 2nd COOL Europe workshop, 6-7 april 2000, Brussels

Based on input from the participants in the sector dialogue groups transport and energy, workshop 1, 29 November 1999

Table of contents

INTRODUCTION

During the first workshop within the COOL Europe project, a brainstorm session was held in which the participants discussed possible future developments for the energy sector and the transport sector in Europe up to the year 2050. This document, which served as input for the second workshop, describes a possible future image for the transport sector. The image is based on the input of the participants during the first workshop. In a separate document the future image for the energy sector is described.

The two images follow the same structure: each image contains four categories: (1)fuel switch, (2) energy efficiency, (3) structure and patterns and (4) awareness, behaviour and lifestyle.

In the first section of this paper the general assumptions underlying the two images are described. The second session contains the Transport Image for 2050.

It must be noted that this document has served as a *starting point* for further discussion within the COOL Europe Transport Group. When it was presented towards the group it was received with some sceptics. The main critic was that the image had a focus that is too technical. Also there was some resistance towards the use of specific numbers. In the course of the discussion in the COOL Europe Transport Group more social and institutional issues have come to the table and the end product of the COOL Dialog has a much more diverse character.

General assumptions

Introduction

In this section we will describe the general assumptions underlying the COOL transport and energy future images. We briefly describe the drivers that determine energy consumption. We also present an overview of the energy supply & demand system, which can be helpful in determining the competition between various energy demands and in checking the consistency between the various images.

The energy supply and demand system

Figure 1 shows an overview of the economy, divided in its subsectors, industry, buildings (including both residential and commercial/tertiary sector buildings), transport and agriculture. For each subsector a number of important drivers are listed. Section B.1.1 of the background paper for the energy image provides a short description of the drivers and how they influence energy consumption.

