CLIMATE OPTIONS FOR THE LONG TERM

COOL Europe

Climate OptiOns for the Long term

Report of Workshop 2

Path Analysis

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COOL 00/E02

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Domenico Rossetti di Valdalbero, DG Research, European Commission
Hans-Eike von Scholz, DG Energy and Transport, European Commission
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Introduction

At April 6 - 7 2000, the second Climate OptiOns for the Long term (COOL) Europe Workshop took place at Hotel Arenberg in Brussels. In this workshop, European stakeholders, policy-makers, and scientists of the energy and transport sectors gathered to proceed with their discussions on long-term (2050) options for substantial CO_2 reduction. The workshop, the second in a series of four, was organised within the framework of the Dutch COOL project, financed by the Dutch National Programme on Global Air Pollution and Climate Change. This project runs for 2.5 years (1998-2001) and involves discussions between policy-makers, scientists and stakeholders on the national (Dutch), European and global levels. The European part of the COOL project is organised by Wageningen University in the Netherlands, Ecofys (Utrecht, the Netherlands) and the Environmental Strategies Research Group (Stockholm University, Sweden).

The four workshops focus on the connection between strategies for Climate Change Policy in Europe with long term sector strategies (Transport & Energy/Industry. The COOL project is not about predicting the future or planning the future. It is about learning about obstacles and conditions for a sustainable future; to deepen the understanding about what is required to achieve far-reaching emission reductions; to explore the long-term consequences of short term actions. Most important of all, the participants, coming from different backgrounds and countries, will learn from each other: exchange views on the future. What are the expectations of colleagues in different countries; what are the different views on desirable actions, are there possibilities for collaboration?
In order to accomplish this, the four workshops are organised in four steps: (1) the exploration of images of the future; (2) implementation trajectories connecting these images to the present; (3) formulation of short-term actions needed to reach long-term goals; and (4) elaboration of strategic visions integrating all these steps.

The second COOL Europe workshop focused on implementation trajectories connecting future images to the present. The participants gathered in plenary sessions and worked in smaller sector groups and sub-groups.

This report summarises the outcomes of this second workshop and has the following structure: Part I describes the presentation and the discussion in the plenary sessions, including the Policy Panel which was held at the end of the second day; Part 2 contains the minutes from the two sector groups, energy (Section 2.1) and transport (Section 2.2). In the annexes the input material for the workshop can be found.

PART I: Plenary Sessions

1.1 Introductory Plenary (Day 1)

1.1.2 The role of Workshop 2.

Introduction by Graham Bennett, Syzygy, the Netherlands.

Graham Bennett gave a brief introduction to the role of COOL Europe workshop 2 and its different sessions. He mentioned that the future images for the energy and transport sectors, elaborated by the COOL Europe project team, will be the first topic for discussion in the sector groups. This workshop has the ambition to clarify the extent to which there is agreement and disagreement about these images with respect to structure, focus and the elements contained in the images. The next element of the workshop is the process of constructing a path back from 2050, from the future images to the present. This exercise involves four main points for discussion:

(1) Major strategic choices to be involved.
(2) Most important preconditions and political, economic and technological boundary conditions which are necessary to achieve the future images. We have to be clear about the feasibility of the options.
(3) Possible surprises which may turn up and how these surprises will affect the robustness of the policy options included in the future images.
(4) Intermediate steps necessary to achieve the desired goals: what do we need to do over the next ten years and what do we need to do over the next 20 years to move the process toward achieving 80 per cent emission reduction?

Graham Bennett emphasised that COOL Europe is dealing with a long-term process which means that we have to make a break with the present. He invited the participants to make a distinction between the following questions: What is feasible? What is probable? What is possible? What is unexpected? In many of the projects and processes we are involved in our daily life we tend to be obsessed with what is feasible. Our focus in the COOL Europe process should be different.

Graham Bennett also made clear that COOL Europe wants to stimulate a diversity of opinions. It is this diversity that drives the process forward. The greater diversity of opinion the better.

Graham Bennett asked the participants to take into consideration the fact in 50 years time, any political arrangements in Europe will be very difficult from what they are now. Furthermore, in the COOL Europe process we have to think about the interactions between the European scale and the global scale and between the interactions between the European level and national/regional level.

1.1.2 Strategic considerations in long-term climate policy

Presentation by Jan Paul Soest, Centre for Energy Conservation and Energy Technology, Delft, The Netherlands.

Key strategic parameters in shaping a climate policy vision seem to be the nature of the climate policy that will be implemented, the development of the economy, and the future energy system. Society, in particular the EU-society and policy makers, can partly choose and (co-)create the future, and partly have to anticipate expected trends and developments. What would be the best position, if there is any? To give some clues, a number of extremes are outlined.

Climate policy can be global and formal, covering most of the countries, and including instruments such as carbon taxes and/or tradable permits, leaving economic sectors maximum flexibility in choosing the options. This is one extreme. Carbon policy could also be more informal, based on shifting consumer preferences, pressure from NGO's, and bi- or multilateral coalitions of countries working on similar goals. This is the other extreme.

It makes a lot of a difference to see what money is available to see what options can feasible. A recent Dutch report[1] analyses carbon emissions rights of the OECD countries under a future global ceiling. The actual outcome depends largely on the moral principles behind the policy. Are we going to deal with historic rights or are we going to a situation of equal rights where per capita carbon emissions are equally divided? The Dutch report proposes an intermediate path going gradually from historic rights to the principle of equal rights, thus creating a transition in the system which might be acceptable for all parties involved. The amount of money that is involved is largely dependent on the moral basis of the system. The flows of money from the northern countries to developing countries, expressed as a share of GNP of the north and the south. If there is a system going to equal rights the amount that the South can earn y trading emissions can come up to four per cent or so. For some smaller countries it cane be the whole GDP. The moral basis of the system (e.g. emission rights per capita or on historic grounds) will strongly affect the money flows from North to South, thereby defining the nature and intensity of investments in carbon reduction.

The *economic development* – which is partly influenced by the nature of climate policy, by the way – is another important parameter. Can we expect or do we even want some sort of 'business as usual', continuing current trends and patterns? Or will something like the New Economy develop, with an exponential use of ICT (information and communication technologies) that will completely reshape economic patterns, production methods, chains, transport systems, and so on. This may result in a rather different energy demand, e.g. decreasing energy demand in industry, with on the other hand a sharp increase in traffic and transport.

A third important parameter is the *characteristics of the energy system*. Roughly two extremes are conceivable. A clean (i.e. low carbon) fossil fuel based system, based on the

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[1] Dutch report….

idea that fossil fuels are more abundant than assumed some years ago, that their prices will remain relatively low, and that they can easily (and cheaply) be reformed, using hydrogen and storing the remaining carbon dioxide (sequestration) in old gas fields and aquifers. Having these low prices, the rate of efficiency improvements remains rather slow, say 1, maybe 1.5 % per year or so. On the other hand, a system can be imagined where much more renewables are being used, 'forced into' the economy by stringent measures. This will lead to additional costs, thus accelerating the energy efficiency improvement rate to some 2–3 % per year. In both extremes, the existing trend towards lower carbon intensity (carbon emissions per unit of energy used) is enhanced.

Having defined a 'strategic playing field' like this, the main strategic questions are: what are the main actors, what are their respective roles and whose strategic vision are we talking about? What is the attitude behind the strategy: do you want to react, to follow, to anticipate or even to (co-)create the future? What influence and power do key actors have in shaping the future? What policy measures will result? How do they affect economic and energy developments? How do the future images of COOL Europe match with the strategic playing field? What options that will fit into this desired or expected future must be given attention and by whom?

Jan Paul van Soest declared that he is not too much interested in the options themselves. It is the policy measures, the boundary conditions, that are shaping the way towards the future. The options themselves will be valid or not depending on the policy instruments that you are going to implement.

Taking economic optimality on a global scale as a starting point for developing a strategic vision, the future would have to look something like this. First of all, developing a global and rather stringent climate policy would be the major challenge. This would include implementing a system of carbon rights on the basis of equity on the longer term, and shaping policy instruments accordingly. Secondly, it seems that the rise of ICT will dramatically change the economic structure, particularly in OECD countries. If one expects such a trend, why not even stimulate it? Or as a base line philosophy: policy makers should not be too reluctant in taking measures that as a side effect enhance a reshaping of the economic structure. Thirdly, looking at the options that are currently available, and looking at their costs, it can be concluded that technology is not likely to be the bottleneck. But willingness to pay and political courage are! In a rather careful scenario, EU policy makers can start with the sheltered sectors, such as housing, building and construction industry, EU internal traffic and transport, and smaller and medium enterprises that do not compete on a world market. Parallel, EU policy makers should aim at realising global climate approaches, by including developing countries in the Kyoto Protocol, defining carbon limits for global industries, aviation and shipping, and by promoting effective international policy instruments. EU policy makers could promote ideas such as a global carbon dioxide tax or tradable emissions rights or instruments like these that give an idea of targets and flexibility in choosing the options. Maximum flexibility, in Jan Paul van Soest's view, is a key in shaping policy futures.

Presently we spend about 12 per cent of GDP on the energy system. Without any climate policy the costs might go down to some eight per cent in 2050. With a severe climate policy the expenditures will end up at ten per cent or so. Looking at these figures no one should say that climate policy is unaffordable.

1.1.3 Discussion

It was initially concluded that in discussing long-term climate policy one has to rethink the institutional framework of policy-making. It is not possible to project the current situation to 2050 or so. It can change dramatically. But one has to be precise about the assumptions one has for the year 2050.

One participant noted that equal rights of carbon emissions per capita are based on the environmental space concept. On the basis of this there is a possibility to introduce a global carbon dioxide tax.

Jan Paul van Soest made clear that the idea of equal rights is very controversial and is avoided in the mainstream of discussions in the UN FCCC process. But if you are not gradually going towards a system of equal rights development countries will resist any international policy. They argue that the only way of sharing the pie of carbon dioxide that can be emitted in the future would be on the basis of equity. Others, particularly the US who is leading the discussion from another point of view, says that we have a right to remain on the same kind of level as we have always been. So far it has been a very sensitive moral issue. Policy-makers are not very good at addressing moral issues but in van Soest's point of view it is the key of environmental policy-making in the future. The outcome - are we going to accept a gradual change towards a system of equal rights - will be of major relevance for the development of international climate policy. Is it acceptable? The idea of COOL is to think about what is necessary and then back-cast the ideas. The crucial questions is: How are we ever going to get to a situation of more or less equal rights knowing that it is a very crucial factor in getting anything across?

What about the historical emissions of developed countries? We developed a transition scenario starting with a historical rights situation and ending with an equal rights situation. We owe developing countries a lot of emissions. It is not only about arriving at an equal level but also to compensate those countries that were not using fossil fuels during our industrialisation period.

Depending on your professional and national background you will find your position in that system. It would be very important somewhere in the COOL process to exchange ideas about the issue of entitlements.

One participant argued that probably we should not be too realistic and pragmatic in terms of what is politically possible. The outcome of the work and the solutions that are chosen would look fundamentally different if we believe that some kind of convergence between historical rights and equity is possible or if we believe it is not possible. It is such a fundamental issue that perhaps we should suggest two parallel scenarios. Because if we dream about equity and there is only a 0.5 per cent that that will happen the whole exercise may be very useless. On the point of equity we should be realistic.

Regarding New Economy it was argued that the important question is: what kind of policy measures are needed to make sure that the New Economy indeed will result in more environmentally benign solutions.

Another participants agreed that equity is important but not as important as the efficiency issue. It should be possible for countries of the world to leapfrog directly into renewables instead of investing in fossil fuel industry. For developing countries who are in the process of investing into infrastructure similar to the one in the OECD area it would be much more useful to invest into something else. Otherwise they will be stuck to the wrong solutions for the next 50 years. It should be kept in mind that equity might not be good in terms of overall efficiency.

One person argued that equity will not determine what will happen. There will not be a major distribution of wealth for the sake of climate change policy. So when one looks at the issue of the transition to sustainability we have to look at low cost transitions, not involving major redistribution of economic wealth. We will never come to a political agreement about how to move to a sustainable system. We have to think about low cost transitions.

Jan Paul van Soest said that the equity issue influences the developments of both European and southern countries. The equity scenario may be a low probability scenario but it would definitively have influence if it should occur. It also will influence efficiency. It gives the opportunity for developing countries to money to invest in carbon technologies (sequestration, efficiency improvements) or going all the way. So the whole formula of the climate policy - geographic scale, distribution of rights - would be very important in the options and possibilities that we will have in Europe. Jan Paul van Soest said that it had been his ambition to shape up the variables and parameters that are at stake and to give an idea about the playing field that we walk around. He admitted that the trends and figures given are based only on today's estimation of costs. If these technologies become cheaper than fossil fuel we are close to the solution of the climate problem. It can be assumed that by implementing policy instruments the development of technologies can be enhanced or slowed down. That is a very important aspect of defining your own vision. There are people who argue that clean fossil fuel will be the future. On the basis of today's cost effectiveness that is definitively the case. Looking at the dynamics of technologies it is motivated to go for a more renewable approach taking the risk that on the long-term it might not be the cheapest solution. But it seems to be a more fundamental solution. The risk we a clean fossil fuel future looking at all the material and energy flows around the world. All the energy has to be subtracted somewhere, probably in ecologically very sensitive areas. Looking only at the carbon dioxide side of it might be a dangerous scenario.

1.2 Plenary session on future images (Day 1)

1.2.1 Report from the energy group (Tomas Kåberger)

Characteristics of the future image

As compared with the present situation the future image contains important changes with respect to energy supply. Natural gas and biomass increase their shares significantly making it possible to do completely without coal and reducing oil use from 41 per cent to 8 per cent. Oil would cover mainly the needs of aviation. Then there were contributions from hydro, almost doubling, wind power (on and off shore) totalling the same as hydro, solar PV and solar thermal almost reaching the same level and significant contributions from heat pump systems for production of low and medium temperature heat. There would also be some nuclear left, 3 per cent going down from the present 14 per cent.

Changes and amendments

The energy group identified eight issues to be discussed. Subsequently five key issues for further discussion were selected via sticker voting. In discussing nuclear the group had the prevailing idea that this option would probably either be a lot or nothing. It was found unlikely that we would have 3 per cent from nuclear because either nuclear would be economically competitive and publicly accepted or not. Furthermore, it was believed that the potential for wind power is much higher than in the image that was prepared. Hence, the contribution of wind power was tripled. The problematic discussion that was not resolved was the distribution in supply between biomass and solar. The calculation of the solar contribution was based mainly on solar PV on buildings. The energy group was not convinced that it was the right share of the built structures that were covered by solar PV. When discussing the land use for biomass it was realised the efficiency in the use of areas collecting energy by solar PV could be better than using biomass. As soon as there would be any land shortage or land demand we would possibly also use solar PV on land rather than the use of biomass. This issue deserves more attention and is a relevant question to science. Subsequently there was a short discussion on the importance of population size. It was, however, not seen as a determining issue. Also the issue of coal gasification was touched upon. The group concluded that it was desirable to rely totally on natural gas but for political and supply security reasons there would probably be a lot resistance to shift completely to natural gas and to have some coal gasification. With respect to fuels for the transport sector the energy group kept creative vagueness on the role and potential of bioalcohols and hydrogen.

1.2.2 Report from the transport group (Graham Bennett)

Characteristics of the future image

As regards the main characteristics of the transport system in 2050 there is, compared with the situation now, a higher diversity of vehicles. Small electric vehicles for city use are in operation. There is an increased share of public transport. New residential patterns have reduced commuting to work. Information and communication and technology also help to reduce the need for transport. Air travel and inter-urban use of the car will increase. The energy used by the transport sector is 20 per cent lower. This includes the energy used in producing certain fuels. The total passenger transport level is 40 per cent higher than the existing level. Freight transport is 30 per cent higher.

With respect to fuel substitution, there is a big increase in the use of cars with fuel cells, to a large extent dependent on biomass. Twenty per cent still use fossil fuels. A large number of the truck fleet use fuel cells. In the aviation sector kerosene is still dominating because the transition to hydrogen has only just started.

The efficiency of the vehicle technologies has increased substantially.

The most important changes in residential pattern and economic structures are decentralised concentrations, with more self-sufficient communities with their own shops, services and tele-cottages where people can work locally. There is a continuing trend toward globalisation of the economy. Many products can be produced locally.

Changes in awareness, values and life-styles will have an important effect on greenhouse emissions.

Changes and amendments

The group had identified several issues for discussion. Most of the issues will have to play a major role in the construction of the pathways and the formulation of the Strategic Visions.

Apart from the request to clarify the figures and the assumptions of the image the issues raised included:

(1) The implication of new decision-making processes in two respects. First of all, ways of ensuring that the decision-making process takes better account of long-term interests of changes rather than the four-five years election terms that we now have. Secondly, determine at which level of policy-making measures should be taken, whether it is local, national, regional or global.
(2) Implications of the new economy for the image. There are a number of points related to this. Firstly, the changing role of the main economic actors, particularly in terms of globalisation and liberalisation. Also the concentration of economic power in fifty years will effect the economy. Secondly, the future effect of information and communication technology on transport patterns. Thirdly, the relationship between the new economy and changes of behaviour.
(3) The issue of transport needs. Transport is a service which responses to the needs of society. The demand for transport services in 2050 must be made clear. This is also a question of price elasticity. Even though we may change the prices for some of the fuels by financial incentives a change in actual transport patterns and modalities cannot be taken for granted.
(4) A specific point was made on biomass. To what extent is large-scale production of biomass through dedicated plantation feasible in Europe? To what extent is it sustainable? This is also a question to the energy group.
(5) Behavioural and social factors that need further consideration. Some people felt that the image was too technological in its profile. The impact of advertising on individual behaviour. That may have a huge difference to the transport sector, especially with regard to car ownership.
(6) Links between the elements of the image were seen as very important. It is important to the way those elements interact. The issue of achieving carbon dioxide emission reductions in sustainable vs. non-sustainable ways has implications for the image.

Social change and technological change are closely linked. This interrelationship shouldn't be forgotten. Individual perceptions about the need for transport is a very important topic. The impact of demographic change (such as immigration patterns, the changing age structure) is also important.

(7) Modal split. A specification is needed with respect to the role of non-motorised transport in use. The impact and the role of land-use planning in helping to facilitate and promote particular forms of transport, including non-motorised transport. One possibility is combined passenger-freight transport, particularly in urban areas.

(8) The role of investment policies, incentives and regulation. Transport is a derived demand which means that the choice for certain investments have very important consequences for the transport sector

Moreover, political factors were mentioned as being important. For example, the West is very dependent on the Middle East for the supply of oils. There may be political reasons for moving away from that dependency towards renewable sources of fuels.

It was questioned whether the significant role of fuel cells in the future image was feasible. Nuclear fusion was mentioned as a possibility. Electronic coupling of vehicles for long-distance travelling was mentioned as an option . The image is considered to be rather conservative on the potential for hydrogen. There might be greater potential for using hydrogen during 50 years. There is a need for clarification which effects the elements of the image will have on other sectors of society.

1.2.3 Exchange of Comments and questions between the energy and transport group

In the discussion that followed, the energy and transport group reacted on each others Images

Hydrogen and biomass in the transport sector

Several comments and questions of the energy group regarded the somewhat conservative approach to the use of hydrogen in the transport image. The question was raised whether this was based on the difficulty of getting the transport infrastructure, or on scepticism as to whether hydrogen is going to be available. The chairman of the transport group answered that it was mainly based on the magnitude of structural changes that you need to make in the energy systems to make hydrogen widely available. Furthermore he noticed that apparently in the transport sector it is easier to switch to biofuels than to hydrogen. There have to be good reasons for thinking of a radical change in energy supply systems. Of course that is a very important issue to discuss in COOL.
The question was raised whether we do need to make biofuels by converting 17 per cent of the land area in the EU into a fuel growing factory. If so, would it not be better covering 2 per cent of the land area with solar PV and generating hydrogen to produce the same amount of energy? The remaining 15 per cent could be used for recreation. It was argued that it may not be possible to get the infrastructure in place to actually use that hydrogen. The energy group had the impression that it is not fundamentally a big problem handling hydrogen in the natural gas grid. It would be a matter of a 15 years adjustment period and therefore it would not be a major issue.

Furthermore it was argued that switching to hydrogen based fuel cells in the cars is an interesting option because it is a carbon free option. However, normally a car is used 45 minutes per day which means that the high efficiency of the fuel cell is used 45 minutes per day. To increase overall energy efficiency it may be a better option to use the fuel cells in power stations etc. An advantage of the car is that the product cycle is relatively short. In other words, there will be different vehicles around and the 45 minutes per day cars may be electric cars rather than fuel cell cars

Figures and numbers

Another question regarded figures and numbers in the images of both the energy and transport sector. Will more detailed figures increase or rather decrease the value and credibility of the work? It was discussed that precise numbers can give a misleading impression of accuracy, which is not applicable for this kind of future studies. Furthermore there is the danger of getting into a discussion on figures rather than on the (more interesting) underlying factors and processes. The chairmen explained that the main purpose of the future images is to give a general idea about what future we want to move towards. The main emphasis should then be on the path analysis: how are we getting in that direction?

Synergy with other problems

One participant noticed that if we concentrate on the climate problem only we are likely to miss some of the opportunities. There are important synergies between different agendas on health, acidification, eutrophication, and so on.

Costs and investments

Some questions concerned costs and the sources of investments. Where is the money for investment going to come from? Who will pay and why? The chairman of the energy group said that costs are very much a question of the learning curves for the new technologies. This is sometimes very difficult to predict, sometimes not that difficult to predict. Development of wind power and solar PV is going at a rather high speed now. Maybe in twenty years time they will be competitive without any other guiding measures. Furthermore there was a question also related to the speech of Jan Paul van Soest. If he would be correct that the cost differentiation between taking care of the CO_2 problem and not taking care of it, is something between 1 and 2 per cent of GDP, how does it come that we have such enormous resistance to do the right things given that the cost differentiation is so relatively small? It was agreed that this is a relevant point that will definitively appear when we do the path analysis and try to identify barriers and obstacles.