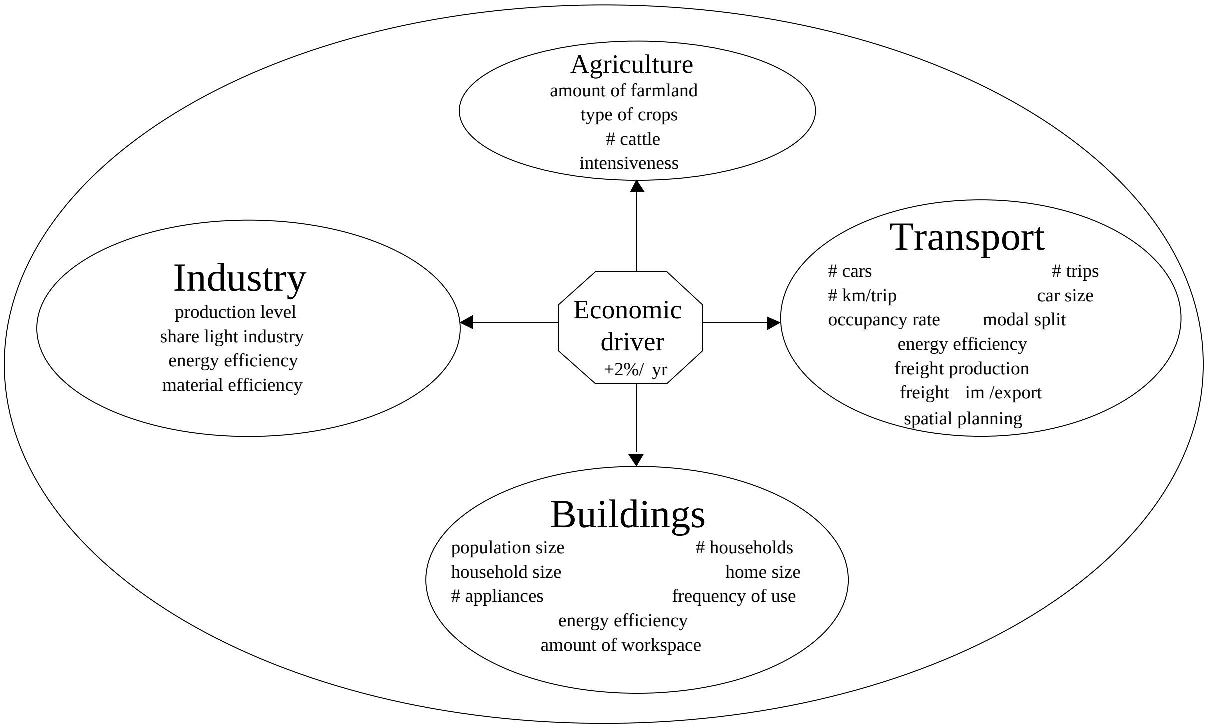

Figure 1: A schematic representation of the economy by sector and important drivers of energy consumption.

Within the energy supply system various sources (e.g. wind, biomass, coal) basically deliver a limited number of energy functions or energy carriers. In Figure 2 we distinguish electricity, heat (low temperature, high temperature and steam) and fuels. With fuels we mean the use of fuels for other purposes than providing heat or steam, such as automotive power. Not all sources can be used to provide all carriers. Nuclear power, wind power and hydropower only deliver electricity. CHP (Combined Heat and Power generation), solar energy and biomass can deliver both electricity and heat. On top of that biomass can also provide fuels. Natural gas, oil and coal can provide all three carriers (in Figure 2 coal is not included and oil is only used to produce fuels as we envision their use to be limited in our future energy image). Of course the electricity from electricity-only sources can subsequently be used to produce fuels through electrolyses (hydrogen out of water). This option is currently not included in our image, but might be used to limit fluctuations in supply or in case more electricity can be generated from renewable sources than required. It must be noted that there can be competition between different energy demands. For example, if a large amount of biomass is used for bio-fuel production there is only a limited potential for biomass-based electricity generation. Therefore, the choices made in the two images are interdependent.

Basic assumptions in our future images:

- Total energy consumption will stabilise at current levels. This is the result of a 2%/yr growth in activity, a 1.5%/yr energy efficiency improvement and a 0.5%/yr structural change. Structural change will be realised by shifts towards less energy-intensive products, and a higher contribution of energy-extensive sectors such as information technology, services, etc. to GDP.
- In accordance with the preferences of the participants of the first workshop the energy supply system will become more decentralised. This means electricity will be generated by decentralised systems, such as solar, (on-shore) wind and CHP (Combined Generation of Heat and Power. Besides CHP, heat will also be supplied by heat pumps. It must be noted that a decentralised supply system, with largely small-scale generation capacity limits the potential for CO2 removal and disposal.
- To achieve both the stabilisation in energy consumption and the shift in energy carriers and conversion processes consumers need to be ‘environmentally aware’ and actively stimulate the supply of energy and carbon-extensive options by creating a demand for these options.