The issue of investments will have to be discussed further in the path analysis as well.

Political action

Finally it was discussed that one important question in relation to both energy and transport is that there is no specific individual or specific company that would be able to harness all the gains and benefits of a certain kind of investment in favour of less carbon dioxide emissions. It is society as a whole. It was argued that the market economy is not well equipped, does not have a design, to deal with global public goods or with public goods in general. A strong political involvement is needed. This is especially obvious in the transport sector. As example the new transportation system in the greater area of Stockholm was mentioned. If we want to harness some of the possible benefits from information and communication technology such as flexible offices, distance work, intelligent transport planning etc., it would require a very strong political action. It was argued that the actors in the market will never be able to bring it about. It was agreed that this is something that we have should have very high on the agenda and which is a critical issue for the path analysis.

1.3 Plenary on Path Analysis (Day 1)

1.3.1 Pathways to sustainable transport – no path without a pathway
Presentation by René Kemp, MERIT Maastricht University, the Netherlands

The plenary session on path analysis started with a presentation of René Kemp from Maastricht University, who provided insights from work on pathways in other research projects. In his talk René Kemp concentrated on the transport sector, but also made a connection with the energy sector.

He introduced some key features of transport:
1. strong **lock-in**
2. transformation requires **co-evolution** (behavioural and institutional changes besides technical change)
3. **competition** between technology systems
4. different product **constituencies**
5. **heterogeneity** of transport infrastructures and people's transport needs and wants

René Kemp argued that the current (infra)structure is the outcome of past choices. The structure is the "medium" for the transport system. We have to be very much aware of the consequences of our choices of today for the future system.
The schematic view below shows the innovations in the transport system that may help to solve problems of environmental pollution and road congestion.

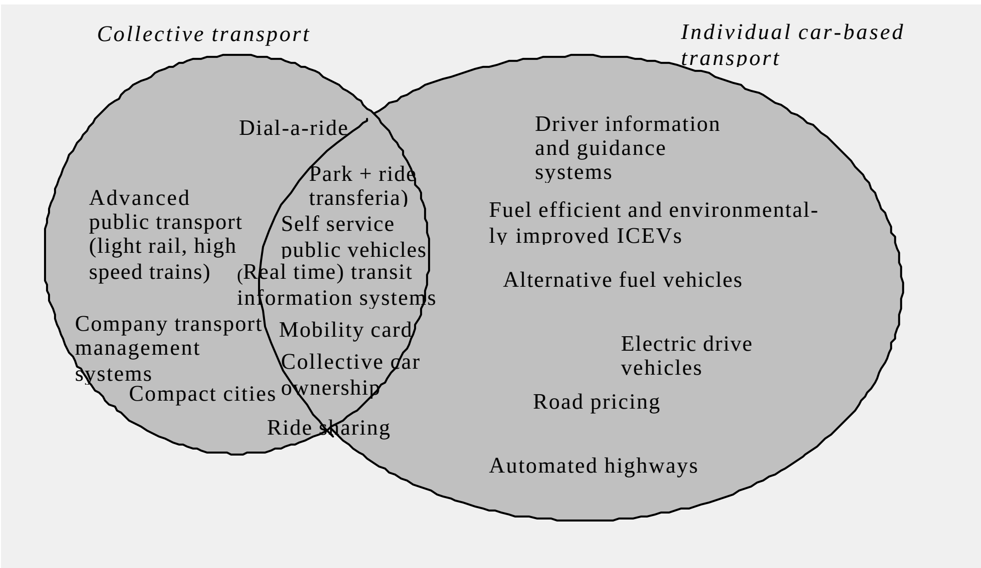

Figure: ***innovations in the transport system that may help to solve problems of environmental pollution and road congestion***

Different pathways could be imagined that lead to sustainable transport. The level of integration and the amount of behavioural change can be variable, and therefore lead to different paths. For example as shown in the graph below, a path towards integrated mobility includes other options than a path to clean and intelligent cars. Another pathway could be imagined which includes both.

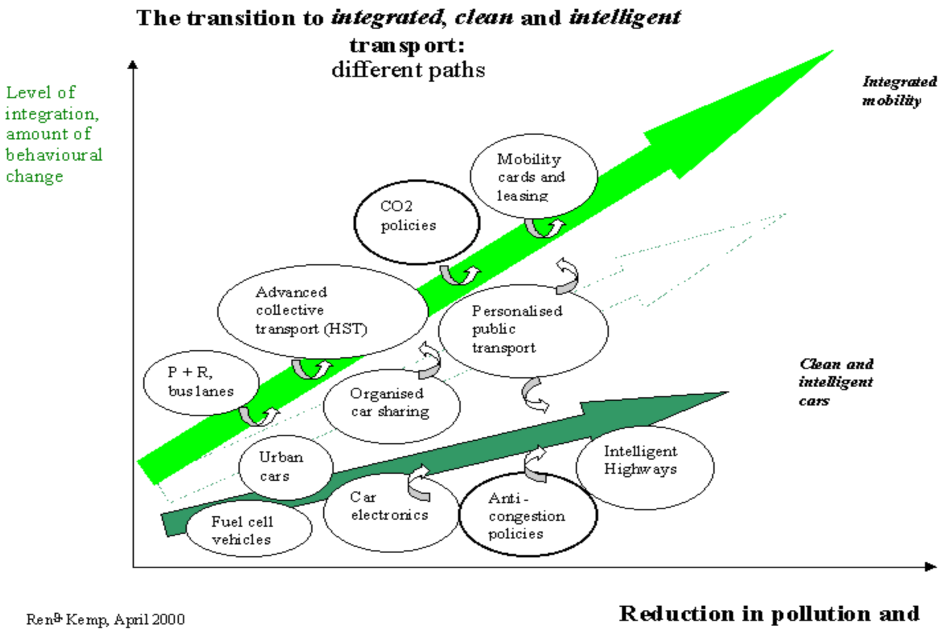

Figure: the transition to integrated, clean and intelligent transport: different paths.

As an example of the interconnectedness of certain options and the feed-backs which occur in travel systems, René Kemp sketched different aspects, drivers and feed-backs in a intermodal travel system

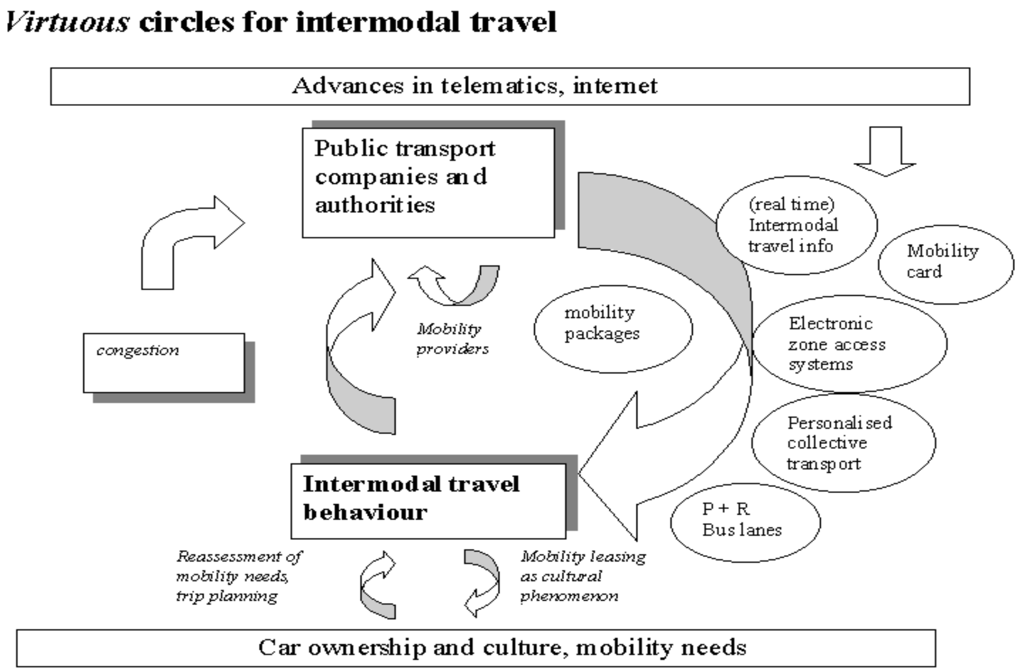

Figure: Virtuous circles for intermodal travel

The focus of COOL Europe is on trying to find solutions to solve the Climate Problem, by formulating strategic visions to reach far-going reductions in carbon dioxide. emissions. Long term sector policies and long term climate policies are naturally connected. In the figure the interconnectedness between climate policies, the development of energy systems and the development of different vehicles is shown.

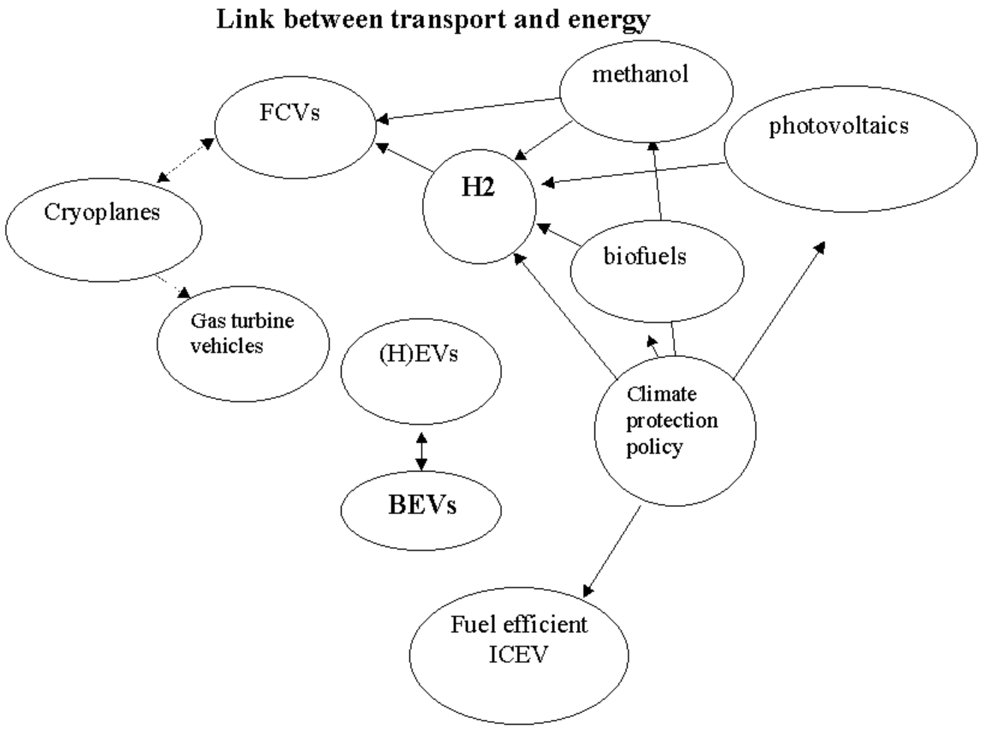

Figure: Link between transport and energy

1.3.2 Discussion

In the discussion that followed the remark was made that the examples that were given mostly concentrated on short distance travelling and on the transport of persons. Path ways for long and medium distance mobility as well as transport of goods would ask for different elements in the path ways and for different choices.

The role of policy making was identified as an important issue in the discussion. Opportunities for experimentation should be created, progress and learning should take place through experimentation projects.

1.4 Policy panel (Day 2)

Participants
Karl Doutlik, DG Enterprise, European Commission
Cees Moons, Ministry of Environment, the Netherlands
Domenico Rossetti di Valdalbero, DG Research, European Commission
Hans-Eike von Scholz, DG Energy and Transport, European Commission
Marianne Wenning, DG Environment, European Commission

Chairman: Tomas Kåberger

1.4.1 Introduction

In order to…. A Policy panel was organised
Before this plenary session questions to the panellists were prepared in the sector groups on energy and transport.

1.4.2 Discussion

Question 1 (energy group): The unanimous conclusion of the first and second COOL Europe workshops has been that in the long-term sustainable energy solutions will be required. What instruments are needed to achieve a decentralisation? How can the EU achieve that without an energy chapter within the treaty?

von Scholz
How to decentralise our energy supply systems in order to create niche markets for renewable energy? The solution, that we see, is not an energy solution. The demand has to be reduced. That means, for instance, home-working and other means to reduce the demand for transport. If we want to come in a larger way to come to a decentralised system we need a decentralised demand. Now, to reply to how much an energy chapter can help us here. It is arguable if it is really desirable. An energy chapter would be supply-oriented. Otherwise we do not need it: we go through taxation, we go through competition, we use the environmental chapter which are for the energy efficiency regulations etc. So if we adopt a decentralised approach we can use existing instruments. People in favour of a strong energy chapter are normally supply-minded, particularly nuclear, coal, oil, gas etc. There is resistance from some member states because they do not want Brussels to intervene in those areas. So it means that we will not have an energy chapter.

Doutlik
On the demand side I agree that there is, looking upon at it from an industry point of view, an interest for implementing decentralised solutions. What superficially is hindering right now seems to be the liberalisation of the market. Decentralised solutions like CHP may not seem viable anymore. But that will change pretty soon. There is definitively scope for big consumers to look into more integrated solutions. The new European Climate Change Programme might provide some new ideas for consideration.

Kåberger
Any institutional measures you would mention to promote decentralization?

Doutlik
We should use the liberty and the flexibility for the economic actors. Incentives and loose frameworks rather than an energy charter. An energy charter seems to be binding the issue too much, which certainly has proven not to be the best solution for every case.

Moons
The government should not be involved in everything with respect to how emissions should be reduced. In the past it was government policy. The best approach is to create the frameworks focused on the results you want to achieve and let the market decide what will happen.

Kåberger
Do you think the present framework is sufficient to give room for decentralised solutions?

Moons
No.

Wenning
If we think in the area of renewables some policy instruments are needed. The market forces will not get the decentralisation going. Even though the technologies in many fields are available to a quite mature extent, still we are facing a situation where the renewables represent a small percentage within the EU. Directive on renewables. We are also looking at guidelines for state aid which could be used to go in that direction. Some instruments are necessary to make that push.

von Scholz
For other legislative basis, in particular the taxation, we are very much bringing in energy in every energy discussion in the Energy Council. For fiscal policy we do not need an energy charter. We need to go from unanimity vote to majority vote.

Rossetti di Valdalbero
When one looks at the damages from a big storm, the advantages of a decentralised energy system become apparent. But in Europe we have already a well-developed infrastructure. We will use it for many years. Decentralised energy systems for developing countries is certainly an option. It is easier than in Europe.
Concerning the question about the energy chapter that is lacking in the Treaty, I just would like to remind that even if European energy policy is not explicitly mentioned, many of its issues are tackled in other policies (Trans-European Networks, Social and Economic Cohesion, Research,…) and that relatively important budgets are dedicated to energy. 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).

There is a need to regulate the liberalised market. You need even more regulation. In the air sector there has never been so many rules as when the market was liberalised. Another question is: what to do with the surplus electricity in a decentralised system?

Question 2 (energy group)
One of the conclusions of the energy group is that pricing of externalities is vital to create a sustainable future. Another point is that liberalisation is reducing price. This is a threat due to the fact that demand usually increases when prices go down. But it also creates a window of opportunity trying to introduce environmentally based taxes. As an example a small graph on the electricity market. At the top level the price has reached….high voltage grid in Europe. This is the estimated equilibrium price of a liberalised market. There is a price drop at a certain point which is estimated to about 5-6 pfennig per kilowatt hour. Looking at Germany that would be 5,000 million DM per pfennig in tax. The window of opportunity is that as prices go down we have an opportunity to impose rather high environmentally based taxes. If we wait one can began to raise the question whether it is feasible to impose these kind of taxes. So the conclusion is that now there is a window of opportunity to make a shift in taxes. If we do not use the opportunity we might not be able to introduce the taxes. The questions to the panel are: (1) what is your reaction on this proposal? and (2) which obstacles do you see to introduce environmentally based taxes?

von Scholz
You have an over capacity. The major companies have tens of billions of DM in reserves at WAIE **(?)**. The falling price over the short and medium term all over Europe has a certain effect which has not been spelled out of replacing a part of the electricity demand of heating to gas. We have some islands in Europe, for instance France, where gas and CHP is little in progress. This is due to the dominant role of the EdF and its emphasis on nuclear power. If it would stay 5, 6, 7 or 8 Pfennig. So for these reasons this a correction I think we need. CHP faces problems of the short term due to low electricity prices but in the medium term it should increase. The state side should intervene and try to support it. Whenever there is a need for short-term intervention (3-5 years) in order to help a market to establish and then it could be self-reliant. Then we are allowed to intervene. This is a deal we have with the Competition DG. The CHP could be for short term protected in some ways (by, for example, pricing, subsidies or release of taxation). But it should at the longer term become a viable solution. I am less in favour of a tax. Simply because that taxes means more money getting out of the productive sector normally getting to the state's hands. The states have normally already a huge amount of GDP to administer. They are not the most efficient ones. So whenever the tax instrument is used we should try to achieve tax shifts so that the net value is not adding something. Moreover, we should use the income to restructure the energy sector. Not just giving more money to the finance ministry.

Comment from a representative of the energy group
We have changed the name from tax to fee to get away with the idea that it is fiscal.

Kåberger
You did not mean a general tax but a carbon fee.

von Scholz
For a limited period of time it could be or should be supported. If you need for a certain source a protection period it is useful for introduce a fee. But the conditions should be that the fee is a transition instrument. There should be certainty that within 3-4 years it would work without a fee. But if it is permanent fee for the long-term then I think we should not do it. We should rather direct the money to areas in the energy sector where the costs are a barrier to gain public support.

Doutlik
It would be interesting to hear some viewpoints on what to do with the huge amount of money from the fee. The idea would be to raise funds to get some things moving. Say, for instance, to influence the innovation cycle. The simple answer to the question about a window of opportunity for taxes does not seem to be available at this moment. There are other means. We could create better access to the grid. Part of the problems for renewables and decentralised energy supplies is that the owners of the grid did not want them on. Many projects could not be justified because the people who wanted to invest money did not get anything unless they could use it on their own.

Wenning
I cannot judge how big this window of opportunity is. In principle, from our point of view, some of the profit should be give to create a market for environmental purposes, for example renewables and CHP. It is a matter of discussion but the idea is interesting. It is doubtful whether the idea is politically feasible. The best chance to realise the idea would be if you do not take the whole of it but rather a certain percentage. The second thing which is worrying is that energy is getting cheaper if you just let liberalisation take place. It is good for the consumer. However, people tend to use more energy when it gets cheaper. If you do not address that problem you go in the wrong direction.

Moons
I also think there is an opportunity. But in my opinion the use of energy is not the problem. The real problem is the carbon dioxide emissions. Policy answers are more logic if you talk about trading of emissions. You create an incentive for renewables. You get the right price related to emissions. Energy will either increase or decrease but that is not the real issue.

Kåberger
The point made in the energy group was not to tax electricity but to tax carbon emissions.

von Scholz
If you put it only on carbon then nuclear and hydro will become untaxed.

Doutlik

The future tax should be an energy and carbon tax, otherwise there will be a distortion among electricity producers.

Kåberger
One of the results of the drop in the electricity price may be that electricity will be cheaper than fuels. This implies that there would be electricity used for heating purposes.

von Scholz
If you look at the heat value from gas and compare this to so-called cheap electricity, say for the next ten years for the price of say eight Pfennig. You have too many reserves in the major electricity companies and you have quite a lot of over capacity.

Bennett
If the idea is to impose some kind of eco-tax for carbon dioxide reduction purposes, I would have thought that a more feasible way of doing it is to introduce carbon dioxide tax on energy production. But the revenue from that tax would be refunded to the sector, perhaps based on the kWh produced, so there is competition within the sector which encourages low or non carbon dioxide electricity production. Those forms of energy production which involve carbon dioxide emission go up. So you reduce the effective price of energy to non-carbon dioxide or low carbon dioxide production means. But you do not increase the overall price of electricity.

Comment from a representative of the energy group
The financing is coming actually due to prices going up. I received two questions earlier. One was about where the tax money was going. Fee is a better word here. But let us start with the efficiency of the market. Liberalisation is intended to increase the efficiency of the market. As a result of this achieving lower prices and also provide customers with a broader set of solutions. Where should the money go? Some of the money should go to demand-side management, maybe financing activities in eastern Europe etc. In order to make everybody happy, a certain percentage should go into the fiscal system.

A comment with regard to the price levels which was mentioned. 8-9 Pfennig is a dream figure. Dream figures with regard to the power supply. The equilibrium price will probably not be higher if you exclude the environmental side. Then 4-4.5 Pfennig and its dreams by the producers they will be higher (?). We will have excess capacity for a very long time. The real problem is that there will be low prices. The price drop will be so large that depending on the elasticity on demand you will have an increase in the demand. We are talking about a period of 10-15 years. So as a power producer this is the opportunity. There are restrictions and problems, yes. But this is the time to do it. This is the view of the energy group. We represent a number of interests in Europe.

von Scholz
If we on the one hand are asking to get in externalities over the next ten years, if we want cost based prices, if we believe that the reserves of the companies are not without end, I ask you: what do you think a normal new nuclear power plant, 1,200-1,400 MW, cost you? You do not get it for 5-6 pfennig, it is impossible. We want taxation. If we succeed in this in the next ten years then you cannot have nuclear power plant or a big hydro. It is

so expensive. 5-6 pfennig is acceptable if you have combined gas etc. But these units are generally not for basic loads. If you have to replace 20-40 nuclear power plants from the year 2015 onwards you need big things (?). This is a very serious issue. If you do not assume that business as usual nothing will change the price, then I will agree with you. Maybe 5-6 Pfennig is OK then. But we are all working in a way that in 5-10 years the price have to include quite a lot of other cost events.