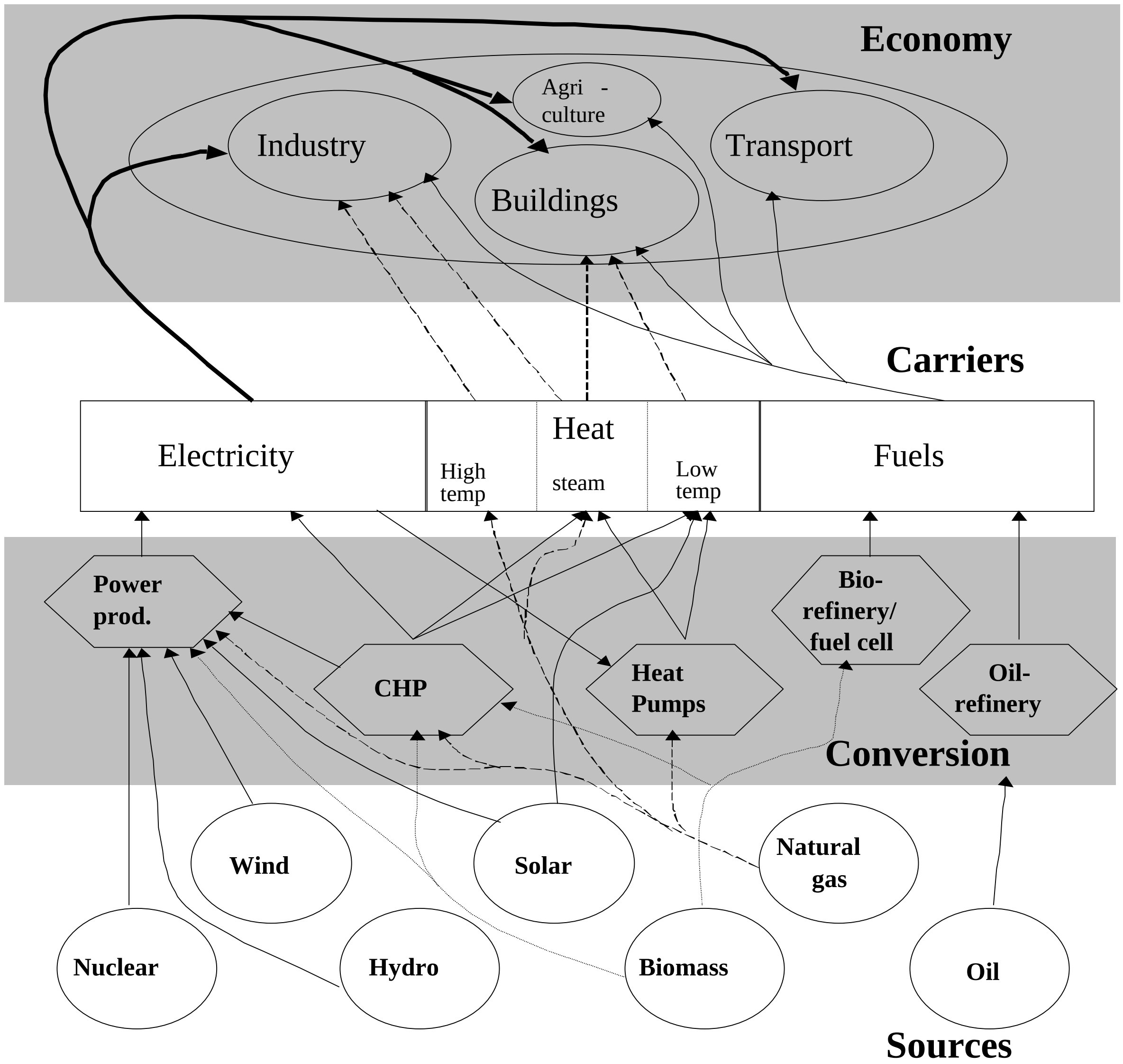

Figure 2: The future image of the energy supply and demand system in 2050.

Categorisation of energy savings and emission reduction options

Energy savings options and emission reduction options can be categorised in many different ways. In this paper we have chosen a distinction in energy savings and emission reductions resulting from:

- Fuel switch
- Energy efficiency
- Structure and patterns
- Awareness, values and lifestyles

Here we will discuss how Figure 2 is connected to these four categories.

- Fuel switch
  Decisions on fuel switching are made in the conversion sector (the bottom half of Figure 2) on the basis of the expected demand for fuels, electricity and heat, the expected prices and considerations regarding the security of supply, regulations, resource availability (i.e. land), import dependency, PR, etc. Of course the consumer can influence this decision-making by demanding certain types of energy (e.g. green electricity, see also bullet 4). In a more decentralised future these decisions will to a larger extent be made by the end-

user (PV panels or solar boilers on homes, CHP in industry).