Comment from a representative of the energy group
When eco-taxation means complete restructuring of the market, it is probably less acceptable. By using this window of opportunity there is no real market restructuring because still industry can plan on the same costs.

Doutlik
You are talking about tax shift. That has nothing to do with environmental taxation. It is a completely different story. I would like to challenge the assumption that increased prices would have a huge impact on the demand side. In areas where you are taking energy as a cost factor I do not think it would change much more in consumption during production. It might change something on investments into new technology. But that the demand goes up in industry due to the reduced prices – certainly not. In the private life: if I just would look at myself, I do not think that we would all start to leave the lights on because the kWh become less expensive than they were before. There you could have awareness raising campaigns etc.
As for the price elasticity for gasoline from cars: In Hungary the price of gasoline is the same as here in the EU countries. Hungarians earn on average 15 per cent of the EU earnings. The Hungarians are sacrificing on many other things rather than on the car. So there is not much elasticity on the consumption side either.

<u>Question 3 (transport group)</u>
The process of enlargement of the EU and the environment. Generally speaking, the process of enlargement is not a sustainable one. It is oriented towards end-of-pipe technology. Sustainable development is emphasised in the Amsterdam Treaty and should be emphasised more in the enlargement process. With respect to transport, a critical issue for Poland is that the role of public transport and railways is decreasing. How can the enlargement process in a better way promote sustainable transport? Perhaps it is necessary to prepare some kind of strategic environmental impact assessment of the enlargement process.

Wenning
I think that we in the DG Environment try to do. It is also about implementing the environmental *acquis* which means that EC legislation is implemented in the environmental field. To a certain extent it deals with end-of-pipe technologies. This is a precondition that we cannot do anything about.
The integration and the sustainability issue are more difficult to apply. It should also be pointed out that the problem described is also dependent on the countries in central and eastern Europe. If there is not a sufficiently strong political will and demand from the various players in the transport sector then it will be very difficult for our side to come

forward with the sustainability criteria. We look at it from the environmental point of view. But we have many other DGs which are involved in the enlargement process and which do not necessarily see the environment as the main factor. I feel very much that the accession countries need in their policies, in their political statements in their own countries, to make a much bigger claim what they really want. They have to tell the Commission what do they want and what do they feel is necessary. Only then will there be pressure for many of us to reconsider and rethink some of the concepts which are currently being transferred to the transition economies.

Rossetti di Valdalbero

In the Research DG we deal with external costs evaluation from about ten years. You have probably heard about the European ExternE project dealing with the external costs for electricity production in the European Union countries. There has been a new publication very recently, at the end of 1999; it is available for anyone interested. Even if there is still important uncertainties (e.g value of statistical life, willingness to pay, effects of air pollution on global warming) similar figures appear in all the case studies. For example, coal has between two and three times more external costs than gas.

To answer the question about the most growing sector, transport, we can expect 40 per cent increase of carbon dioxide emissions between 1990 and 2010. That is our modelling expectation. I would like to remind the Director General of DG Energy and Transport, Mr. Lamoureux that highlights an illustrative figure for transport sustainability. In the EU we are closing 600 km of railway per year and in the same time we are building 1,200 km of motorways. Are we on the way of sustainability?

If you go in southern European countries which benefit from structural funds (Portugal, south Italy and Spain) you see the motorways that we are building. Some of the financing comes from EU sources, for example the Trans European Network. In proportion to the total project cost it is a small part. Of course countries like Poland and Hungary will need such kind of help. It is important to try to have an integration of the environmental aspects into the different policies for example that carbon dioxide reduction targets are coherent with the transport policies. We could eventually imagine an "observer" that raises the point of coherence policies in different Council of Ministers (environment, transport)[2].

von Scholz

[2] As Domenico Rossetti di Valdalbero had to leave before the end of the meeting, he after the session added the following elements of information.

(1) In the short term (until Kyoto), the role of research and innovation is limited. But considering the longer term (2020-2030), new technologies will have a crucial role to play (cf. the post-Kyoto period when the marginal cost of emission reduction will be doubled or tripled);

(2) As a lot of work has already been done to evaluate external costs (cf. the EXTERNE project financed by the Research DG), the question is now how to practically internalise these socio-environmental costs.

(3) With the current economic growth of some developing countries (cf. India and China), political, environmental and technological measures should be taken in order to avoid a drastic increase of emissions at the world level.

(4) The distinction among electricity sector and transport sector will tend to be reduced with the emerging fuel cells.

You touched upon a very important point. In fact, enlargement is for sure the second driving force in energy policy. The first one is environment. With respect to enlargement, the real problem, as far as we see from the energy side, is the transportation sector. I just speak now about energy demand. So if you look at it from the demand side: yes, you are right, transport is really the sector were we have a problem. From your side, central and eastern Europe, we would like that you try to influence, even before you join the EU. We have now two or three revisions of policies, of legislation chapters, which are on the table. They will be revised before the CEE countries will join the EU. This is very good news I hope. The first one is a revision of the common transport policy. It will come out by summer 2000. Here you find the most important issue, modal shift. The Commission, together with the Member States, to stop and reverse the trend that rail and waterways are losing market shares. For example, we have to learn how to combine road traffic with rail traffic. These things are not new. But really we have to put it more in a substantive policy. The first thing is to abolish in the ministries and the EU these supply side minds in the transport sector. In probably every transport ministry you have a rail department, a road department, a navigation department etc. We have the same in the Commission. That is not very helpful. Because every department tries to increase its share toward the other ones. So what we really need, and this will be number one, in the revised common transport policy is a modal shift and a more horizontal demand use. Here obviously we have to work with fiscal pricing etc. The second important point is urban transport. We will come with a green paper before the end of this year; this is a first start. We hope to come with quite a lot of measures and proposals in the course of 2001, partly under DG Environment's Climate Change Programme. For sure, urban transport as such has never been tackled from the side of the EU. That is a problem per se. The third thing is the issue of TransEuropean Networks (TEN). We believe that we should with the help of the candidate countries try to work more on waterways and railways. Within TEN they have been more or less abandoned. People are much more focusing on roads. Here we need the help and understanding of the candidate countries.

Comment from a representative of the transport group
It was a very diplomatic answer. One question: how could the policy of the European Investment Bank be changed? The EIB is generally focused on roads and unfortunately less on the railways. There is probably nothing done on public transport in cities. From my knowledge, the EIB tend to support motorways.

von Scholz
That is exactly the reason I told you. If we would have had a revised common transport 1.5 years ago we could have brought this in the decision of the government board of the EIB. And we could bring this in when you define the criteria for the ISPA mechanism. But as long as you do not have it we cannot go to Luxembourg and say in the EIB governing board, where the Commission is a member, that you have to do this and this. Because there is not yet a Community viewpoint on this. This will be done within six months and then you will hear, I hope, the voice of Commissioner Depalacio and of Mr. Lamoureux. They will have something then that has been brought forward, discussed in the parliament – the parliament has a very media efficient resonance – and also quite a lot of Member States will probably will go down this road.

Comment from a representative of the transport group
What about ISPA?[3]

von Scholz
For ISPA also. ISPA is an instrument which has been only conceived. It will work for the next 3-7 years, until the last country comes in. For sure, we can and have to correct it. But first we need to define a common attitude. We do not have a common Commission attitude; we do not have agreed it with the Member States or the parliament. Here we need another 12 months.

Doutlik
On the industry side, maybe there is a bit more light at the end of the tunnel. First of all, for new investments I think it is no question that you go ahead to apply technology which do not need end of pipe solutions to combat emissions. Certainly there is a problem with existing installations. Will they be kept? Many of them you will have to keep for a while to avoid social problems. A mixture of end of pipe installations and management improvement is required. Moreover, awareness raising and information assistance. Cleaner production centres are in place in all of the accession countries. There is a network between these centres. There is also the Regional Environmental Centre in Hungary which is doing an excellent work. The people working there are highly motivated. Maybe you need ten times as many people in those areas. That would be a good investment. A second area where especially Poland might come to focus on is the Baltic 21 initiative. It is combining all the countries around the Baltic Sea. There is an industry part of Baltic 21 trying to move towards sustainable development. Maybe that is a nucleus which you could build on in order to get your own people motivated. But there is room for assistance from outside too.

Kåberger
Going by car you can manage to produce about 25 kg of carbon dioxide per hour. By flying you can produce about 200 kg per hour.

<u>Question 4 (transport group)</u>
The transport group discussed something that would be vital for making transport more environmentally sound. In my view it would be strategic environmental assessment (SEA). It would be good to have SEA being implemented as soon as possible. National governments are occupied with expanding infrastructure which creates additional demand for transport. Furthermore, aviation is lacking a general master plan regarding the transport infrastructure that we have. For instance, in Germany every city that wants to construct an airport may ask for permission at state level. In the case that certain regulations are fulfilled they will be allowed to do so. Therefore we do not have any national discussion at all on the overall capacity. It does not happen because there is a competition between the different airports and the people who ask for additional airports.

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[3] ISPA (Instrument for Structural Policies for Pre-Accession) is an EU financial instrument to support environmental protection and transport infrastructure among accession countries in Central and Eastern Europe.

Another issue, also related to aviation, is internalisation of external costs. In this regard there is hardly any progress. We are not even having a level playing field. It is not even so that excise duties that normally have to be paid on the road or value added tax are levied on aviation. So there is really a lack of policy in this field. So the questions is: what is the Commission planning to do with respect to SEA and a level playing field for transport/aviation?

Wenning
I think it is very clear that there is something not right in the aviation sector. We also know that international competitive issues are very important here. We are referred to International Civil Aviation Organisation (ICAO) to come forward with some sort of global arrangement/measures. We know that there is very little progress on that. There is an environmental committee of ICAO which is not going very far. At the Community level we are facing the problem of taxation. At the moment we are not getting very far with that. I do really fear that on that particular issue it is very difficult to go ahead. I have to admit we have to rethink what we can do. Until some very basic things like majority voting is clarified it will be very difficult.

von Scholz
With respect to SEA, there has been a joint position by the Parliament and the Council. We hope that within 1.5 years this will finally come to a European directive. It needs another two years to be implemented in the Member States.
One additional thing on aviation: for the time being there are really perversions. A flight Brussels-Nice can cost 1,500 Belgium Franc. That is about 40 USD. It can be the same to go from Brussels to Berlin. Our DG, Transport and Energy, really tries to find a way out that aviation inside EU on what we call short distances, should be brought to prices which are not going under the railway prices. For the time being, air transport is challenging the rail transport and this is technically and economically non-sense. We know the problem but we do not know how to tackle it.

Doutlik
The fuel consumption in aviation is four times higher than for the car. But modern airplanes use 30-40 per cent less fuel than older ones.

Comment from a representative of the transport group
But the growth completely counteracts the efficiency improvements. This means that aviation is consuming more and more energy.

Kåberger
Any more comments?

Moons
Regarding competition between cities to have their own airports. I think that one of the biggest challenges that are related to infrastructure is to have a more co-ordinated policy-making within Europe. In the Netherlands we have had a big discussion about Schiphol

airport. In Belgium there has been a big discussion about Brussels airport. In my opinion, one option could be one airport for both the Netherlands and Belgium.

Andersson
What can be said about the general capacity of the EU, especially the Commission, to deal with the long-term challenges?

von Scholz
Obviously we know that before we can come to an enlargement we need to get our home more clearly as far as decision-making is concerned. In order to be more efficient the Council of Ministers needs to go away from unanimous voting. It is already today almost impossible within 15 Member States, it will be worse with 25. Countries like Malta and Cyprus can block decisions for 450 million people. That is the limit of reason. Furthermore, for sure we need an increased role of the EU parliament. The parliament should be more in power and should have a better control of what we are doing. The control via the national parliaments is also very efficient but it is an indirect control. It may be not enough. At the recent Lisbon Council there is a certain taking in hand by the head of states of being more directed. This may be a good thing if it is accompanied by a reorganisation of the decision-making process. If this will not be organised then I think we are going into a mess. The heads of 20-25 states will direct the European business. Here it would be better if there was a strong possibility for the Commission to discuss with the Member States.

Rossetti di Valdalbero
For long-term challenges, it seems to me essential that Europe gives enough resources to Research and Technological Development. In relation to our GDP, we spend less than USA and Japan. In the energy and environment field, especially for the long-term, new technologies will not only be essential but really necessary. When the easiest and cheapest measures will have been taken, to struggle climate change, industrialised countries will need new solutions behind the traditional policies and measures. Technology has a great role to play.

Wenning
I think the fact that sustainable development has become more common on the Commission's agenda – it is moving slowly but it is growing – that as such is a positive factor in terms that we had to think more long-term. If we take sustainable development serious we can not allow us only to look at very short-term options. The integration process with regard to sustainable development will help to look at more long-term solutions. We have just set up on climate change a European Climate Change Programme. It is a programme which tries to bring the stakeholders together to come to some understanding - economic, technical and scientific understanding – of what are the options for change in various sectors. There is particular emphasis on transport and energy. This is a programme which is not itself making big policy proposals, that is the right of the Commission, but it will hopefully prepare a basis on which we have some consensus among the different stakeholders within the EU. This can be a basis for the Commission to make relatively quickly proposals. We are just in the process to set up

specific working groups which will deal with energy supply, energy consumption, and transport. The purpose of the whole exercise is very concrete proposals on what can be done. This initiative points in the direction that sustainable development is getting bigger attention. It is not only a lip service. At the Commission level I feel that the different DGs which have been operating rather apart from each other for a long time are really now moving closer together. This has also to be done at the national level. Still policy-makers from different ministries do not talk to each other. I think that the EU Member States can learn from the Commission.

Moons
In the Netherlands we are working on our fourth National Environmental Policy Plan. We think that we need a real fundamental change. There are some reasons for that. It is related to persistent environmental problems like climate change. Sustainability is more or less only about the environment. But real sustainability implies that one should look at the linkage between environmental problems and problems related to economic and social issues. With respect to climate change one of the biggest challenges is bridging the gap between North and South.
We have a lot of discussions in the Netherlands. If one Member States talks then it is the Netherlands. But because we have so much fragmentation with different agencies etc it is very difficult in practice to get a real impact and make a real change.

Kåberger
In the economic analysis of industrial development there is a theory of about he need for a government that puts modernisation pressure on industry to make them act quicker in taking up new technology than they will do by themselves. The issue of getting the industry to be more strategic than they are themselves. Energy efficiency and the challenges of climate change may be one example which could favour the European industry by making them be ahead? Is this an issue for the European Commission or should this be dealt with by the Member States?

Doutlik
Industrial policy is rather weakly embedded in the treaty. But nevertheless the last Lisbon summit recognised the need for a change of modernising the economy and taking up the new challenges. Although the term sustainable development was not used in Lisbon if you look carefully at the text between the lines things are supposed to happen along the lines of sustainable development. On the other hand I think that referring to the way politics are made and governments are acting we have been doing very much end of pipe politics. A problem is recognised and then something is done at the end. We have to move into integration and interaction. Realising things ahead of time and acting with long-term perspectives. Maybe the Commission is a unique body. In contrast to national governments we do not have a four year cycle. We are more of a constant body because we do not have the four year election to election procedure going on which should help. That needs to be put into perspective with the overall political situation. There I think very much the way decisions in Europe are made in the Council needs to be improved. No way we can continue in this manner.

Kåberger thanked the panellists for their participation and for their constructive contributions.

Part II: Sector Group sessions

2.1 Report from the energy group

Participants
Magnus Andersson, Wageningen University, the Netherlands (secretary)
Rob Bradley, Climate Network Europe, Belgium
Mats Eriksson, European Parliament (day 1)
Ewaryst Hille, Foundation for Effective Energy Use, Poland
Tomas Kåberger, Chalmers Technical University, Sweden (chairman)
Simon Minett, Cogen Europe, Belgium (day 2)
Arthur Mol, Wageningen University, the Netherlands
Katharina Ossenberg-Frances, Future Studies Unit, European Commission (day 1)
Bjorn-Olof Svanholm, Birka Energy, Sweden
Dian Phylipsen, Ecofys, the Netherlands (day 1)
Diana Vorsatz-Urge, Central European University, Hungary

2.1.1 Future Image (Day 1)

The chairman started by describing the key features of the future image (2050) compared to the situation in 2000: roughly the same energy use as in 2000, the use of gas is doubled, the use of biomass has increased twelve times (according to the image 17% of total land is used for biomass), nuclear power has reduced its share from 14% to 3% and solar PV and hydro power have increased their shares. He also emphasised that the future image was based on a decentralised system.

After this presentation Dian Phylipsen (DP) addressed some of the questions to science formulated by the energy group at the first workshop. Some of her conclusions were the following:
Learning curves: PV production needs to increase a few hundred times in order to become competitive. Niche markets may provide interesting opportunities, especially for risky investments.
The price of CO2: The current price is between 5-80 USD per tonne.
CO2 storage experiences: The technology is available but much can be improved. First project made by Norway is 1996. Most promising is insertion into aquifers. The cost is varying from 10-80 Euro per tonne.
Hydrogen in the gas grid: It is possible on the medium term but the grid and equipment (e.g. furnaces, boilers) should be adjusted.

The subsequent discussion focused on the future image. A question about the definition of biomass was raised. It was noted that the role of solar PV/thermal was too small. Furthermore, 3% nuclear power was seen as an arbitrary figure.
One participant wanted to hear something about directly and indirectly related working places related to the image. Another participant called for a discussion on the driving forces. One question in this respect is: who in society will support solar in the future? Another participant questioned the assumption that the price of carbon dioxide will be

lower than the costs for carbon dioxide removal and storage. People may very well be prepared to pay for clean and safe energy.

At this stage the chairman proposed to vote (with stickers) about how the image should be changed.

Proposed change	**Number of votes**
Eliminate nuclear power	****
More wind power	****
More solar	*****
The role of the population size	-
More ideas about behaviour/awareness	*****
Gasification of coal	-
Automotive fuel	-
Biomass land use	******

Energy security. The question was raised whether security of energy supply is improved in the future image compared to the present situation. DP declared that there was an increased dependency for natural gas, but that on the on the hand less oil consumption means less dependency on OPEC countries.
It was emphasized that there is a huge potential for behavioural changes in the households. One participant argued that this potential was not explicitly quantified in the image. DP explained that without any behavioural and structural change, energy consumption would have tripled, instead of stabilised. In order to achieve that change a lot of behavioural changes are needed (and are included in the image, although not explicitly quantified, the reductions in energy consumption are a combination of the effect of behavioural changes, energy efficiency changes and structural change.) Will there be any manufacturing left in Europe by 2050? Yes, but a different type. There will be more focus on knowledge intensive industries, recycling, refill etc. How about gas production via coal cracking?

Nuclear power. The role of nuclear power was discussed. It was concluded that either nuclear power will be phased out completely or it will play a very important role. Something in between is not conceivable. A final decision was taken to leave out nuclear power.

The chairman drew a figure on the relation between supply and price.

Wind power. Wind power was discussed extensively. It was noted that the learning curve has become very steep the last few years. Wind power will become cheaper and cheaper and a breakthrough is near. It was suggested to increase the share of wind power in the future image threefold to 15%.

Solar. DP argued that solar had a very small potential. This was seen as a serious issue. A questioned was raised about how the contribution of solar could be become non-trivial. DP stated that the only way to substantially increase the share of PV (above maybe a doubling or tripling of the figures currently in the image) is having large-scale systems, such as in the Sahara. The suggestion was made for replacing part of the biomass land with PV systems. Centralized PV systems may be an option for the future. Furthermore, Shell's interest in solar was seen as very promising.

Decision-making criteria. What will be the criteria in 2050 to support the structure suggested by the future image? There is a difference between the future criteria and the present ones. Criteria for decision-making should be addressed. There is a risk that this exercise will generate a large number of options without clear criteria for choices to be made.

Biomass. Land-use implication of biomass was discussed. It was noted that in the national dialogue biomass is considered to be "the option". The role of biomass in the future image implies that 17% of the total EU land area should be devoted to biomass. (Of this 80% would be excess crop land.) 40% of the current crop land will be used for biomass. The land for biomass will exceed cropland by 2050. It was pointed out that trees could be planted around houses. The biomass policy could in this way be integrated with the building codes. The negative effects of large-scale biomass plantations on recreation were addressed.

It was stated that 17% of land use for biomass could be replaced by 2% with solar PV. The latter option is better given, *inter alia*, the recreational aspects.

In a thirty year perspective biomass is a natural alternative for Poland. It can contribute to reduce employment. (After 2030 solar, wind and other sources should have higher priority in Poland.) Structural change may be slowed down if there are no mechanisms to deal with accumulating unemployment.

Behavioural change. The potential for behavioural change is high. The role of green electricity schemes was mentioned. It was noted that it is impossible to enforce behavioural change. For that purpose you need a fascist regime. Behavioural changes cannot be taken for granted.

Key conclusions of the session

- Either there is a lot of nuclear power in the future image or there is nothing. In other words either nuclear power is economically viable and accepted or it is not. Economic viability is not the only criteria! Acceptance can be different for different countries.
- The role of wind power in the future image should be increased threefold.
- Solar can be an alternative to large-scale biomass plantations due to the potential shortage of land. But probably it is more expensive.
- It is important to take into account the labour market, energy security and leisure in designing long-term energy policies. These aspects should be taken into account in designing policies for the long term (2050), the medium term (2030) and the short term (2010).
- Behavioural changes are very important even though they are not explicitly quantified in the image. However, these changes cannot be taken for granted since they cannot be enforced in a democratic state.

2.1.2 Strategic Choices (Day 1)

Initially it was concluded that it is important to create a setting that can make the transition possible. We need to have the right institutions to achieve the changes.