- Energy efficiency
  Energy efficiency improvement can take place both on the supply side and on the demand side. The current energy efficiency of conversion processes, such as electricity plants, CHP plants, heat pumps and refineries can be improved, thereby reducing the amount of primary energy carriers required to fulfil final energy demand. Within the economy the efficiency of industrial processes, cars, farm vehicles, houses and offices (in terms of insulation, orientation etc), appliances, etc. can be improved.
- Structure and patterns
  A shift in structure and patterns can result in either an increase or a decrease in energy consumption. Shifts that reduce energy consumption can, for instance, be an increased railroad capacity (for passenger or freight transport), a shift towards less energy-intensive products (e.g. from aluminium soda cans to glass or plastic bottles), towards more recycling, towards a more service-oriented economy or a shift away from intensive farming. Also spatial planning can influence energy consumption, i.e. large malls on the outskirts of town vs. local shops.
- Awareness, values and lifestyles
  Behaviour and awareness can strongly influence energy consumption, but is relatively difficult to quantify. In order to realise the full potential of emission reductions that can be obtained through fuel switch, energy efficiency improvement and a shift in structure & patterns a change in behaviour and awareness is required. This holds for car drivers (are they willing to carpool, to switch to public transport, or to move closer to their work?), for buyers of appliances (are they willing to pay a higher initial price for reduced operation costs?), for electricity consumers (are they willing to pay extra for green electricity?). for manufacturers (are they willing to accept higher pay-back periods on their energy efficiency investments), etc. Also the awareness of policy makers plays a role: Are they willing to use policy instruments such as carbon taxes and regulation? Values of ‘the society’ as a whole are of influence: Do we accept a higher energy import dependency? How do we value biodiversity (monocultures in biomass production)?

Consistency between the images

It must be noted that the transport image is not consistent with the energy image (e.g. in terms of assumptions on inputs of natural gas, biomass, electricity and solar-based fuels).

2. Transport Image for 2050

In this chapter an Image of the transport system 2050 is outlined. It is based on the assumptions regarding energy supply and emission levels specified in the Introduction to this paper. The Transport Image is described as regards the overall picture (2.1) and four specific elements that contribute to the "solution". These main elements are *Fuel Substitution* (2.2), *Improved Efficiency* (2.3), *Structures and Patterns* (2.4) and *Awareness, Values and Lifestyles* (2.5).
Improved energy efficiency and new fuels directly affect emissions (emissions per unit of transport), while new patterns of human activities and values and life-styles mainly have an impact on transport volumes. For each element the achievements (for example, the level of efficiency improvement for different vehicles) are specified in a box and factors that would make these possible are outlined. Finally, a *Profile of the Image* (2.6), i.e. how much each element contributes to the solution, is outlined in a table.
In order to ensure that the image is consistent and meets the CO_2 target, some calculations have been made concerning the use of different kinds of fuels and energy-saving techniques as well as transport volumes – a kind of transport energy balance. The methodology for this was developed in a Swedish transport futures study and has also been applied in the EU Fourth Framework Programme project Policy Scenarios for Sustainable Mobility (POSSUM).[1]

2.1 Introduction: An Overview of the Transport System in 2050

The *passenger transport* system is characterised by a great variety of niche vehicles (for example, small electric city vehicles), all-purpose cars and new systems such as personal electric vehicles that can link to each other and form trains that go on special tracks. Buses, trams and trains have increased their share somewhat, especially in urban areas. There is no single system that dominates the market to the same extent as the private all-round car did at the beginning of the century. Another prominent feature is the spread of inter-modal transport with smooth and short transitions between modes. Car pooling also has a market. IT is being widely used in intelligent traffic control and information systems, and also for flexible road pricing.
The energy efficiency in the transport sector is high. On average 25 per cent less energy is used per person-km compared to 1995, including energy for production of fuels (i.e. gross energy use). For freight the corresponding figure is 20 per cent less energy per ton-km than 1995. The efficiency improvements of vehicles – i.e. excluding energy used in the production of fuels – are even better, on average 40 per cent for both passenger vehicles and freight vehicles.
The volume of short everyday trips is less than in 1995, due to "decentralised concentration" and the use of IT as a substitute for commuting to work. IT shopping is also widespread. Long-distance journeys are well above the figures for 1995, especially those by air.
All this has resulted in more efficient, flexible and cleaner passenger transport.
Also, when it comes to *freight transport*, inter-modality is widespread, which has led to an increased share for fast trains. Dematerialisation and structural changes in industry have led to a slower growth rate for the tonnage transported, but the increase in average distances continues to be high.