Three possible routes were pointed out:
(1) Carbon dioxide certificates
(2) Environmentally based carbon dioxide taxes or carbon dioxide fees
(3) Administratively based measures. For example, it could be stated in a law that certain reduction should be achieved each decade. (Or: all persons must buy their energy produced by renewables.)

This way of structuring the problem was met with support in the group. However, more than one person pointed out that more than carbon dioxide policies will be needed. A more complex set of policies is required to address the problem properly. One has to define the roles of the scientific, policy and business communities. One has to consider the pros and cons of bottom-up versus top-down approaches. Furthermore, the dynamics of the technological development is extremely important. Stranded asset creation should be avoided. The backcasting method could be a helpful tool for this purpose.

A table of key aims, policy instruments and required institutions was elaborated.

Strategic options: key aims, policy instruments and required institutions

Key aims	**Policy instruments**	**Institutions**
Carbon dioxide reduction	Tradable quotas or Carbon dioxide tax	Best: Global trading system organised by the WTO 2nd best: other multinational approaches
Avoid other/new external costs	Environmental taxes Nuclear liabilities	
Minimise cost of reduction Make alternatives competitive	Information Education R&D Standardisation Procurement Fiscal instruments No Fossil Fuel Obligation (NFFO)	
Avoid stranded costs	Use back casting	
Public awareness	Education Access to information	

New/and or intermediate institutions		There are actors who have a potential interest in creating a coalition to build the new institutions. Examples: think tanks, trans national companies, environmental NGOs, insurance companies etc.

The most important obstacles that were identified are presented in the table below.

Obstacles and possible measures to overcome them.

Type of obstacle	**Possible measure**
Prices may play a limited role in an affluent society.	Other than economic policy measures are needed.
Lack of awareness and high transaction costs are important obstacles for mobilising support among existing actors	Education.
Microeconomic actors will not take risks.	Political decisions are needed to take these risks. Therefore, a key issue in the beginning of the transition is risk reduction. Flexibility should be built into the prices so that risks can be handled.
People are not 100% (economically) rational.	Create a system to help people to value decisions (or in which economic incentives are not the only instruments used)

In approaching the long-term policy challenges it is useful to decide the general setting before the means (policy instruments) are be discussed. Moreover, complex problems should be divided into segments to facilitate a constructive analysis. Different types of institution may be needed at different stages of the transition. It may also be necessary to create different trajectories towards the future image.

Technological solutions are not a real barrier. A lot of work is still needed on R&D, cost reductions, etc but these are in principle feasible. The key issue is how to implement the carbon restriction.

2.1.3 Stories on Pathways (Day 2)

At the beginning of the second day of the workshop the energy group was divided into two subgroups. Each group was given the task to write a story on a pathway. The two stories were entitled "Deregulation and sustainable development in Europe" and "Bioenergy made energy sustainable".

Story number 1: Deregulation and sustainable development in Europe

European conditions were helped considerably by the appointment in late 2000 of Rob Bradley as president of the Union. The European Union, following its conversion to the use of market forces, set the framework conditions correctly from the outset. These conditions included:

- Completion of the deregulation process, giving rise to complete price transparency and low barriers to entry for new technologies and companies
- Removal of environmentally damaging subsidies for e.g. coal and nuclear power
- Internalisation of environmental costs through a change in tax structure to apply levies to carbon, air pollutants, radioactive waste, etc.

These reforms were easier to implement because of the economic climate in the EU in the early part of the century. As well as losing their senses over their late conversion to the internet economy, Europeans were enjoying steadily declining prices. They were therefore relaxed about a steady increase in taxation of energy products. Rising environmental awareness also increased public support.

The later technological development in the market was somewhat chaotic, and incorporated several brilliant inventions by President Bradley, but intervention in the market was minimal. New renewable technologies were exempted from tax and their implementation increased rapidly.

Demand side issues were more problematic. Although the price signals from environmental levies helped, it was still necessary to provide additional impetus to efficiency through for example building codes.

The use of biomass proved most complex. The reform of agricultural policy in parallel with the enlargement process freed up land, but pressure also grew to conserve the sites of natural importance in the new EU member states. Biomass did play a significant role through co-generation, but constant tensions remained over the use of land.

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. Concerns over instability declined as prosperity increased, especially as Egypt's accession to the EU in 2038 gave hope of similar treatment of neighbouring countries, particularly the Democratic Republic of Libya.

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 200 levels. Exploitation of renewable energy sources has reduced imports. China's draining of Russian energy supplies helped push this process, but the market responded rapidly to it. The USA was similarly untroubled, especially due to the statesmanship of President Leonardo Di Caprio.

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 the North natural gas is still important. Cow-generated methane declined in importance following the Vegetarianism Directive of 2045.

<u>Story number 2: Bioenergy made energy sustainable</u>

As Andrej Schmidt retires as president of Europower yesterday he gave a presentation of the history of his company. His main point was that the 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 the 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.

Bioenergy 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 were two points that made the market increase rapidly:

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 directs cogeneration. Later they were central units refining biomass into a set of different products.

By 2010 the use of biomass for energy was expending 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

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 bio-refineries developed to produce fuels and fibre-materials and heat from biomass.

Bio-energy 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. As methods to extract metals developed we could use energy-plantations for decontamination of land

and later for metal extraction. Some metals were deliberately sought by planting energy crops on lands with high concentrations.

Already in the early 21 century there were district heating systems in the eastern countries joining the Union

2.1.4 Path Construction (Day 2)

Strategic elements of the pathway

The scenario is based on extensive, complete deregulation in which deregulation causes lower prices and higher demand. Furthermore, all subsidies have been removed.

The following recommendation is made: carbon dioxide fees and other environmental fees should be imposed. See figure below.

Pf/kW

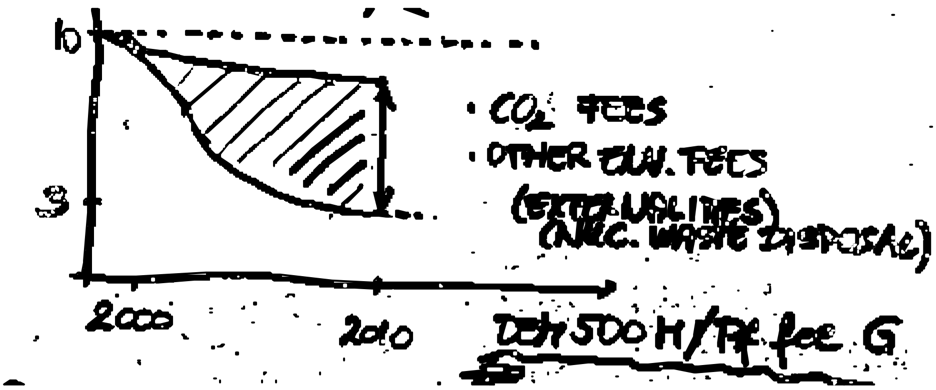


Figure: ………(impression of the sketch presented on overhead sheet at the energy group.

Revenues should be used for: (1) replacing income tax (partially), (2) support to renewables via R&D, procurement etc, (3) demand-side efficiency based on building-codes, standards, labelling, demand-side management etc, (4) education, and (5) environmental investment in connection with EU enlargement in central and eastern Europe.

The key allies in achieving this change would be the following actors: voters (reduced income tax), government (extra revenue), power industry (after some time…), environmentalists and possibly also some consumers.

Opposition is expected to come from large energy consumers (industry) and perhaps also the power industry.

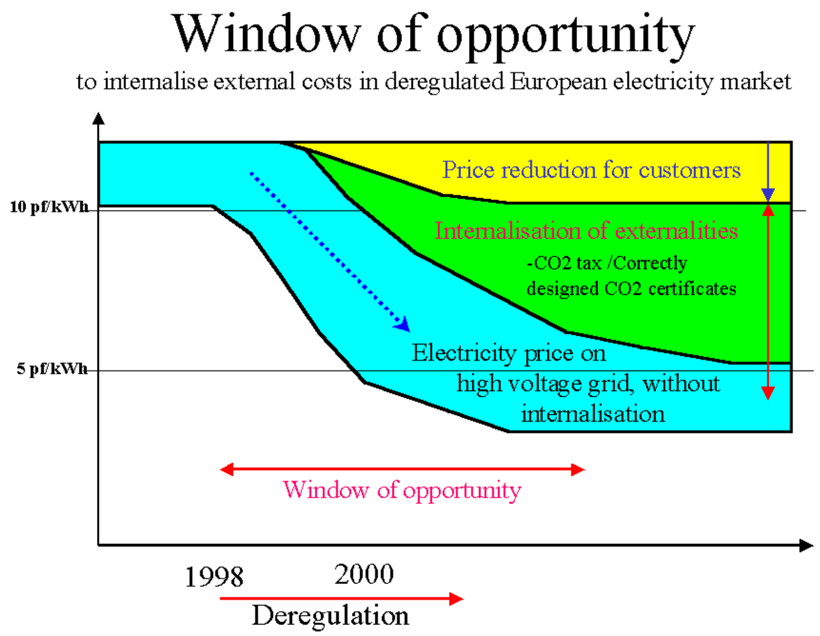


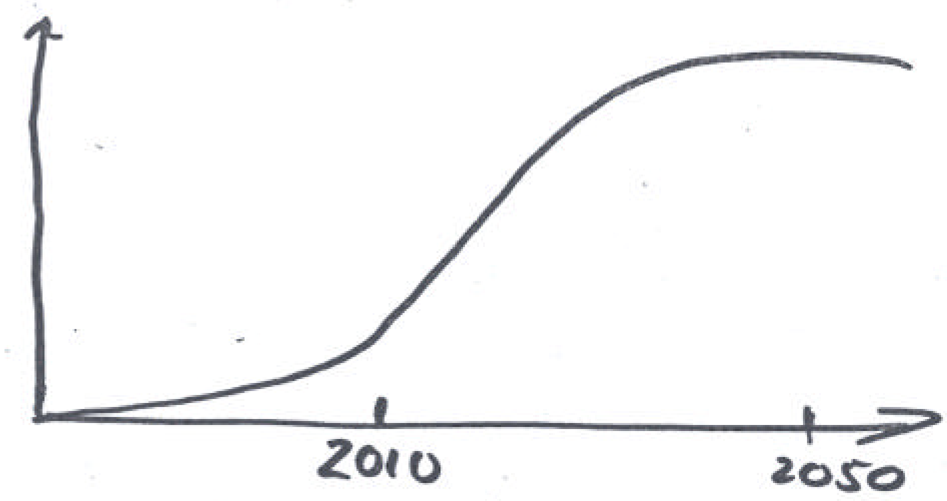
Figure: Window of opportunity to internalise external cocsts in deregulated European electricity market.

Further fees
Demand side efficiency, policies
Education, information

A major benefit is that the electricity price will still be lower than in 2000. Moreover, there is no need for market intervention. It is the best opportunity to introduce fees.

Two major drawbacks were identified. First, while prices do not completely reflect full costs, there is a need to invest in demand-side efficiency, R.E. (?) Second, market barriers prevail despite of high long-term prices, especially in consumer sector. Hence, corrective policies will be needed.

Intermediate steps



	2010	2030	2050
Deregulation and sustainable development	Planning constraints for dinosaurs Electricity labelling schemes Micro CHP starts to penetrate Network issues (power grids) need to address decentralisation	Market driven system development Labelling schemes become dominant in customer choice Micro CHP large share of domestic market Decentralisation is the norm with local networks connected to each other with DC links	Land value a limit - food demand Competition from solar - hydrogen
Bioneergy	Trade in refined biofuels Working gasification Planned bioproduct use Integration into agricultural policy	Metal extraction from biofuels Land is becoming valuable	Hydro resources are used for peaking power in preference to base load

PMI - Plus-minus-interesting

Agree	Carbon pricing
Disagree	Attention to be paid to demand-side analysis

Interesting	Window of opportunity for taxation Technological optimism

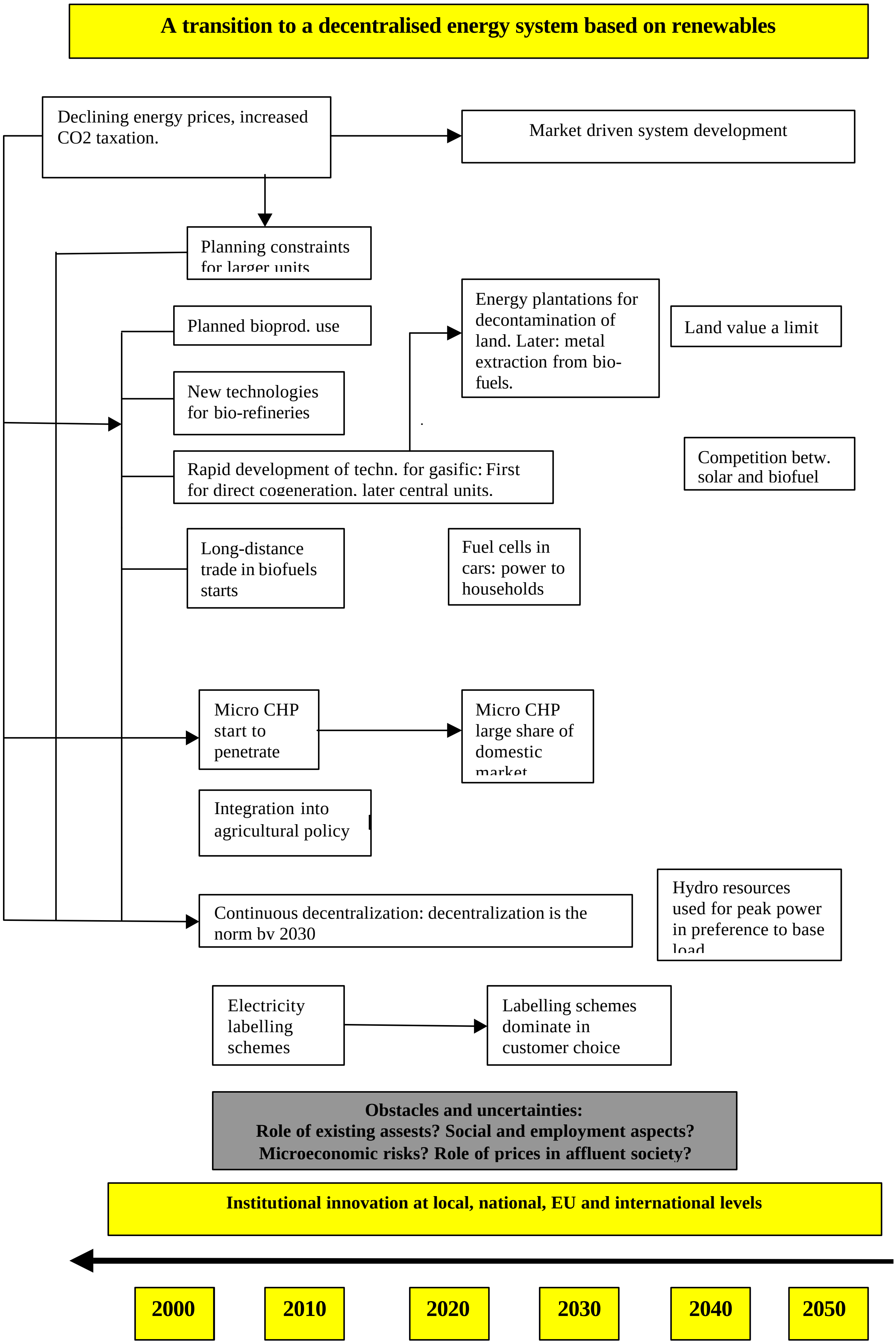
The energy group formulated the following questions to science:

Questions to science formulated by the energy group.

Question	Priority
1. What will be the role of existing assets in the transformation?	*
2. What will be the role of existing players in the transformation? What incentives should be given to current players to make changes which are required for the long term?	**
3. What is the potential of solar PV?	*
4. What are the complementary benefits of major new technologies?	
5. What is the equilibrium price for electricity in Europe without environmentally based taxes?	***
6. What measures should be taken to move from a central/top-down transmission system to a small scale/bottom-up system?	*****
7. How will the price level be if the electricity grid is run efficiently?	**
8. To what extent much does the size of the population matter?	
9. What is the potential for energy efficiency?	

Questions to the policy panel

Question	Priority
Is there a window of opportunity in the EU for new carbon fees/taxes?	High
How could be transition to a decentralised energy system be facilitated?	High
Can greenhouse gas reductions reduce the competitiveness of EU industry?	Low
Can the Commission deal with the long-term?	Low
Is there a potential for a legal basis for a common energy policy in the EU?	High
What can be done to facilitate integration of climate concerns into the sectoral policies?	Low


A transition to a decentralised energy system based on renewables
Declining energy prices, increased CO2 taxation.
Market driven system development
Planning constraints for larger units
Planned bioprod. use
Energy plantations for decontamination of land. Later: metal extraction from bio-fuels.
Land value a limit
New technologies for bio-refineries
Rapid development of techn. for gasific: First for direct cogeneration, later central units.
Competition betw. solar and biofuel
Long-distance trade in biofuels starts
Fuel cells in cars: power to households
Micro CHP start to penetrate
Micro CHP large share of domestic market
Integration into agricultural policy
Continuous decentralization: decentralization is the norm by 2030
Hydro resources used for peak power in preference to base load
Electricity labelling schemes
Labelling schemes dominate in customer choice
Obstacles and uncertainties:
Role of existing assests? Social and employment aspects?
Microeconomic risks? Role of prices in affluent society?
Institutional innovation at local, national, EU and international levels
2000
2010
2020
2030
2040
2050

2.2 Report from the Transport group.

Participants:
P Beeckmans, Community of European Railways, Belgium
G Bennett, Syzygy, the Netherlands (Chair)
U Hartman, DaimlerChrysler, Germany
A Kassenberg, Institute for Sustainable Development, Poland
R Kemp, MERIT, Maastricht University, the Netherlands
A Pastowski, Wuppertal Institute, Germany
J-P Paul, European Commission
B Schell, European Federation for Transport and Environment, Belgium
B Thorborg, Ministry of Transport, Public Utilities and Waterways, the Netherlands
W Tuinstra,Wageningen University, (Secretary)
A Wijkman, European Parliament

2.2.1 Future Images (Day 1)

The chairman started with describing the key features of the future image (2050). As regards the main characteristics of the transport system in 2050 there is, compared with the situation now, a higher diversity of vehicles. Small electric vehicles for city use are in operation. There is an increased share of public transport. New residential patterns have reduced commuting to work. Information and communication and technology also help to reduce the need for transport. Air travel and inter-urban use of the car will increase. The energy used by the transport sector is 20 per cent lower. This includes the energy used in producing certain fuels. The total passenger transport level is 40 per cent higher than the existing level. Freight transport is 30 per cent higher.

With respect to fuel substitution, there is a big increase in the use of cars with fuel cells, to a large extent dependent on biomass. Twenty per cent still use fossil fuels. A large number of the truck fleet use fuel cells. In the aviation sector kerosene is still dominating because the transition to hydrogen has only just started.

The efficiency of the vehicle technologies has increased substantially.

The most important changes in residential pattern and economic structures are decentralised concentrations, with more self-sufficient communities with their own shops, services and tele-cottages where people can work locally. There is a continuing trend toward globalisation of the economy. Many products can be produced locally.

Changes in awareness, values and life-styles will have an important effect on greenhouse emissions.

Changes and amendments

The group had identified several issues for discussion.

A major comment regarded the somewhat “conservative” perspective of the image. The image has a industrial society perspective and future society might be completely different. It was agreed that for the COOL-process it is especially interesting to explore new kinds of societies. Furthermore it was noted, that though in consultation with the group it had been decided that for pragmatic reasons just 1 future image would be presented, just the presentation of 1 future image could give the misleading impression that this would be the expected or the only one future. This impression of course should be avoided.

Apart from the request to clarify the figures and the assumptions of the image the other issues raised included:

1) The implication of new decision-making processes in two respects. First of all, ways of ensuring that the decision-making process takes better account of long-term interests of changes rather than the four-five years election terms that we now have. Secondly, determine at which level of policy-making measures should be taken, whether it is local, national, regional or global.
2) Implications of the new economy for the image. There are a number of points related to this. Firstly, the changing role of the main economic actors, particularly in terms of globalisation and liberalisation. Also the concentration of economic power in fifty years will effect the economy. Secondly, the future effect of information and communication technology on transport patterns. Thirdly, the relationship between the new economy and changes of behaviour.
3) The issue of transport needs. Transport is a service which responses to the needs of society. The demand for transport services in 2050 must be made clear. This is also a question of price elasticity. Even though we may change the prices for some of the fuels by financial incentives a change in actual transport patterns and modalities cannot be taken for granted.
4) A specific point was made on biomass. To what extent is large-scale production of biomass through dedicated plantation feasible in Europe? To what extent is it sustainable? This is also a question to the energy group.
5) Behavioural and social factors that need further consideration. Some people felt that the image was too technological in its profile. The impact of advertising on individual behaviour. That may have a huge difference to the transport sector, especially with regard to car ownership.
6) Links between the elements of the image were seen as very important. It is important to the way those elements interact. The issue of achieving carbon dioxide emission reductions in sustainable vs. non-sustainable ways has implications for the image. Social change and technological change are closely linked. This interrelationship shouldn't be forgotten. Individual perceptions about the need for transport is a very important topic. The impact of demographic change (such as immigration patterns, the changing age structure) is also important.
7) Modal split. A specification is needed with respect to the role of non-motorised transport in use. The impact and the role of land-use planning in helping to facilitate and promote particular forms of transport, including non-motorised transport. One possibility is combined passenger-freight transport, particularly in urban areas.
8) The role of investment policies, incentives and regulation. Transport is a derived demand which means that the choice for certain investments have very important consequences for the transport sector

Moreover, political factors were mentioned as being important. For example, the West is very dependent on the Middle East for the supply of oils. There may be political reasons for moving away from that dependency towards renewable sources of fuels.