Box 1. Energy and emissions data for the transport sector in 2050

- The total net energy use in the transport sector is 7200 PJ in 2050, a decrease of 40% compared to the 1995 level.
- Gross energy use is 11,100 PJ, a decrease of 20% compared to the 1995 level.
- Hence, 3900 PJ is used in the production of fuels for the transport sector, an increase of 80% compared to 1995.
- The CO_2 reduction is 80% compared to the year 2000.

[1] See Steen et al. (1998). *A Sustainable Transport System for Sweden*. WCTR Conference Proceeding, WCTR, Antwerpen, Elsevier Science Ltd. For POSSUM, see Banister et al. (1999). 'Transport Policy Scenarios for the EU 2020: Images of the Future. *Innovation*. Also POSSUM (1998). *Final Report*. London, University College of London.

2.2 Fuel Substitution

The trend in this image is that solar cell-based energy, with hydrogen as a carrier, will increase its share. This fits well into the energy system for the transport sector, which is already adapted to using hydrogen and fuel cells. A transition to hydrogen as a fuel for aircraft is underway, but H_2 fuel has not yet penetrated the aircraft fleet to a significant extent because of the long lead times involved.

Box 2. Fuel mix in 2050

- 70% of the car fleet are fuel-cell vehicles.
- 20% of the cars use fossil fuels (natural gas) in combustion engines, but in highly energy-efficient vehicles.
- 10% of the car fleet are electric powered.
- 80% of the trucks are fuel-cell vehicles and 20% use fossil fuel.
- 80% of the buses are fuel-cell vehicles and 20% use fossil fuel.
- Aircraft still use fossil fuel (kerosene).
- The fuel for fuel-cell vehicles is completely based on renewable sources, mainly bio-mass.
- A minor segment of the fleet uses hydrogen from solar energy.

Context

The transition towards renewable fuels requires that society implement taxes on fossil fuels or CO_2 emissions. It is also important that niche markets are created where new solutions can be tested and improved. Electric vehicles and fuel-cell vehicles are favoured in environmental zones where they can hit a learning curve, cut costs and are more competitive.
The extensive use of bio-fuels has resulted in tough competition for arable land. Improved farming methods that raise the yield per hectare will be necessary.

2.3 Improved Efficiency

Decreased driving resistance through lighter materials, improved aerodynamic design and reduced rolling resistance are one factor behind these improvements. Another factor is improvements of the *drive-train* (engine, gearbox and transmission system).

Box 3. Efficiency improvements for different vehicle types 1995-2050

The energy efficiency has increased much since 1995 for all kinds of vehicles. Specific net average energy use (energy per person-kilometre or ton-kilometre) has decreased by:

- 45% for fossil-fuel cars
- 60% for fuel-cell cars compared to conventional cars in 1995
- 80% for electric vehicles compared to conventional cars in 1995
- 50% for aircraft
- 35% for fossil-fuel buses
- 50% for fuel-cell buses
- 20% passenger trains
- 25% for freight trains
- 30% for fossil-fuel trucks
- 45% for fuel cell trucks
- 15% for inland-water shipping.

Context

What are the conditions that make this happen? The improvements indicated above are definitely possible from a technological point of view. For aircraft, buses, trucks and trains the market forces will work in this direction because of the cost reductions that will be gained. However, financial incentives may be necessary to strengthen the process. The situation is more difficult when it comes to private cars, because people have a more complicated relation to the car. In the 20th century people in general preferred efficiency improvements in the form of stronger and faster cars, rather than energy savings. The above savings in energy use will require strong economic incentives, regulations or changes in values and attitudes to the car – or a mix of these factors.

2.4 Structures and Patterns

Structural changes in residential patterns and industrial structure have to some extent reduced transport volumes when compared to a trend scenario. However, transport volumes are considerably higher in 2050 than 1995 (see box below).

Box 4. Increase in transport volumes 1995–2050

- Cars +15%
- Aircraft +150%
- Buses +100%
- Passenger trains +140%
- Trucks +20%
- Freight trains +65%
- Inland water transport +50%

Increase total passenger transport = +40%
Increase total freight transport = +30%

Compared to a trend-like scenario, these figures imply that transport volumes have been generally reduced, but in particular for passenger transport by car and air. Transport by public-transport modes has been stimulated. The changes in market shares are shown in the box below.