It was questioned whether the significant role of fuel cells in the future image was feasible. Nuclear fusion was mentioned as a possibility. Electronic coupling of vehicles for long-distance travelling was mentioned as an option . The image is considered to be rather conservative on the potential for hydrogen. There might be greater potential for using hydrogen during 50 years. There is a need for clarification which effects the elements of the image will have on other sectors of society.

It was concluded that most of the issues will have to play a major role in the construction of the pathways and the formulation of the Strategic Visions.

2.2.2 Strategic Choices (Day 1)

For the identification of trajectories from the past to the present it is important to identify the main strategic choices which have to be made at a certain point. The chairman discerned further two other aspects, which play a role next to the strategic choices: important preconditions for certain choices and actions, and surprises that would have an impact on the choice.

In a brainstorm round the group came up with a list of strategic choices, which subsequently were ordered according certain categories: Actions for Policy, Public investments, Information/awareness, Structural Change and Institutional Change.

Main Strategic Choices
Policy • Develop Instruments (economical, legislation, others) • Enhance competitive public transport (price) • Acknowledge changing driving forces (business, NGO, Public, government) • Set challenging performance standards→ Environmental benefits should be included in business "games". Stimulus on innovation needed • Leave it to the markets to reach the standards • Identify convergence criteria on transport and energy (for countries inside and coming into the EU) • Remove perverse subsidies
Public Investments • Reshuffling of R&D investments • Reshuffling of investments in public transport/ infrastructure (de-coupling) • Green procurement, public purchasing • Funds for leap - frogging

Information /awareness

- Changing mindsets (pre-conceptions about the car)
- Long term communication plan (costs of health, acid rain, climate etc. links) → show implications

Structural change

- Acknowledge geographical/regional differentiation
- Enhance changes in public transport: appealing economical valuable
- Acknowledge changing driving forces (business, NGO, Public, government)
- Enhance changing production patterns and consumption patterns-> reduce need for transport
- Consider how economy relies on car industry and other industries
- Encourage learning/experimentation programmes, developing niche markets

Institutional Change

- Level of decision making has to be on the scale of the system it is concerning
- SEA

The group agreed that the categories were partly overlapping and that it was not always clear in what category a certain issue should go. Also the list turned out to be rather a list of suggestions for action than real strategic choices. It was agreed that for the path construction certain actors and intermediate steps and milestones had to be identified in addition.

The group identified the following preconditions:

Preconditions

- internalisation of external costs
- supply of sustainable energy
- dematerialization
- forerunners (companies, countries)
- Information and Communication Technology (ICT)-access
- “mechanisms” to reward long term thinking
- mechanisms to facilitate structural change
- stimulation of assessment of win-win solutions
- partnerships of green stakeholders, ongoing stakeholder dialogue

Furthermore the following surprises were identified:

Surprises

• Change in Oil price • Technology break through • Nuclear accident • Climate disaster • Economic crash • Paradigm change in mobility • New scientific evidence of a major environmental problem which has implications for climate change policy • Increase fundamentalism in politics: decline in international co-operations • Conflicts / wars

2.2.3 Stories on Pathways (Day2)

In order to be able to discuss certain pathways in the transport sector in more detail, the group was divided in two sub-groups. One sub-group worked on a path-way for Aviation and one sub-group didn't select a specific issue but discussed the changing framework of transport in general.

At the beginning of the session the chairman gave the groups instructions. Intermediate steps should be identified: What are necessary Achievements in the year 2030 and 2010? Key actors and key coalitions should be identified. The level of action should be decided upon: what are key decisions on the European, regional and national levels? Furthermore the groups were asked to elaborate on the interface between policy, business and community. Finally the necessary conditions and important uncertainties and surprises were to be mentioned. If possible the four categories as used in the Future images ha to be used: fuel substitution, efficiency, structures and patterns, awareness/values/lifestyles.

Results of Subgroups and discussions:

<u>Aviation:</u>

The group on aviation presented an outline of its pathway:

Aviation is showing exceptionally high growth rates. Taking the 150% growth in the sector as assumed in the image we end up with a growth of 25 % in aviation's CO_2 emissions. This would require other sub-sectors of transport or other sectors will have to compensate for this growth in emissions.

Key Decisions	*Technology*: • Government spending for R&D investment in hydrogen fueled aircraft (national, Europe) • Technology forcing via emission standards for NOx at cruise altitude (Europe, global) *Demand-oriented Instruments*

	• Full market liberalisation with regard to government ownership of airlines and airports (national, Europe) • Introducing an airport capacitiy policy including SEA (national, Europe) • Enhancing intermodality to reduce short range flights (national, Europe) • Awareness raising for travellers (all levels) *Financial Instruments* • A level playing field as regards taxes (level of excise duties as for motor fuels) (Europe) • Emissions trading (global)
Key Actors	Customers • Airports • ICAO • Tourism Industry • Airlines • Aviation Industry • NGOs
Coalitions	*Market-driven* • Airlines • Airports • Airlines-Airport *Politically-driven* • NGOs and tourism industry
Milestones	• Governments get out of the aviation business (2010) • Excise duty on kerosene introduced (2005) • Emission trading regime for aviation introduced at regional or global scale (2015)
Surprises	• Oil price New scientific evidence on the climate impact of aviation
Necessary Conditions	There was no time to discuss this issue

In the subsequent discussion the issue of specifying emission standards as main technology forcing instrument was addressed. The remark was made that air lines could play major role in pushing industry and technology developments.

There was a question why there was no use of hydrogen in the pathway. The sub-groups reply was that hydrogen was not supposed to be implemented yet in the general transport image. The group agreed that it would be worthwhile to introduce hydrogen in a quicker way. If it should be introduced, we should speed up the process. It will take 20 to 30 years to have hydrogen in aviation.

Another remark concerned the capacity problem of the airports. It was suggested that there should be a system in which travelers could change into high-speed trains to reach another airport to take a flight. Another suggestions was to differentiate airports into freight airports, regional airports and local airports. It was agreed that it is really important that there is a less strong link between national governments and airports to facilitate more flexibility. An overall capacity planning for Europe is needed. Coalitions between airports could play a very important role.

The changing framework of transport

The group which discussed the changing framework of transport constructed its path in a different way by identifying certain trends, givens and needs.

As *trends* liberalisation, the growing influence of finance, the development of transport conglomerates (DB), and the increase in freight and passenger transport were signalled. Furthermore the sub-group saw as *given* that mobility can't be reduced, transport is derived demand, that dematerialization is important and that there is a changing government business relationship: the government stepping back

The sub-group argued that there is a *need* for a policy framework to promote environmental sustainability. This would include:
- regulation
- road pricing, CO2 taxes
- emission trading
- co-ordinated planning of transport infrastructures
- land use planning
- restructuring of rail companies esp. in CEE countries

Furthermore the following developments in technology were foreseen:
- Developments in ICT (info + logistics)
- Clean and fuel efficient propulsion
- Underground transport coupling of vehicles-system innovation will occur at jot spots

The sub-group concluded that transport alone will not take account of CO_2 reductions; reduction have to be found in production and consumption in all points of the chain.

2.3.4 Path Construction (Day 2)

As in the earlier sessions the identification "Milestones" had been missing, the chairman initiated a short discussion on milestones. This resulted into the following suggestions:

Milestones
• market introduction fuel cell in Europe • EU finishes its Environmental assessment directive • Policy gets actively involved • European trading system(country by country or sector by sector) is implemented • A monitoring system to monitor environmental development in eastern Europe is implemented.

It was felt that in the earlier discussion on strategic choices and preconditions only listing and no prioritising had been taking place. Therefor, in a new round the issues which were felt to be most important were identified.

With regard to strategic choices:

- effect oriented policies
- policies taking account of boundary conditions
- clear environmental goals
- leaving the means to the market
- creation of ownership of the problem
- consistent long term policy framework (long term certainty for investors, (framework focussed on trading system)
- criteria for green investment
- system innovation
- real use projects, starting with problem areas and preparing for radical change
- forerunners
- recognition of different priorities in different parts of Europe.
- sustainable enlargement

With regard to Preconditions and boundary conditions:

- internalisation of costs
- transport should be seen as a problem. Eco auditing (ISO exists?0
- information on transport actions of goods
- awareness of transport needs
- societal awareness/consumers
- move to local production
- clusters and coalitions to solve problem

ANNEXES

Annex I: List of participants

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Annex II : Letter to participants

Dear participant, Wageningen, March 24th, 2000

On behalf of the project team at Wageningen University I would like to welcome you to the second COOL Europe workshop to be held at Hotel Arenberg in Brussels on 6-7 April. We hope you will find it a fruitful and inspiring meeting!

This workshop has two major aims. The first aim is to adopt Future Images for the energy and transport sectors. The second aim is to discuss possible pathways (implementation trajectories) for the sectors. This process is called Path Construction. The central question with regard to Path Construction is: *how* are the desirable changes going to be achieved, reasoning “back” from the future in 2050 to now?

With this letter you receive:

*** Images of the future for the energy sector and the transport sector**.
Please note that you receive images for both of the sectors. To prepare yourself for the workshop it is only necessary to read the image of your own sector group.
The Future Images have been elaborated by the COOL Europe project team in Wageningen in cooperation with Ecofys in Utrecht and the Environmental Strategies Research Group in Stockholm. They are based on the outcome of the discussions at the first COOL Europe workshop 1 (November 1999). We ask you to carefully read these texts. They serve as the most important input material for the workshop. They will be discussed at the first day of the workshop. Please note the following:

(1) At COOL Europe workshop 1 the transport group discussed two images. After telephone and email consultations with the members of the transport group it was decided to work with one instead of two pictures. Hence, both sector groups will work with one image each.
(2) We do not expect the workshop participants to agree upon the content of the images. You are all invited to indicate on what elements you agree and on what elements you disagree. The COOL Europe project team thinks that the revised future images should be allowed to be pluralistic, that is, there must not be consensus in the sector groups on what elements should be included in the image. But a certain degree of consensus on some key elements is requested for the backcasting process
(3) The future image is a starting point for the backcasting process. After consultations with the workshop participants it has been agreed that the backcasting process should be allowed to be relatively flexible vis-à-vis the future images. This means that not everything that is concluded in the backcasting process must be fully consistent with the future image. The future image should be seen as a reference point to facilitate a focused discussion on strategic issues rather than a straightjacket.

*** Background information on Path Construction**
This paper gives a first introduction to the method of Path Construction. It also gives some first elements to start the path construction in the sector groups.

Furthermore, please find enclosed the programme for the workshop, a list of participants, a map of Brussels, and a list of important addresses.

We kindly ask you to fill in the sheet regarding possible dates for the third and fourth COOL Europe workshops and bring this paper to the meeting.

Finally, you are all welcome to bring material (booklets, information sheets etc) presenting your own organisation/company/institute and information on other things that you think is of potential interest for the participants in the COOL Europe process. This material will be made available at a special table at the workshop facility.

If something is unclear to you, do not hesitate to contact me or Ms Willemijn Tuinstra
(tel: +31-317-48 33 40).

Looking forward to welcome you at to our next workshop,

Yours Sincerely,

Magnus Andersson

COOL Europe project manager

Attachments:
I Programme for the workshop + list of participants
II Future Image for the energy sector
III Future Image for the transport sector
IV Background paper on Path Construction
V Practical information (map of Brussels and important addresses)
VI Sheet regarding possible dates for workshop 3 and 4

Annex III: Background paper for COOL EUROPE : Path analysis

1. Introduction

According to the Canadian scientist Robinson, who coined the term 'backcasting', the backcasting methodology involves "*…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*."[4]

The key point is that you start by designing a Future Image that meets certain criteria, and then try to find a path that links the present with that Image in a credible way. Also, the facilitating role of policy making to the desired evolution must be highlighted. However, there is really no reason why one *must* start from the Future Image and work backwards, when exploring the path. It may be a better idea to try both ways, i.e. working from the present state into the future and from the end-point backwards to the present state. By iterating in this way the chances of finding a credible path increases.

Robinson's emphasis of the *physical feasibility* of the investigated future seems too restrictive. The socio-economic feasibility ought to be equally relevant.

Robinson also points out that the aim is to find policy measures that would be required to reach the Image. It should be stressed, though, that the idea is not to work out a plan to be implemented step by step. Things will happen that are not possible to foresee, making plans obsolete. But a plausible Future Image and a credible path leading up to it indicate that a quite different society is possible, which may work as a mind-opener. As for policy making, the point in this work is that it can guide policy making *today*, but with a view to long term goals, such as sustainability etc.

When studying a large and complex socio-technical system, such as the transport system, one cannot take a linear development for granted. Rather, the development is more likely to follow a co-evolutionary pattern, making exact quantification difficult and dubious. Instead, an essentially qualitative analysis seems to be more relevant. In general terms, the important issues for a path analysis are:

- Identify change processes and trend breaks that are necessary in order for society to meet the criteria by 2050. Analyse time-lines for such processes - e.g rate of diffusion of fuel cell technology - and when they will have to start.
- Identify strategic options for policy making, e.g. whether to go for a direct transition from fossil fuels to hydrogen or to stimulate some intermediary solution, such as methanol.
- Identify important preconditions to be fulfilled, e.g. concerning changes in awareness, perceptions and values.
- Find a 'logic' for the development of society, such that the path and the Future Image look plausible.

In this paper relevant issues for the path analysis are presented in a structured way, in order to facilitate a discussion at workshop 2. Furthermore, some background information is given. The structure is the same as in the Future Image document.

2. Energy sector

An important issue for all of the following is whether external costs of energy will be internalised. One way of internalising external costs could be changing the current tax system in a way that shifts the tax burden from labour to energy and materials consumption.

Fuel substitution

For renewable energy, generation costs will have to be reduced significantly to allow for a large-scale introduction. In case the above-mentioned shift in the tax system differentiates between fuels on the basis of their carbon-content (e.g. through a carbon tax or emission permits) the price difference between conventional energy sources and renewable energy sources would be reduced.
In addition, adopting a non-fossil fuel obligation or a renewable energy portfolio standard could create a niche for renewable energy. This means that a minimum amount of total energy consumption would have to be supplied from non-fossil or renewable sources. This would assure a market potential for renewable energy technologies. Particularly when the minimum amount is increased over time, the costs of supplying renewable energy will decrease.

[4] Robinson, John. 'Futures under glass – a recipe for people who hate to predict', *Futures*, October 1990.

In general, a lifetime of 25-30 years for conventional power plants is assumed, but plants can be kept in operation longer for economic reasons. In a privatised energy market this extended operation can be expected to occur more frequently. On the other hand, the internalisation of external costs may influence this decision by changing the cost/benefit ratio. Irrespective of this, the long lifetime of conventional power plants warrants early action to avoid a carbon-intensive lock-in.

Energy efficiency

Although the energy efficiency of existing power plants can be increased through retrofits, the largest increases in energy efficiency can be obtained when old plants are replaced by new plants. It must be noted that the choice for a particular fuel type significantly influences the efficiency of electricity generation. Gas can be used more efficiently in power plants than coal and conversion losses are even smaller for non-combustion processes (e.g. hydropower). The use of small-scale systems with high efficiencies, such as heat pumps, can be stimulated through subsidies to residents or building corporations. Another option is the implementation (or strengthening) of building regulations with regard to maximum energy consumption for new and/or existing buildings. Furthermore, (voluntary or binding) agreements can be made with architects and building corporations that require the implementation of specific systems. For industry, a CHP obligation can be implemented, requiring a minimum amount of their energy to be delivered through CHP. For energy efficiency too, an increased energy price will help promote higher efficiency options.

Structure and patterns and Awareness, values and lifestyles

The internalisation of external costs also provides a vehicle for accomplishing changes in structure and patterns, and in awareness, values and lifestyles. One area in which structure and patterns are closely linked with awareness, values and lifestyles is a shift towards a less material-intensive consumption patterns. Examples are an increased use of recycled materials, refillable packaging, a prolonged lifetime of products, etc. With a tax on virgin materials, an economic incentive is created to promote the use of recycled materials and products. Other options, that could be instrumental in realising a change in behaviour, are environmental certification, ‘green labels’, etc.
An increase in energy price in general will lead to an increased awareness of energy consumption and will increase the viability of energy savings options on the demand side. A differentiation in energy price based on their carbon content may create a larger demand for ‘green energy’.

3. Transport sector

Fuel substitution

One strategic question is whether to wait for the ultimate fuel (probably hydrogen) or to go for an intermediate fuel option such as methanol.
Fuel cell vehicles and electric vehicles would benefit from experiments with environmental zones, which would give them a small niche where they could get experience, make improvements and cut costs. This could start early with voluntary participation from interested European cities.

Efficiency

Development of new car models typically takes 1 – 5 years depending on how new the new model is. For lighter and more energy efficient cars it would rather be 5 than 1 year, even if the increases in efficiency are taken in smaller steps. Production of a model usually goes on for between 2 and 10 years, and the cars are then used between 10 and 20 years. That means that the time from decision of a model to its being out-phased from the market could be up to 35 years. If the average efficiency of the car fleet should improve by 45 – 60 % (based on net energy use) up to 2050, the process ought to get started pretty soon. Feebates (*fees* on vehicles that use much energy and *rebates* on vehicles that use little energy) is a way to stimulate this process. CO_2 taxes are also an option.
Comparative figures for aircraft are, 5-10 years for development of a new model, 15-20 years of production, and a vehicle life-time of 25-35 years. This means that the time from decision to out-phasing of a model is up to 65 years. This indicates that it is even more important that incentives for energy efficiency of aircraft be implemented early on. Energy efficiency is already important in the development of new aircraft, but if the very high target should be attained that is set in the Transport Image, then the incentives may have to be strengthened.

Structures and patterns and awareness, values and life-styles

The Transport Image that was designed to meet the CO_2 target of 80 % reduction, presupposes some changes in residential patterns and travel behaviour. But how does such changes come about? Can policy makers induce them?

Historical examples of major changes in life-styles, such as the spread of better hygiene and personal care during the 19th century, indicate that a small group takes the lead and actually develops a new life-style. Social institutions are gradually adapted (e.g. sewage systems, better housing standard, educational institutions), making it easier for followers to join in. At first the new option is hardly open to the broad majority.

A pattern of less daily travel and more of decentralised concentration might arise out of a process started by information workers, who choose to work at home or at nearby tele offices. Today this does not suite so many people, but these fore-runners will support a larger market for lunch restaurants and shops in the local centres. This in turn will make them more attractive etc. Local authorities may help by offering good localities for information workers (tele offices).

This is just one example of a possible new life-style that is less resource and transport consuming, although the forerunners may have chosen it for other reasons, e.g. flexibility and freedom.

The point is that policy making is not just about trying to get people change from one to another of the present alternatives, e.g. from private car to commuter train. Often the alternatives do not have capacity enough to meet a much-increased demand. Therefore, policy making should also encourage a variety of emerging life-styles, especially if they seem to be in line with long term societal goals such as sustainability. At least some of these new options may in the long run develop into an alternative for the many. Policy-making can help by gradually adapting institutions and incentives.

Test and pilot projects could start early, e.g. investments in tele-cottages in urban centres and sub-centres, environmental zones etc.

Appendix IV: Future Images for 2050 Transport and Energy

Future Images for 2050
Transport and Energy

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

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 serves as input for the second workshop, describes a possible future image for each of the two sectors. The images are based on the input from the participants during the first workshop.

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, values and lifestyles.

In the first section of this paper the general assumptions underlying the two images are described. The second section contains the Energy Image for 2050 and the third section contains the Transport Image for 2050. Participants may wish to concentrate their reading on the first section and the section relevant for their own sector.

1. General assumptions

1.1 Introduction

In this section we will describe the general assumptions underlying the energy and transport images for 2050. 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.

1.2 The energy supply and demand system

Figure 1 shows an overview of the economy, divided in its sub-sectors, industry, buildings (including both residential and commercial/tertiary sector buildings), transport and agriculture. For each sub-sector a number of important drivers are listed. Section B.1.1 of the background information (see p …) provides a short description of the drivers and how they influence energy consumption.

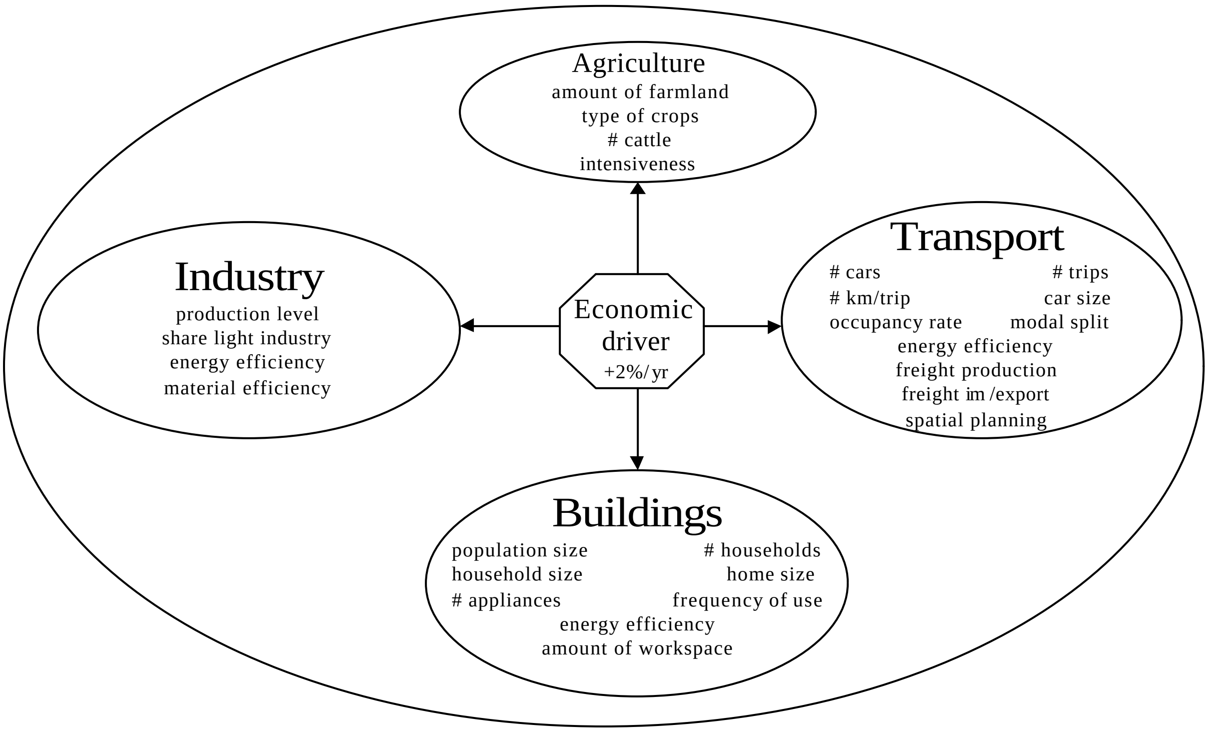

Figure 1: A schematic representation of the economy by sector and important drivers of energy consumption.