Box 5. Market shares in 1995 and 2050 for different modes of passenger transport (person-km)

	1995	**2050**
• Cars (fossil-fuelled)	77%	11%
• Cars (hydrogen-fuelled)	–	45%
• Cars (electric-powered)	–	6%
• Air transport	9%	15%
• Buses (fossil-fuelled)	8%	2%
• Buses (hydrogen-fuelled)	–	10%
• Trains	6%	11%

Context

Conditions that would make this happen are related to the way in which socio-economic activities are structured. Where people live and work and the degree of concentration of services and shops have an impact on travel and mode choice. Likewise, the spatial patterns of production affect the volumes of freight transport. Below, a picture of societal patterns 2050 is given, which we think would make the figures in the boxes possible.

Modal split

Intermodality and seamless transitions are a prominent feature of society 2050. One can order a trip over the Internet and get a combined trip by, for example, taxi, train and rental car. Or you can take the electric vehicle from home and drive to a station where you get linked to other vehicles into a long train that takes you into the city centre, where you de-link and drive to your destination. This has contributed to diminishing the role of the private car, but the ease with which a trip can be made tends to stimulate travel.

Residential patterns and urban form

The degree of structurally enforced travel, which was considerable in 2000, is reduced due to the residential pattern and the large amount of telecommuting and tele-shopping. Everyday short-distance travel has decreased, especially by car. Also, a considerable shift from private cars to public transport and bicycle has taken place. However, this does not hold to the same extent for non-urban car travel. People to a large extent live in urban centres or sub-centres that are more self reliant than they were in the year 2000 ("decentralised concentration"). The supply of services is good and these centres can easily be reached by public transport. New residential areas are usually situated along public transport corridors or in city centres. Existing sub-centres are being upgraded to a higher degree of self-reliance with a rich supply of workplaces, goods and services. In many of these centres there are well-equipped "tele-cottages", making it possible for people to work in the vicinity of their residences. Tele-shopping in combination with electric delivery vehicles has cut trips to market stores considerably. This possibility also makes it possible to do without a car in many urban areas.

Information workers, who form approximately 25 per cent of the work force, largely work at home or at nearby tele-cottages, where they keep in touch with their colleagues and business contacts. Many enterprises have a network character.

Policy measures will be needed to facilitate developments along these lines. Possible measures are land-use and city planning, "park-and-ride" schemes, road pricing, restrictions on parking areas in city centres, improved public transport services and bike networks etc.

On the other hand long-distance business travel has increased, especially by air. This also holds for tourist trips.

Industrial structure and patterns of trade

Trade is more liberalised than 50 years ago and in general global. The predominance of high-value goods in the European economy has led to an extensive use of freight transport by air.

The use of resources per unit of output is considerably less than in 2000, largely due to increased durability of goods, recycling and a shift to lighter materials. There has also been a major shift in the industry mix, favouring less resource-intensive and more knowledge-intensive industries. Furthermore, industry is highly globalised, especially with respect to knowledge and the development of new products. Despite this, production is in many cases adapted to different customers and tailored for each local market. The knowledge economy is global, but actual production is predominantly local ("glocal production").

Due to the trend towards less resource-intensive production, the average weight of traded goods has not increased much since 2000, although the average duration of freight-transport journeys has increased. Measured as ton-km, freight transport volumes are some 30 per cent above the level of 2000. However, the value of traded goods is much higher than 50 years ago, reflecting the structural shift in industry and trade.

2.5 Awareness, Values and Lifestyles

Sustainable development is an important issue for a majority of the population and is acted upon at all layers of government. There is strong public support for CO_2 taxes and large and environmentally sound financial flows to developing countries.

Education and public-awareness policies play an essential role in international greenhouse-gas mitigation strategies. Green attitudes among a majority of the consumers have increased the speed of uptake of climate-friendly products and technologies throughout European countries.

40 per cent of the European population use computer-based programmes to define their individual carbon budgets. More than half of the consumers buys green electricity via green power schemes. One-third of citizens save their money in green equity funds which, due to green fiscal policies, provide a relatively high return on investment and invest in Clean Development Mechanism projects all over the world.

Sustainable development has become an obligatory subject in all primary and secondary schools in Europe. The subject addresses issues such as the global environmental situation, glocal development, intra- and intergenerational equity and the history of sustainable development. It also offers practical skills such as civic participation.

All municipalities in Europe have approved their own local Agenda 21+50. The local policy-makers rely on partnerships with citizen groups in implementing schemes for, for example, energy efficiency and renewable energy. At many places environmental consultancy shops are operating. Many activities at the local level are supported by the regional and local branches of the European Bank for Sustainable Development.

The environment has emerged as the most important political issue in all European countries. Because of a number of serious natural disasters, which have been attributed to the effects of climate change, public pressure in Europe has forced governments at all levels to apply strictly the precautionary principle. Europe is pressing other political regions to do the same.

Box 6. Awareness, values and lifestyles

- Sustainable development and the precautionary principle are guiding principles for policy.
- Green consciousness and values are widespread.
- Widespread application of ICT enhances efficiency of movements.
- Fiscal policies promote green investments, including in environmentally friendly transport systems.
- Road pricing and other measures in order to internalise externalities are generally accepted.
- Tele-shopping is a natural part of everyday life.

Context

There are tendencies today in this direction, but there are also contradicting tendencies. Conditions that would strengthen the inclinations stated above are, for example, more apparent greenhouse effects, strong scientific evidence for the role of CO_2 in this context and a responsible and co-operative attitude among world leaders.
Changes in values and lifestyles cannot be enforced, but education, information and opinion-forming campaigns may help.

2.6 Profile of the Image

Table: Overview of the main elements of the transport image

Elements	Importance to Fulfilling Image	Facilitating Measures and Factors	Potential Obstacles
1. Efficiency			
• Reduced driving resistance	Very important	CO_2 taxes and "feebates" that promote energy efficiency	Lobby groups for the car, lighter cars less safe
• Improved drive train	Very important	–	–
• Modal shift	Some importance	Road pricing, dedicated bus lanes, improved public transport, park-and-ride schemes, efficient inter-modal terminals	Lobby-groups for the car, "predict-and-provide"-type of planning for infrastructure
2. Fuel substitution			
• Bio-fuels and H_2	Very important	Test and pilot projects, environmental zones	Land needed for food production, oil companies
• CO_2 storage	Important	CO_2 taxes	Public opinion and transporters
• Solar and H_2	Some importance 2050, but potentially very important	Test and pilot projects, environmental zones	High commercial risk to investors
• Wind and hydropower	Not so important	–	Environmental drawbacks
3. Structures and patterns			
• Structure of industry (=> freight transport)	Important	Tax base reform: from labour to use of natural	Resource-intensive industry

		resources	
• Decentralised concentration (=> everyday passenger transport)	Important	Urban planning, commuter trains, local centres for tele-commuters	Preference for dispersed housing and car driving
4. Awareness, lifestyles, values • Green consciousness and support for policy measures	Very important as a precondition for the other improvements	Curricula for civic values and environment at schools and universities, information campaigns	Materialistic values

ANNEX 12 TABLE PATH ANALYSIS including options (1)

ELEMENT	DEVELOPMENT AND IMPLEMENTATION OF FACILITATING MEASURES 2000-2050			ISSUES
	Short Term	**Medium Term**	**Long Term**	
1. Improved efficiency • reduced driving resistance • improved vehicle drive train • modal shift • new transport systems	**Research & development**			**Obstacles** • resistance from car lobby • lighter cars less safe • increase in government expenditure • need for EU harmonisation • existing aviation treaties • interests of other policy sectors **Opportunities** • ICT developments • increased efficiency lowers costs **Pre- & boundary conditions** • new technologies • increased awareness • institutional reforms **Uncertainties** • degree of changes in societal values
	Intermodal systems			
	Improved infrastructure			
	Dedicated bus lanes			
	Intermodal terminals			
	New public transport systems			
	Improved management systems			
	Intermodal transport			
	Co-ordination between different networks & regions			
	Park-&-ride schemes			
	Policy measures			
	Promote research & development			
	Carbon tax			
	Feebates			
	Emissions trading			
	Reduce tax on low-emission vehicles			
	Abolish aviation tax exemptions			
	Road pricing			
	Abolish perverse subsidies			
	Technology-forcing performance/emission standards			