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.

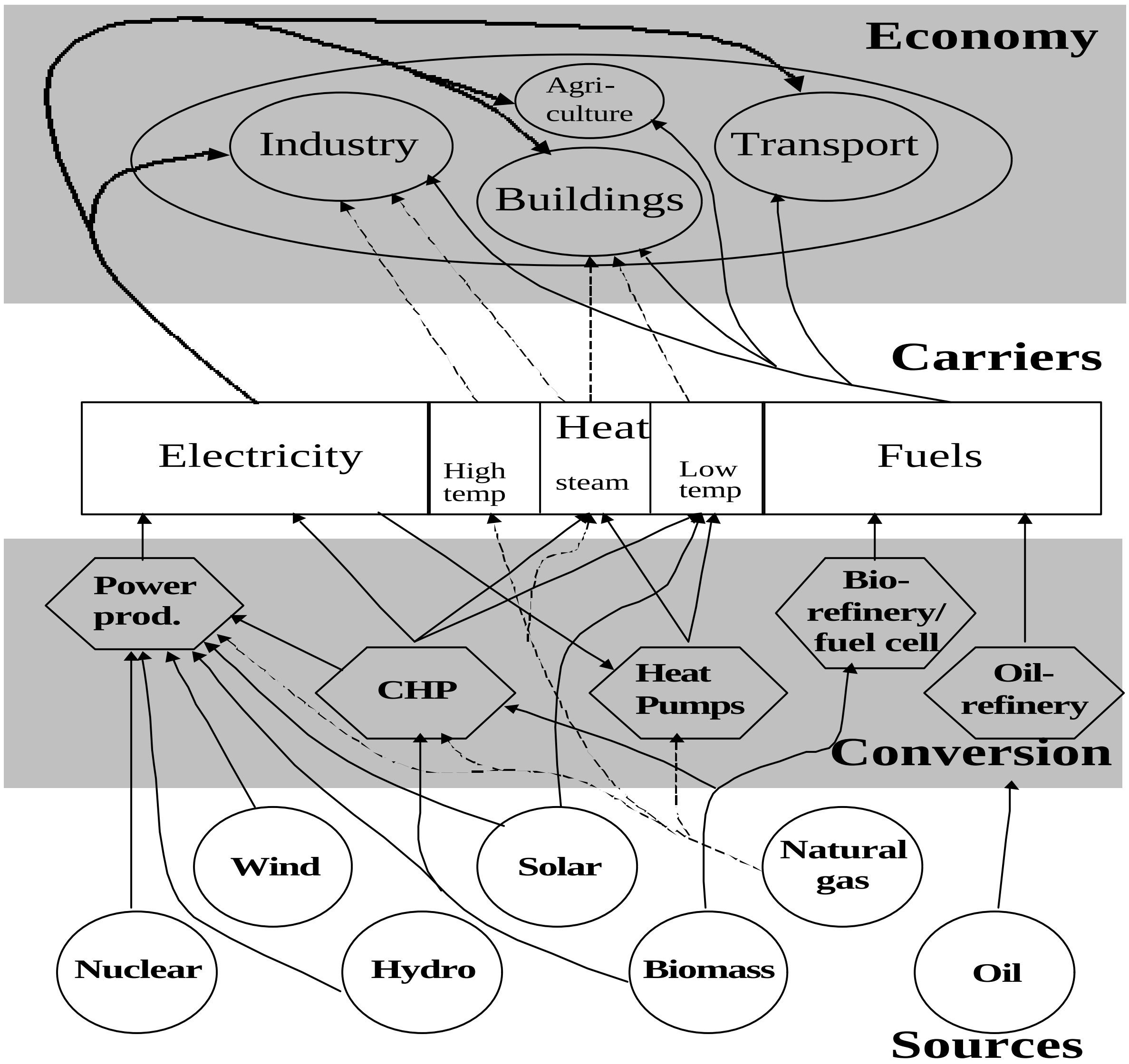

Figure 2: The future image of the energy supply and demand system in 2050.

1.3 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)?

1.4 Consistency between the images

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

2. Energy image for 2050

2.1 Introduction: an overview of the energy system in 2050

In this section we will present the energy image. We will give a summary of the basic assumptions, results and the consequences of the choices made. More detailed background information can be found in Appendix I.

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;
- Biomass will mostly be used for fuels (except for aviation fuels);
- Electricity will largely be supplied by Combined Heat and Power generation;
- Low temperature heat will be supplied by heat pumps;

Consequences of the energy image:

- Large renewable input can result in a reduced security of supply, unless storage capacity can be developed.
- Biomass consumption requires 80 Mha land (or 17% of total land area in Europe, the estimated long term excess crop land in Europe is estimated at 65 Mha).
- 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 35 million houses (roughly one sixth of total number of houses) with a panel size of 20 m^2.
- An increasing import dependency for gas might become an issue.

The energy image is constructed on the basis of the potentials for the various sources, the estimated requirements for each type of carriers and the relative growth paths for the different sectors. For more details see the background document.

It must be noted that the current image leads to a reduction of 75% of CO_2 emissions, falling short of our target of 80%. The required additional 5% emission reduction can be obtained by installing carbon emission recovery units at the larger CHP installations. It must also be noted that a large part (about one third) of the remaining emissions are from non-energy use of energy carriers. We have assumed that the products made from these energy carriers are ultimately burnt, resulting in their carbon content to be released to the atmosphere. Potential carbon removal from waste incinerators or increased recycling of such products may also be an option to obtain the additional 5% of emission reduction. The large input of natural gas and biomass might result in an increase of emissions of other greenhouse gases (such as methane and N_2O), but measures to mitigate such emissions are assumed to be sufficiently implemented in 2050.

The image

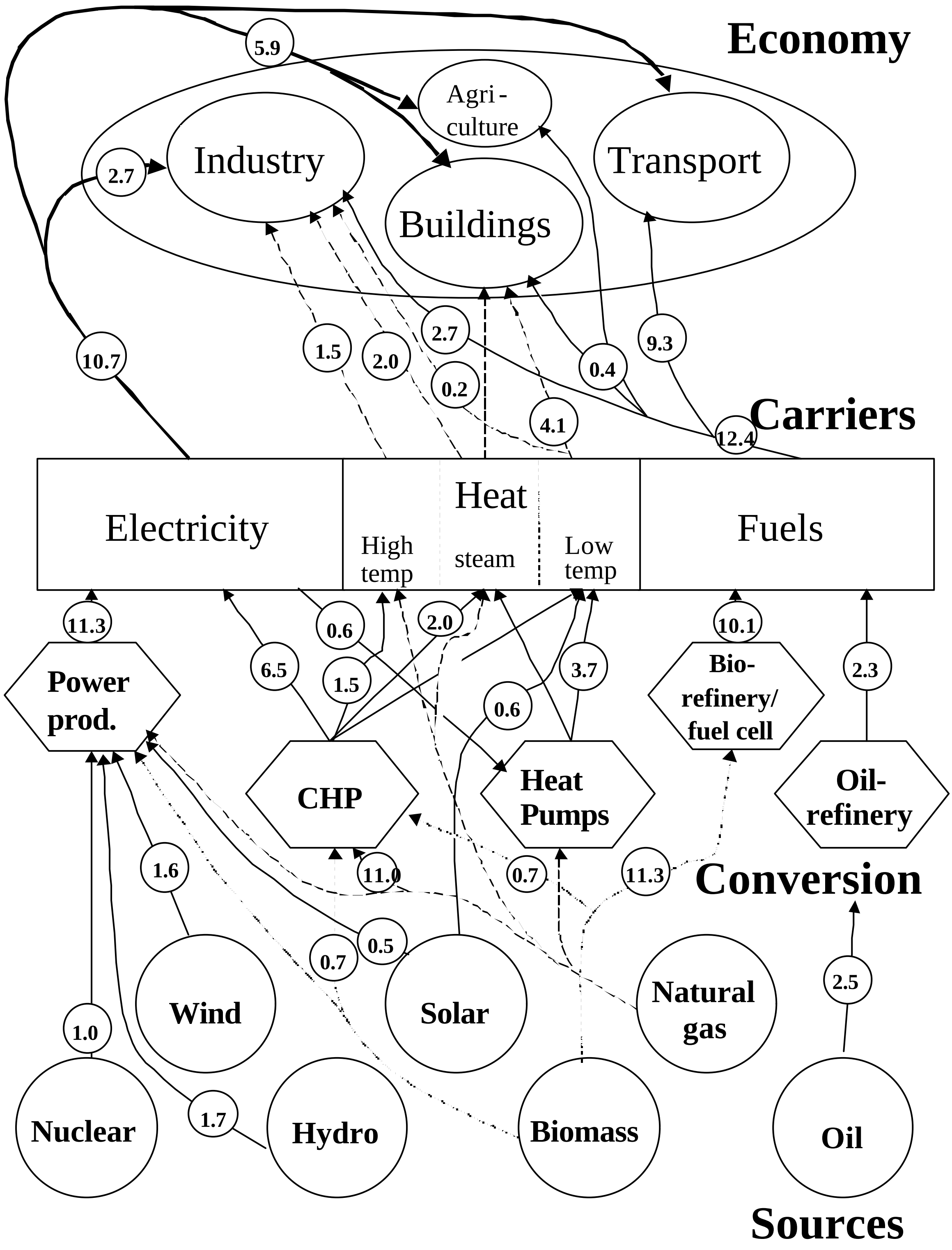

Figure 3: The energy image quantified for the year 2050. Shown are sources, the energy carriers to which they are converted to and the economic sectors they are used in. The numbers represent energy consumption in EJ. Note that on the supply side (sources), numbers represent the consumption of primary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

2.2 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 B.2 in the background information (p...)

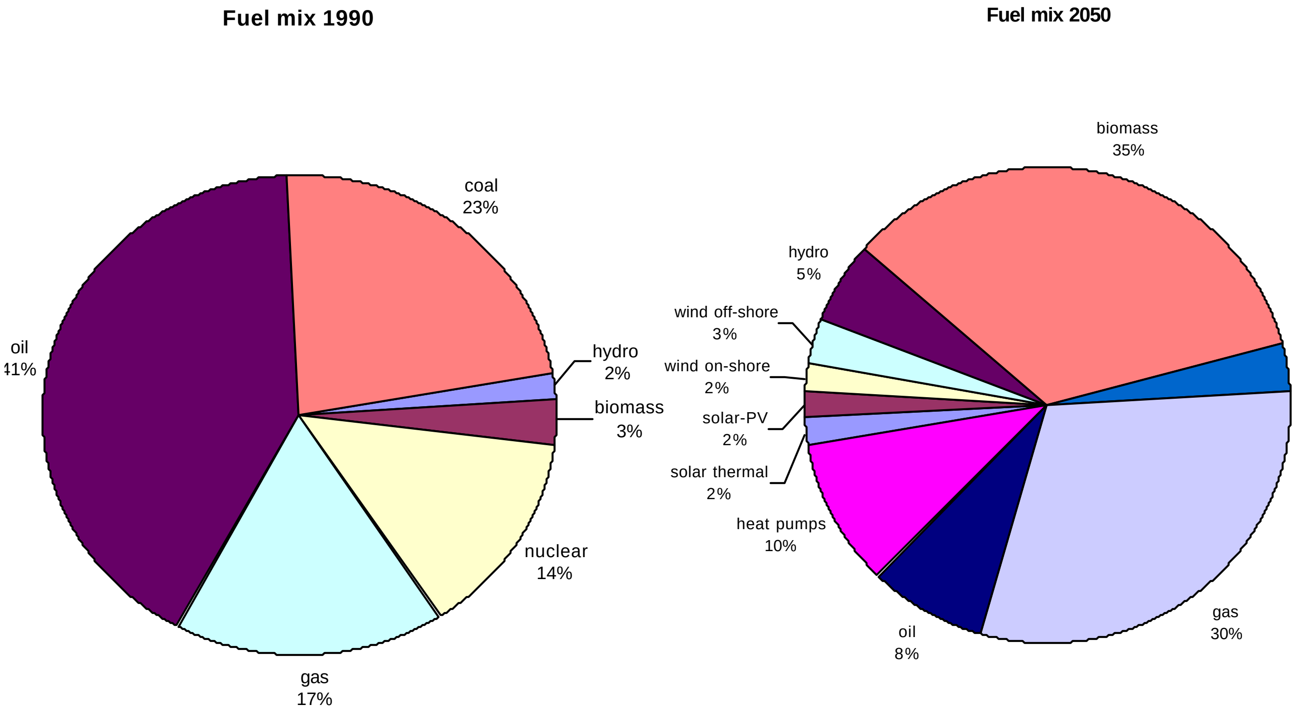

Figure 4: Fuel mix in Europe in 1990 and 2050.

2.3 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 B.1 in the background information (p…) 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 B.3 in the background information (p…) shows potential improvements in specific conversion processes.

2.4 Structure and patterns

Shifts in structure and patterns are responsible for a 0.5%/yr reduction in final energy consumption. See Table B.1 in the background information (p…) for a more detailed breakdown of changes by carrier and by sector (for a combination of energy efficiency effects, structural effects and activity effects).

2.5 Awareness, values and lifestyles

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).
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 buy 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 ffects 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.

- 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.
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)

2.6 Profile of the image

Table: Overview of the main elements of the energy image

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	very important	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	some importance	carbon tax, NFFO, subsidies	utilities (security of supply), local residents (visual impact), environmentalists (bird safety)
• solar	some importance	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	important	efficiency standards, energy tax	liberalised energy market
• demand side	very important	efficiency standards, energy tax	
3. Structures and patterns • energy-extensive industry	important	tax base reform	energy-intensive industry, ministry of economic affairs
• increased recycling, refillable packaging			shop keepers
• increasing lifetime through higher quality products and reparability			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

Background information on the Energy Image

B.1 The energy image

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 reparability 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. Table B1 shows the expected annual change rates for different energy carriers by sector.

Table B1: 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**

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 B.2: 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) Off shore: 2800 TWh	Current cost: 0.05 ECU/kWh Probably higher	Fluctuation in supply Bird safety Noise 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 B.3: 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	Electrochemical conversion	Hydrogen	70-75%	90-95%
Nuclear				
Renewables				

Table B.4: 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

For more information on CO2 removal and disposal, see the document "Questions to science".

3. 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 (3.1) and four specific elements that contribute to the "solution". These main elements are *Fuel Substitution* (3.2), *Improved Efficiency* (3.3), *Structures and Patterns* (3.4) and *Awareness, Values and Lifestyles* (3.5).

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* (3.6), 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).[5]

3.1 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.

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5 See Steen et al. (1998). *A Sustainable Transport System for Sweden*. WCTR Conference Proceeding, WCTR, Antwerp, 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.

3.2 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.

3.3 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.

3.4 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.

3.5 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 buy 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.

3.6 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 resources	Resource-intensive industry
• Decentralised	Important	Urban planning, commuter trains, local centres for tele-	Preference for dispersed

concentration (=> everyday passenger transport)		commuters	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

Appendix V: Questions to science

1. Introduction

At Workshop I of the European COOL project (Brussels, 29 November 1999) an inventory of “questions to Science” was made among the participants in the transport and energy dialogue groups. Participants listed and prioritised certain issues on which they would like to get more information (See workshop I report p. 27 and p. 33). In this paper, a selection of the issues will be addressed.

First, questions from the transport sector are being addressed (corresponding with question 2,3, 6 and 7 respectively on page 33 of the Workshop I report)
1.What is the potential of specific technologies - road, air, rail (technical & economic)?
2.What is the potential of efficiency improvements through operational means?
3.What are social/technical/economic barriers to new technologies?
4.What can non-technical options deliver in terms of CO_2 reduction?

Second, for the energy sector the following questions are addressed (question 3,4,5,6,8 and 9 respectively on p. 27 of the Workshop I report)
1. What does the energy picture look like in 2050?
2. What is the availability of m^2 for biomass, solar, etc. ?
3. What could be said about learning curves?
4. What will be the price of CO_2?
5. What are the expectations of CO_2 storage? What are the recent developments in this field?
6. What are the possibilities for using hydrogen in the national gas grid?

2. Transport

2.1. Potential of specific technologies – road, air, rail (technical & economic)

The energy efficiency of vehicles can be improved by *decreased driving resistance* (through lighter materials, improved aerodynamic design and reduced rolling resistance) and improvements to the *drive train* (engine, gearbox and transmission system). The maximum potential for improvements up to 2050 is estimated according to the table below. Essentially, the technologies involved are known today and have been tested in concept cars (for example GM’s Ultra Light, which uses 3.8 litres per 100 km).

Box. Efficiency improvement potential for different vehicle types

Estimated potential for reduction of average energy use per person-km and ton-km up to 2050 under ideal conditions (net energy use, i.e. energy for production of the fuel is not included):[6]

- 75% for fossil-fuel cars
- 80% for fuel-cell cars compared to cars in 1995
- 90% for electric vehicles compared to cars in 1995
- 55% for aircraft
- 50% for buses
- 50% for passenger trains
- 30% for freight trains
- 40% for fossil-fuel lorries
- 45% for fuel-cell trucks
- 30% for inland-water shipping

This box should be compared with Box 3 in the transport image.

[6] Steen et al. 1998. *A Sustainable Transport System for Sweden*. Conference proceedings, WCTR, Antwerp, Elsevier Science Ltd.

2.2 Potential of efficiency improvements through operational means

Operational means to raise efficiency are *higher occupancy* (passenger transport) and *load factors* (freight transport), and *logistical improvements* (better co-ordination and timing of transport). Another means is *inter-modal transport services* with smooth transitions between modes (seamless transport). All this would lead to more efficient use of existing systems, reduced costs and, probably, a higher demand. Because of the demand effect, efficiency improvements will not be enough to cut CO_2 emissions much in the long run.

We have not found any estimates of the overall potential for efficiency improvements by operational means. However, differences in driving style may lead to a 10 per cent difference in fuel use.

2.3. What are social/technical/economic barriers to new technologies?

Barriers to more energy-efficient vehicle technologies are higher for privately owned vehicles than for business fleets (trucks, buses, aircraft, trains). Consumer preferences have so far favoured strong and fast cars rather than low energy use. This indicates that the fuel price has not deterred people from driving big cars. A reason may be that the car is more than a practical means to get from point A to point B. A considerable number of car owners are dedicated to their cars and are relatively insensitive to fuel-cost increases (low elasticity of demand). They may, however, be more sensitive to the price of the car. "Feebates" then become a possible way to raise the price of heavy cars while subsidising light cars.

As long as the car manufacturers can continue to sell the present type of cars, one would expect them to be reluctant to invest in costly development projects in order to reduce fuel use per km. However, several car manufacturers have programmes aimed at raising energy efficiency.

Another problem is safety. In order to increase fuel efficiency much, one has to reduce the weight of the cars. Under a transition period both old and heavy cars and new light cars will appear on the roads. Heavy trucks and buses will also continue to be around. In the case of accidents the small and light cars will give less protection than the big and heavy ones, it is argued.[7]

Use of biomass-based fuels is not a technical problem, but the total energy efficiency is lower than for fuels based on crude oil or natural gas. It takes considerably more energy to produce fuels out of biomass than out of crude oil. Therefore, bio-fuels are at an efficiency disadvantage compared with fossil fuels. This could be counterbalanced if the externalities (contribution to the greenhouse effect etc.) were to be included in the price.

Technical barriers exist when it comes to solar-cell efficiency. This is a real challenge and there is a need for a technical breakthrough that cuts the costs per unit of the energy supplied.

Uncertainty as regards effects of man-induced CO_2 emissions on the climate is perhaps the most important barrier to effective policies, making politicians hesitant and sensitive to pressure groups.

In the air sector there are already incentives for reducing specific fuel consumption. More radical solutions, such as ultra-efficient propeller aircraft require a reconsideration of the need for speed, because there is a trade off between speed and fuel efficiency.

2.4 What can non-technical options deliver in terms of CO2 reduction?

If present trends continue as regards increases in transport volumes, technological improvements may not be enough for society to reach the CO_2 target of an 80% reduction. Then transport volume growth will have to be checked. This is the rationale of what has been labelled *decoupling*.[8] The idea is to weaken the link between GDP growth and transport growth, which has been very strong at least since the Second World War. During recent decades both have grown at approximately the same rate, with variations between sectors of industry. Therefore, transport intensity, measured as ton-km per unit of GDP, has remained more or less constant. How could we have a steady economic growth without a comparable growth in transport volume? This is the key issue of decoupling.