	Promote public transport	
	Promote intermodal systems	
	Promote innovation	
	Promote application of innovations	
	Policy integration	

PATH ANALYSIS (2)

ELEMENT	DEVELOPMENT AND IMPLEMENTATION OF FACILITATING MEASURES 2000-2050 Short Term / Medium Term / Long Term	ISSUES
2. Fuel substitution • biofuels • hydrogen from solar energy • electricity	**Research & development** Pilot & demonstration projects **Policy measures** Promote research & development Carbon tax Abolish perverse subsidies Technology-forcing performance standards Promote market introduction of fuel cells Promote innovation by market forces Promote technological leapfrogging Promote application of innovations Promote learning/experimentation programmes Designate environmental zones Ban conventional cars from central urban areas Policy integration	**Obstacles** • availability of land for biomass • resistance from fossil-fuel & haulage interests • high risk to commercial investors • some environmental disadvantages • increase in government expenditure • need for large markets for new fuels • need for technical harmonisation of vehicles & fuels • interests of other policy sectors **Opportunities** • potential high return venture capital • biomass alternative arable crop **Pre- & boundary conditions** • increased awareness • fiscal reforms • institutional reforms • new technologies **Uncertainties** • consumer acceptability new vehicles • societal capability to change fuel production and supply system • reaction of fossil-fuel interests

PATH ANALYSIS (3)

ELEMENT	DEVELOPMENT AND IMPLEMENTATION OF FACILITATING MEASURES 2000-2050 Short Term	 Medium Term	 Long Term	ISSUES
3. Structures & patterns • spatial structure economy • decentralised concentration	**Research & development**			**Obstacles** • new transport modes lead to new mobility • different needs of different regions • increase in government expenditure • interests of other policy sectors • magnitude of necessary structural change **Opportunities** • consumer preference for new structures & patterns **Pre- & boundary conditions** • spatial planning reforms • institutional reforms • improved public transport • dematerialization • “glocal production” • new technologies **Uncertainties** • capability of spatial planning system to change structures and patterns • magnitude of dematerialization • other forces that influence structures, patterns and demography
	Promote underground transport			
	Pilot & demonstration projects			
	Improved management systems			
	Improved logistics through ICT			
	Local teleworking centres			
	Park-&-ride schemes			
	Co-operation between different regions			
	Partnerships between green stakeholders			
	Policy measures			
	Promote R&D underground transport			
	Promote technological leapfrogging			
	Promote innovation by market forces			
	Promote application of innovations			
	Fix criteria for green investments			
	Road pricing			
	Internalise external costs			
	Shift tax from labour to natural resources			
	“Full-cost” land taxation			
	Promote investments in infrastructure & distribution systems			

	Promote learning/experimentation programmes Policy integration	

PATH ANALYSIS (4)

ELEMENT	DEVELOPMENT AND IMPLEMENTATION OF FACILITATING MEASURES 2000-2050			ISSUES
	Short Term	**Medium Term**	**Long Term**	
4. Awareness, values & lifestyles • green consciousness • environmental education	**Education/awareness**			**Obstacles** • materialistic values • market processes **Opportunities** • visible effects of climate change • financial return on green investments **Pre- & boundary conditions** • convincing scientific evidence of greenhouse effect • conspicuous climate change impacts **Uncertainties** • degree of changes in societal values • other factors that affect values
	Environmental education curricula			
	Public awareness campaign			
	Experiments with individual carbon budgets			
	Improved management systems			
		Individual carbon budgets		
	Support for new mechanisms			
	European Bank for Sustainable Development			
	Green equity funds			
	Clean Development Mechanism			
	Reform existing institutions and mechanisms			
	Policy measures			
	Stricter application of precautionary principle			
	Agenda 21+21			