For *passenger transport* a possible solution is to reduce the structurally dependent travel that is essentially daily short-distance travel, such as commuting to work, shopping trips etc. This segment of passenger transport has increased considerably during recent decades, mainly because we have changed to more dispersed urban structures

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[7] Amory Lovins at the Rocky Mountains Institute maintains that lighter cars can be as safe as the conventional cars if they are made of carbon fibre. Lovins. 1993. *Supercars – The Coming Light-Vehicle Revolution*. Rocky Mountains Institute.

[8] Peake. 1994. *Transport in Transition: Lessons from the History of Energy*. The Royal Institute of International Affaires, Energy and Environmental Programme, Earthscan Publications Ltd, London.; Peake & Hope. 1994. Sustainability in Context: Three transport scenarios for the UK. *Transport Policy*, 1994 1(3) 195-207; POSSUM. 1998. *Final Report*. London, University College of London.

and the functional separation of areas and buildings: there are residential areas and areas for work and services. Shopping centres also tend to be fewer and bigger and situated on the edge of cities etc. An integrated land-use and traffic planning might change this. Tele-commuting and tele-shopping are other factors that may help. Some regional researchers advocate a spatial pattern of decentralised concentration because it would minimise daily travel.[9]
Although few people would attach an intrinsic value to the daily trips to work, many are prepared to accept spending a lot of time in the car or the train because it makes it possible for them to live in attractive residential areas. Therefore an active policy of decentralised concentration may not be popular. On the other hand, there seems to be a tendency for information workers to work at home or at nearby office hotels ("tele cottages") where they can link up with their colleagues and business contacts. This may reduce travel as such, but may also vitalise urban sub-centres. When more people stay in the suburbs during daytime, the market for local services such as lunch restaurants and shops will grow, making the suburb more attractive to other people. This may lead to a positive-feedback process where local centres gradually become more self-contained, i.e. a reversal of the functional separation of the recent decades described above. It is far too early to say whether this will happen, but it is a possibility.

Freight transport may be partially decoupled from economic growth if a development towards dematerialisation takes place. Some tendencies are already working in this direction. The ongoing structural change of industry entails a shift from resource-intensive industry (mining, metal manufacturing etc.) to knowledge-intensive industry such as medical equipment, pharmaceuticals and information technology. This means that the average weight of transported goods tend to drop. An increased share for services in the economy also tends to reduce the transport intensity of GDP. On the other hand, the globalisation is leading to increased average transport distances. A shift of tax base from levies on the use of labour to taxes on the use of natural resources would strengthen the tendencies towards decoupling.

It is very difficult to gauge the degree of potential decoupling. However, an attempt was made by the EU project POSSUM (Policy Scenarios for Sustainable Mobility).[10] The estimated potential for decoupling was estimated at roughly the same as the potential of technological improvements, if prevailing attitudes and values in society are very favourable. Decoupling will reduce *transport volumes* compared to a business-as-usual development, while technological improvements will reduce specific emissions, i.e. emissions per person-km or ton-km. The POSSUM report concludes that in the most pro-environmental scenario these two factors will have a comparable effect on CO_2 emissions. It must be emphasised that these estimates are very uncertain. Furthermore, the time horizon in POSSUM is 2020.

The conclusion of POSSUM presupposes that a tax-base reform has been implemented, that urban planning and traffic planning are integrated in an effort to attain structures of decentralised concentration and that IT shopping and IT commuting are widespread. Furthermore, green values are dominant and local demand favours nearby producers of, for example, food and beverages.

3. Energy

3.1 What does the energy picture look like in 2050?

The energy picture is described in the main document, “Future Images for 2050. Energy” Section 2.

3.2 What is the availability of m^2 for biomass, solar, etc.?

- The amount of biomass energy currently assumed in the energy image requires 80 Mha of land (or 17% of total land area). Estimated excess crop land in 2050 amounts to 65 Mha (see also Table B.2).
- The amount of solar energy currently assumed in the energy image requires PV panels to be installed on 32 million houses (or 1/6th of total number of houses) with a 20 m^2 panel.

3.3 What could be said about Learning curves?

9 McGlynn, Newman & Kenworthy. 1991. *Towards Better Cities: Reurbanisation and Transport Energy Scenarios*, Australian Commission for the Future Ltd, October 1991. See also Cervero, Futuristic Transit and Futuristic Cities. *Transport Quarterly*, 1992: 2, 193-204.

10 POSSUM. 1998. *Final Report*. London, University College of London.

Attached is a short document from the IEA Committee on Energy Research and Technology on learning or experience curves, including a number of examples (see Attachment A).

3.4 What will be the price of CO_2?

Current estimates of the price of CO_2 vary from 5$/tonne to 80$/tonne and more for the coming period (the first budget period of the Kyoto protocol). On the long term estimates are even harder to make. Generally it can be assumed that the costs will be no higher than the costs of carbon dioxide removal and disposal. In case the price of CO_2 will become higher than that, installing CO_2 recovery equipment will become more profitable than buying CO_2 emission rights.

3.5 What are the expectations of CO_2 storage? What are the recent developments in this field?

Attached is a short overview of the current status, potential and costs of CO_2 removal and storage (see Attachment B).

3.6 What are the possibilities for using hydrogen in the national gas grid?

It is not possible to replace natural gas by hydrogen from one day to the other. First of all, the natural gas grid needs to be adapted to transporting hydrogen (decrease leakages, lower energy content per unit of volume, i.e. larger tubes of higher pressures are required).
On the short term, hydrogen can be added to natural gas (up to 15%, leakages will increase slightly). On the medium term, an intermediate can be used, consisting of a mixture of natural gas, hydrogen and biogas (triple gas). On the longer term, the grid can be extended to be able to transport hydrogen. Also the gas-based domestic appliances need to be adapted to triple gas (to be able to deal with variations in the Wobbe index) and hydrogen.

ATTACHMENT A

ENERGY TECHNOLOGY PRICE TRENDS AND LEARNING

Summary

The purpose of this paper is to argue for the use of technology experience curves in the development of energy technology policy. The *experience curve* is an empirical, quantitative relation between price and the cumulative production of a good or service. In the present context,"price" refers to what an investor pays to buy equipment. There is overwhelming empirical support for the price-experience relation from all fields of industrial activities, including in the production of equipment that transforms or uses energy. For instance, market observations on new, clean technologies like photovoltaics and wind power show that prices for these technologies follow experience curves. Experience curves for photovoltaics indicate that the price per MW of PV capacity has been reduced by 20% for each doubling of cumulative production. An interesting issue in relation to international collaboration is the international transfer of knowledge and experience: to what extent do experience curves reflect global versus local learning?

Empirical evidence suggests that experience curves can be used to *explore technology and policy options*. The concept may be helpful in identifying areas for policy intervention, supporting the selection of policy targets and guiding the design of policy measures. This paper presents two examples of the use of experience curves to explore technology and policy options. The first example (Section 3) describes the results of a modelling exercise designed to identify areas where intervention may be necessary to have efficient CO_2 mitigation technologies available in the future. The second example (Section 4) illustrates how experience curves can be used to help set policy targets and design measures to reach them for technologies that are in the early stage of the experience process.

1. Can We Estimate Future Technology Prices?

Price is the most important barrier keeping new, environmentally-friendly technologies out of the market. To overcome this barrier, governments have supported deployment of these technologies, for instance through R&D or through pricing subsidies. Such support for environmentally superior technology is considered legitimate because the policy-maker expects prices to come down as producers and users gain experience. The crucial question is how much support the technology needs to become competitive.

Can we find any way to *estimate* how prices may be brought down in the future? If there is a method to make such estimates, then the policy-maker would know what to expect from the market and would design better interventions.

There is strong evidence from all industrial activities that experience reduces price and that there is a simple, quantitative relation between activity and price. Figure 1. shows estimated experience curves that have resulted from a sample of empirical studies, which all indicate a steady, progressive decrease in prices by cumulative production.[11] The data are presented in the usual way for such studies, in double-logarithmic diagrams, where the experience relationship can be described by straight lines[12]. The decrease in price that comes with cumulative production can be characterised by a *progress ratio*, which indicates how quickly prices come down. A progress ratio of 80% means that prices are reduced by 20% (=100% - 80%) for each doubling of cumulative production. Figure 2 shows the spread of progress ratios in studies of price-experience relations for different technologies and products.

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[11] In energy-related industries, prices are usually expressed in US$/kW or US$/W and cumulative production in MW or GW.

[12] We can write price, P, as a function of cumulative experience, X: $P = P_0 * X^{-E}$. P_0 is the price for the first unit, for instance the first MW of a new electric technology. E is the experience parameter and the progress ratio $PR = 2^{-E}$.

As we gain experience with new, clean technologies it is interesting to consider the price-experience curves associated with them. Figure 3 shows results from recent studies of the world market for photovoltaic modules and wind turbines produced in Denmark. PV shows a progress ratio of around 80%, which is expected for a modular technology. Progress ratios for the semiconductor industry are typically in the range 60-80%, but the producers of PV modules do not have the option of miniaturisation, which may explain some of the lower values in the semiconductor industry. The high progress ratio for wind turbines (96%) is a surprise. From experience curves for comparable products, lower progress ratios would be expected. Understanding why they are not observed in this case would require a closer study of the market for wind power equipment from which the data come. It is possible, for instance, that subsidies may have reduced producers' costs more substantially, but that these cost reductions have not forced down prices to the same degree.

An important question to deal with in this project is whether technologies can be classified by progress ratios. If it is reasonable to predict that progress ratios tend to be low for certain types of technology and higher for other types, the analyst would have a tool with which to roughly estimate price trends for new technologies for which there has been little market experience.

For new technologies, investment is usually the most important factor determining the cost of output from the technology, independent of whether this output is electricity, process heat or low temperature heat. Studies of technology learning tend, therefore, to focus on the price of buying a unit of the technology, in order to estimate future investment costs. There are, however, corresponding experience or learning curves for other factors that enter into determining the cost of producing electricity or heat; maintenance, reliability and fuel efficiency are examples. (These separate effects of technology learning can be integrated, so that it is possible to see the price-experience relation for electricity production or for refining a barrel of oil. For instance, the price trend for electricity production in the US indicates a progress ratio of about 80%.).

2. Experience Curves to Support Energy Technology Policy

Experience curves are already used as management and planning tools in many technology-intense industries. To what extent are they, or could they be, used by government analysts to contribute to the design of energy technology policy? One of the tasks for the Secretariat's project on technology learning is to find and describe cases where experience curves are used to explore technology and policy options. Such exploration can allow the identification of areas where policy intervention is necessary to reach societal goals, support the selection of realistic policy targets and guide the design of policies to reach the targets.

There are several outstanding issues that need to be solved in order to establish experience curves as a tool for supporting policy generation. One interesting issue is whether there are global experience curves for specific technologies – like photovoltaics, wind power and CCGT – or whether the curves are local; i.e., specific for countries or regions. Both cases raise the question of knowledge transfer, which is of special concern for the IEA and for the technology transfers implied by the Kyoto outcome. Thus, an objective of this project is to establish contacts with research centres working on experience curves and related subjects and also to explore the possibility of international collaboration.

The following two sections present examples of the use of experience curves to explore technology and policy options. The first one presents results from a modelling experiment undertaken to identify areas where intervention may be necessary to have efficient CO_2 mitigation technologies. The second one shows how policy measures can use niche markets to achieve price targets.

3. Modelling Experiment: Competition May Make Mitigation Technologies Unavailable

There are several research groups working with policy-relevant energy modelling where technologies are characterised by experience curves. This section reports on the work of one of these groups[13].

Figures 4 and 5 illustrate the point of departure for the modelling experiment. Figure 4 elicits the fundamental problem for new technologies which have just started to acquire experience, but for which the price is still too high to compete with existing, old technologies. They are, however, considered potentially superior to the old technologies. In order to become commercial, the new technologies require a large amount of advance investment in learning. This learning investment will appear to be non-commercial at the time when it is done, but it is expected to be repaid in the form of lower prices in the future. Figure 5 is based on ATLAS-data and shows the deployment of selected electric technologies within the European Union 1985-1990.[14] The figure indicates, that the new technologies not only compete with old technologies, but also with new versions of these technologies such as natural gas combined cycle or coal technology based on advanced thermodynamic cycles. The new technologies also compete among themselves for learning investments. In this complex market situation, how do we know that a new technology will be superior, that is, how do we provide the rationale for policy interventions to ensure the future availability of the technology? How do we know that a new technology will capture so much of the market, that it will pay back the investments in learning?

The modelling experiment looked at learning and market opportunities for new electrical technologies assuming that there are global experience curves. The assumed discount rate was 5%. Figure 6 shows two quite different electricity world views, but with the same present value. All assumptions of cost and market availabilities are the same for the two cases. Case 1 is first dominated by CCGT and later clean-coal technologies, which lock out photovoltaics and fuel cells from the market. In case 2, learning investments are made for photovoltaics and fuel cells; CCGT and clean-coal technologies lose markets to these technologies. At the 5% discount rate and considering only the cost aspects, the modelling experiment tells us that photovoltaics and fuel cells cannot be considered superior to clean coal technologies or CCGT.

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[13] Details of the work are found in two publications:
N. Mattson and C.-O. Wene, "Assessing New Energy Technologies Using an Energy System Model with Endogenized Experience Curves", *International Journal of Energy Research*, Vol.21, p. 385, 1997.
N. Mattson, "Internalizing technological development in energy system models", Licential Thesis, Energy Systems Technology Division, Chalmers University of Technology, Gothenburg, November 1997.

[14] See "Energy Technology Cost Trends: The Case of Renewable Energy", (IEA/CERT(98)7) and "Energy Technology - Summary findings from the ATLAS project", European Commission, December 1997.

Figure 7 shows how the picture changes when CO_2 emissions are considered. Considering a global CO_2 target, case 2 becomes the preferred solution. Figure 8 indicates the extra investment necessary during the next 25 years to realise case 2. A considerable amount of risk capital is needed in case 2. As a result, the most probable outcome is that photovoltaics and fuel cells will be locked out, as in case 1, if there are no policy measures to stimulate learning for these two technologies.

The modelling experiment demonstrates how experience curves can be used to provide structured reasoning about technology options and the need for policy interventions.

4. Niche Markets: Making Photovoltaics Commercial

With a progress ratio of 80%, cumulative production of several hundred GW is needed to bring the price of a photovoltaic power plant to a level where it can compete with existing conventional electric technologies. The cumulative production of PV modules in the world is at present only about 0.5 GW, indicating that several hundred times the present production is required before PV becomes a cost-efficient alternative in conventional applications of electricity generation technologies. In the near term, the prospect of conventional application can therefore not be expected to drive PV production up and PV prices down the experience curve. Realistic measures to make PV commercial must rely on markets which put a premium on the specific characteristics of PV technology, e.g., modular, applicable in very small scale, independent of fuels, free of emissions. Thus, we are looking for niche markets, where a new technology can gather experience and cut prices. Typically a *niche market* is one in which a new product can compete with established substitutes because consumers are willing to pay for specific properties of the new product. At the turn of the century, electricity found a niche market in home lighting, where it was much more efficient and cleaner than kerosene or gas light.

Japanese niche markets for photovoltaics have been proposed by Tsuchiya, who also studied the experience curve for PV in Japan.[15] Figure 9 shows his results. The table indicates the niche markets, their demands and the willingness to pay in these markets. The "market curve" in the diagram has been constructed from the table. Experience curves are constructed for progress ratios of 80%, 76%, and 70%. The demands from niche markets places the break-even point at 50 GW, 6 GW and 1.4 GW for PR=80%, 76% and 70%, respectively. This is a huge improvement over an approach which relies only on the utility market for conventional electric technology. However, before break-even, the price of PV is still larger than the willingness to pay. Policy measures are therefore needed to start up the markets and move them towards the break-even point.

Japan's "70,000 roofs" programme[16] started in 1993 and uses subsidies to move the market for roof-mounted PV-systems towards break even, which is projected for 2001. Figure 10 shows the results for 1994-1997 and the proposed programme through 2000. The line "Price before subsidies" corresponds to an experience curve with a progress ratio for the total system of slightly less than 90%, which is consistent with a progress ratio around 80% for the PV-module in the system. The line "Price after subsidies" is the cumulative demand curve for the niche market represented by roof-mounted PV-systems. The difference between the two lines at any particular year is the subsidy.

The "70,000 roofs" programme shows how experience curves can be used to set up annual targets and design subsidies that are gradually phased out as the producers gain experience. The producers on their side are forced to show the effects of experience in their market prices. The programme leads to a

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[15] H. Tsuchiya, "Photovoltaic Cost Based on the Learning Curve", *Proc. Intl. Solar Energy Society Clean & Safe Energy Forever Symposium*, Kobe city, Japan, sep 4-8, 1989, p. 402.

[16] The data on the "70,000 roofs" programme are taken from *PV News*, Vol.16, No 12, p. 3, December 1997.

considerable expansion of the total PV-market. It will be very interesting to follow the results of this expansion, to see if the experience curve is robust in response to such strong policy intervention.

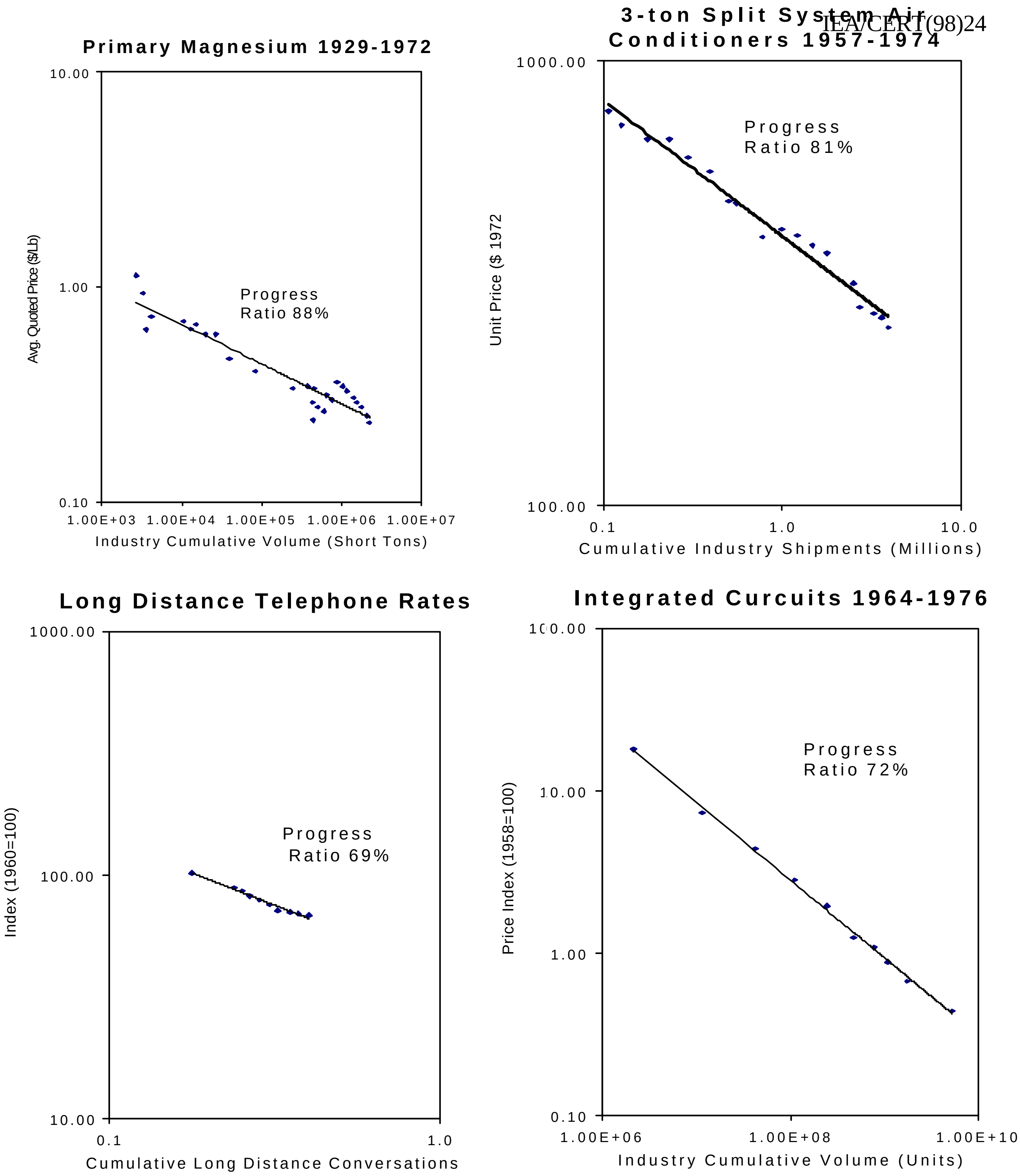


Figure 1. Examples of Experience Curves

Sources: D.F. Abell and J.S. Hammond, "Cost Dynamics: Scale and Experience effects", in *Strategic Planning: Problems and Analytical Approaches*, Prentice Hall, Englewood Cliffs, N.J. 1979 and R.U. Ayres and K. Martinás, "Experience and the Life Cycle: Some Analytical Implications", *Technovation*, Vol. 12, No. 7, p.465, 1992.

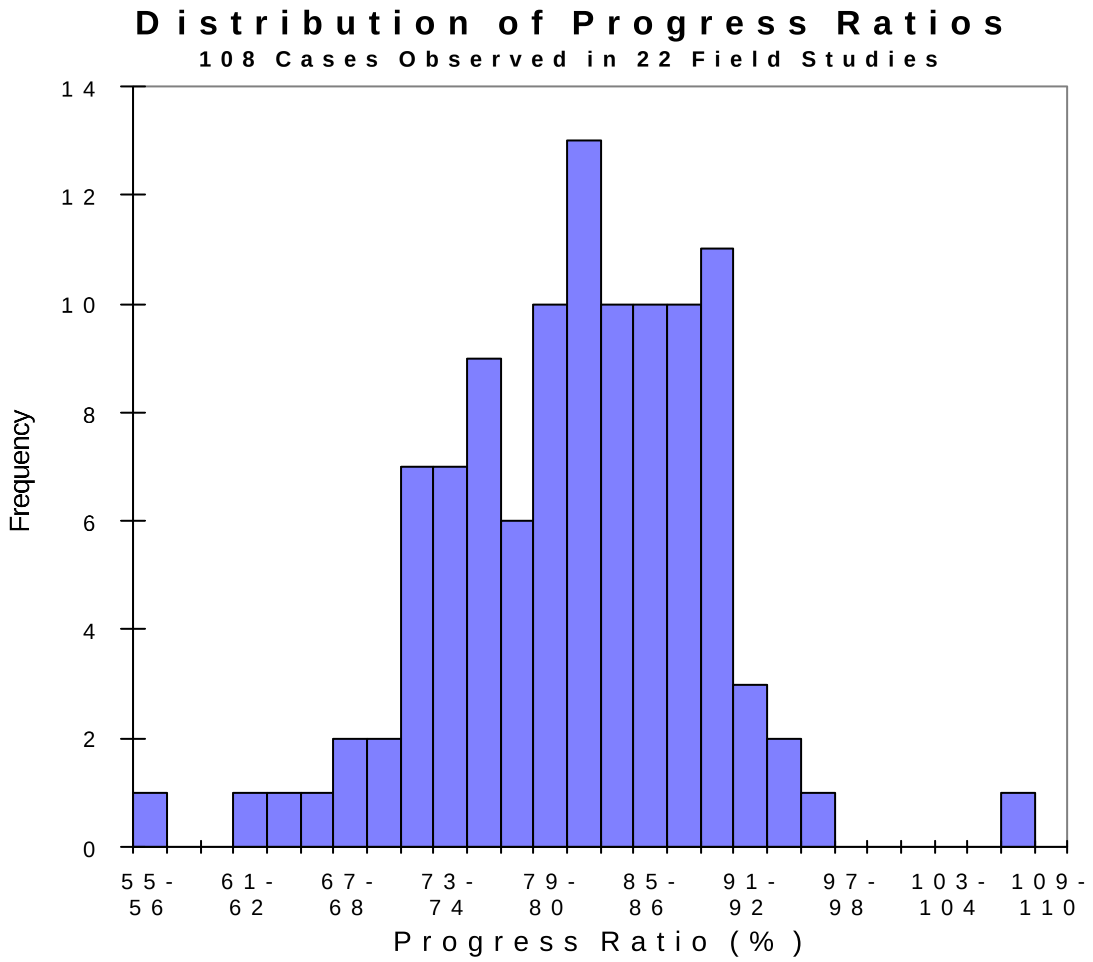
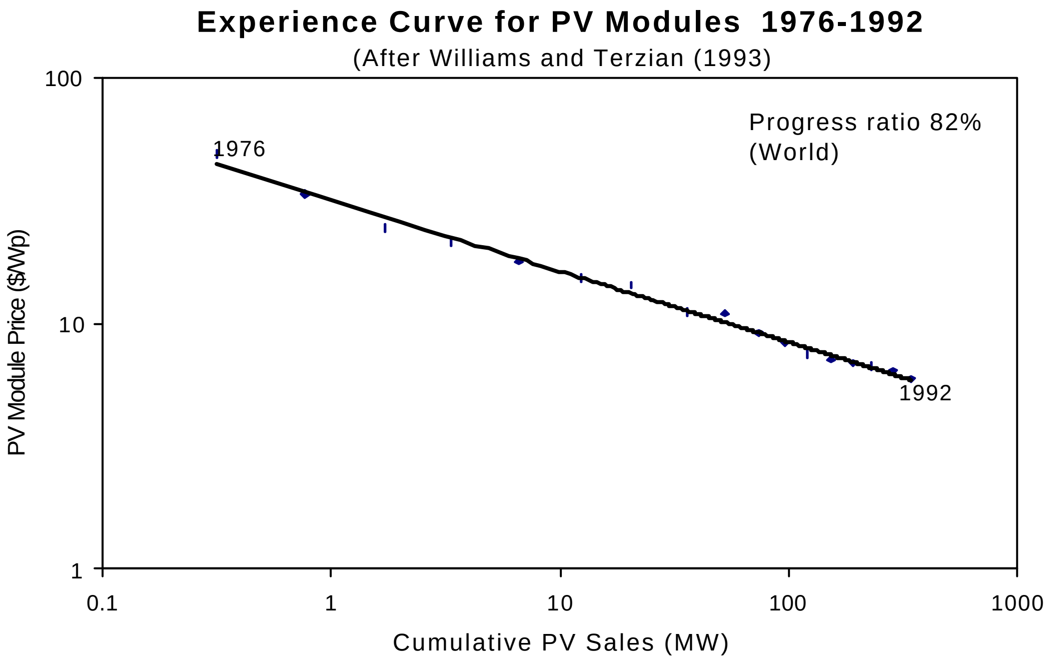


Figure 2. Progress ratios measured in field studies

From J.M. Dutton and A. Thomas, "Treating Progress Functions as a Managerial Opportunity", *Academy of Management Review*, Vol.9, No.2, p.235, 1984



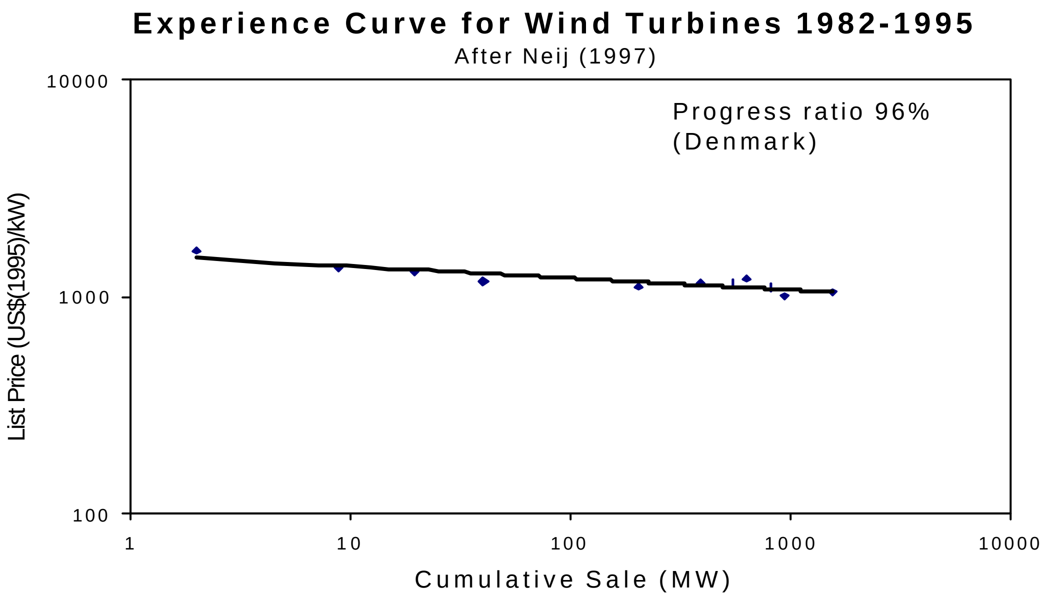
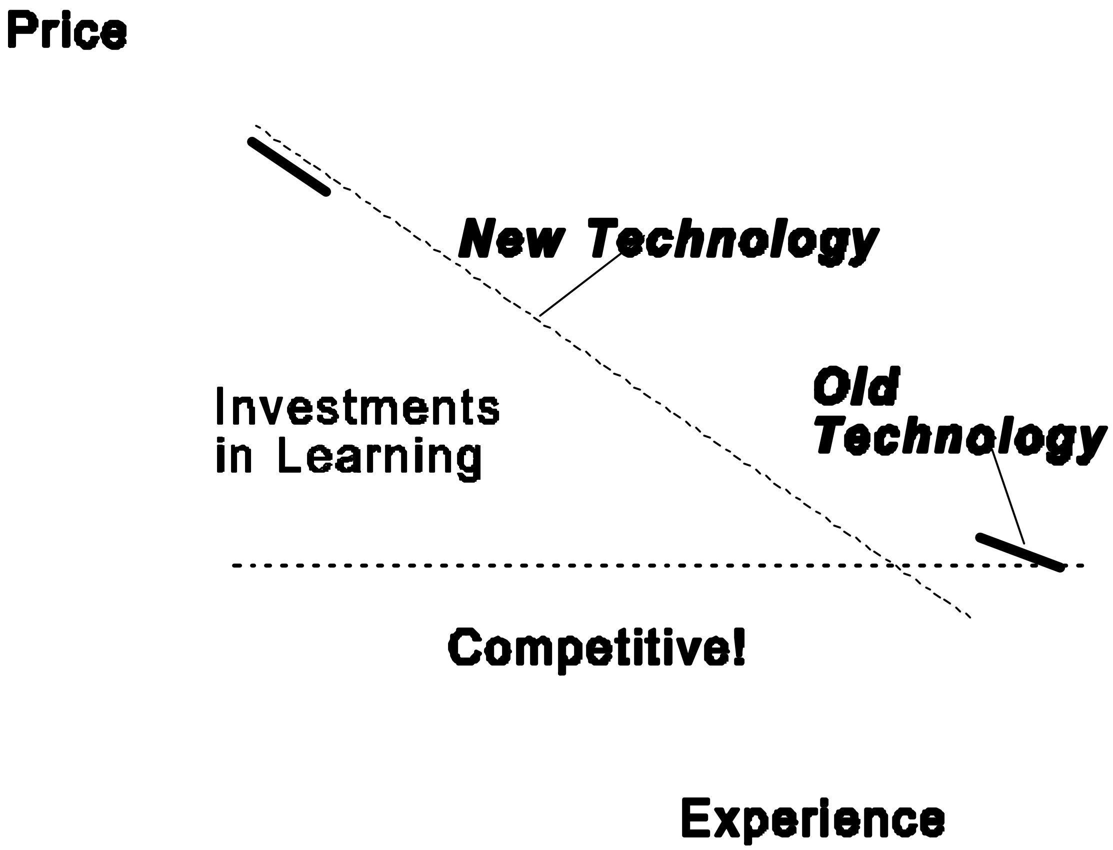


Figure 3. World market experience curve for photovoltaics (upper diagram) and experience curve for wind turbines produced in Denmark (lower diagram)

Photovoltaic experience curve after R.H. Williams and G. Terzian, "A Benefit/Cost Analysis of Accelerated Development of Photovoltaic Technology", *PU/CEES Report No. 281*, Princeton University, October 1993. Wind turbine experience curve after L.Neij, "Use of experience curves to analyse the prospects for diffusion and adoption of renewable technology", *Energy Policy*, Vol 23, p. 1099, 1997.

Competition Might Make CO_2 Mitigation



Technologies Unavailable

Investments in learning are necessary to make a presently expensive but potentially superior technology competitive in a market dominated by an old but cheap technology.

But how do we know that the new technology is superior? Will the new technology capture so much of the future market that it will pay back the investments in learning?

Figure 4. Competition between a new technology and an existing, old technology

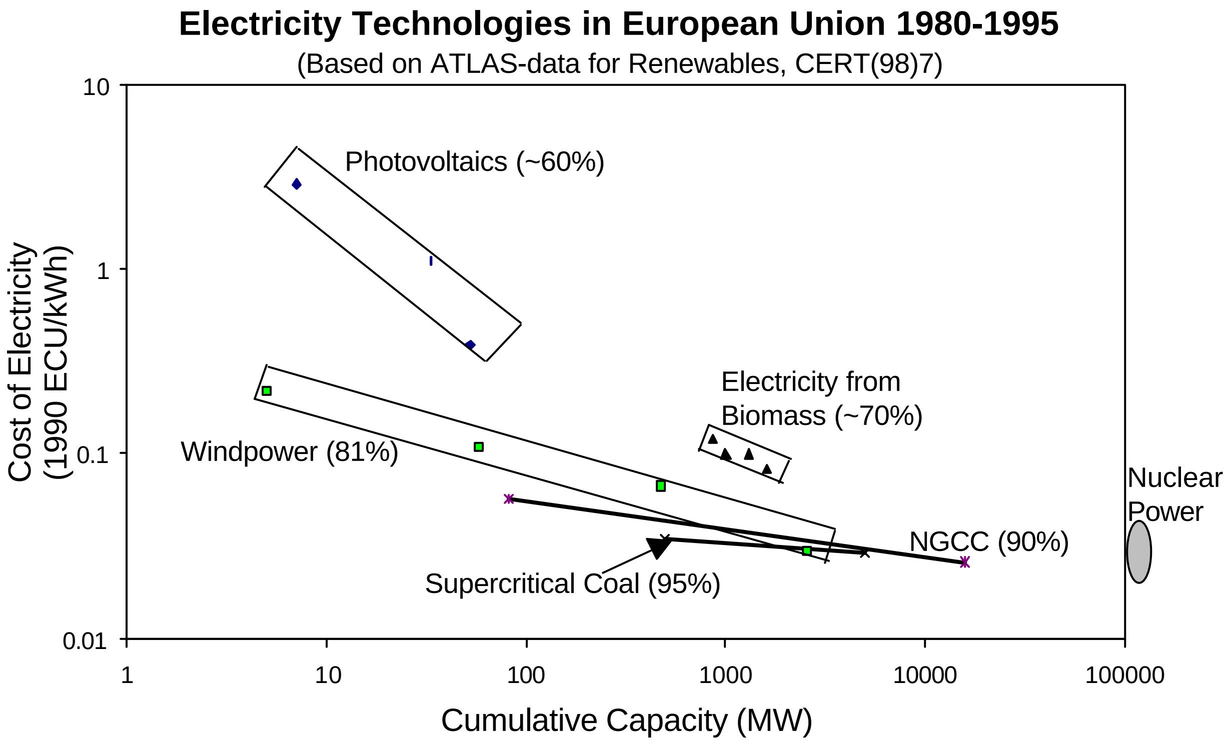
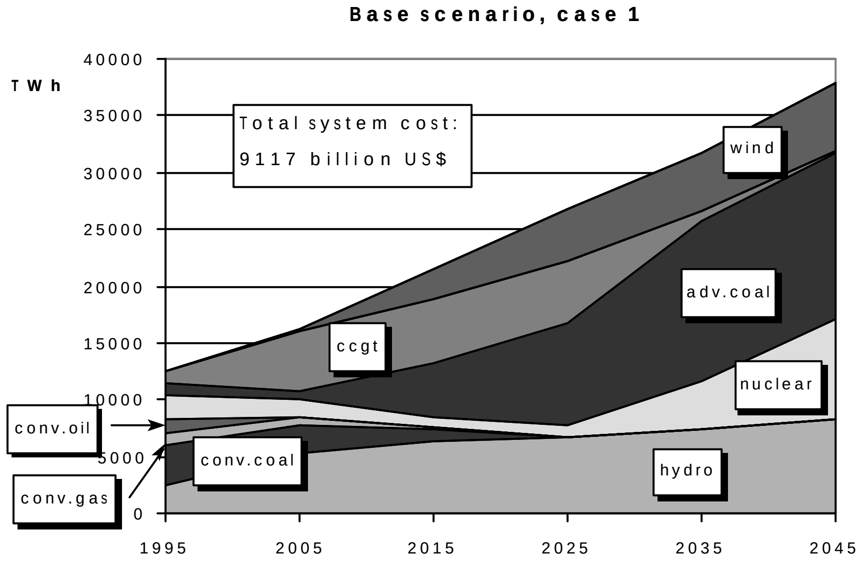


Figure 5. Deployment of selected electricity technologies in the European Union

Numbers in parentheses are estimates of progress ratios. The estimates for renewable technology are based on data in "Energy Technology Cost Trends: The Case of Renewable Technology", IEA/CERT(98)7. The available ATLAS-data do not permit more than very rough estimates of the progress ratios for photovoltaics and electricity from biomass.[17] The value for supercritical coal are from a US study, P.L. Joskow and N.L. Rose, "The effects of technological change, experience, and environmental regulation on the construction cost of coal-burning units", *Rand Journal of Economics*, Vol.16, p.1, 1985. The estimate for natural gas combined cycle (NGCC) represents an educated guess to be verified.

[17] The experience curve for photovoltaics seems much steeper than the corresponding curve for photovoltaic modules on the world market in figure 3. There are several explanations for the apparent higher learning rate in the ATLAS data. One explanation is the change in PV applications over the studied period, discussed in IEA/CERT(98)7, p.11. From mid 1980's until now, such applications have changed from remote systems to grid connected systems, which have substantially reduced BOS cost, exaggerating the experience effect. Another possible explanation is that EU was a late starter in 1980 compared to USA and Japan, and could rely on importing experience on PV during the 80's. The latter explanation illustrates the distinction between global and regional experience curves. Both explanations indicate that a high rate of learning cannot be maintained, and that future progress ratios for electricity from PV in EU will depend on the global progress ratio for PV modules. The modelling experiment assumes a progress ratio of 82% for the cost of electricity from PV.



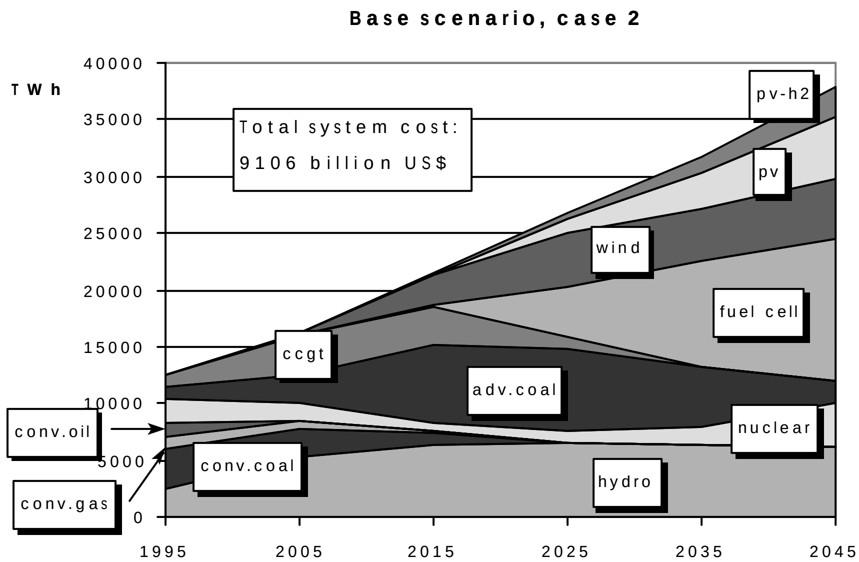


Figure 6. Two views of the future for the world electric system obtained in a modelling experiment with experience curves

The diagrams show the production of electricity from different technologies 1995-2045. The term "pv" refers to photovoltaic solar cells, and "pv-h2" to a combined photovoltaic and fuel cell technology which produces and stores hydrogen at day time and uses this hydrogen to produce electricity from a fuel cell at night time. From Mattson (1997, full reference in footnote 3).

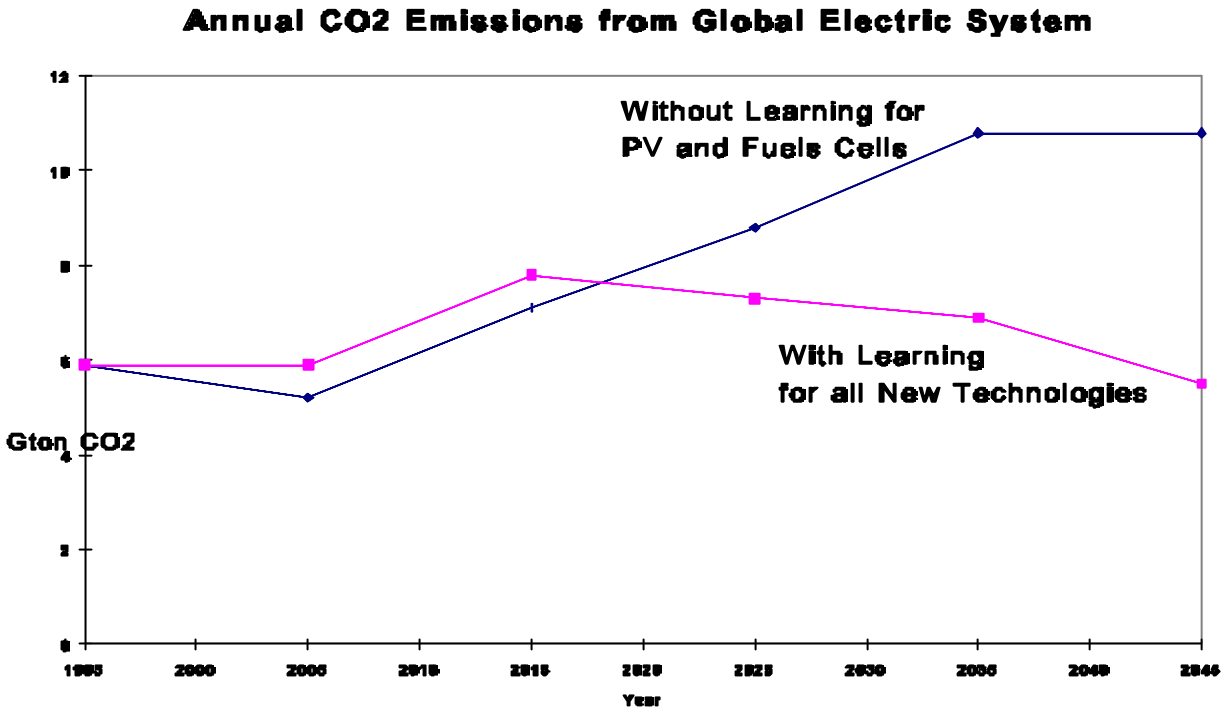


Figure 7. Modelling experiment: CO_2 emissions from global electric system for cases without and with learning investments in photovoltaics and fuel cells

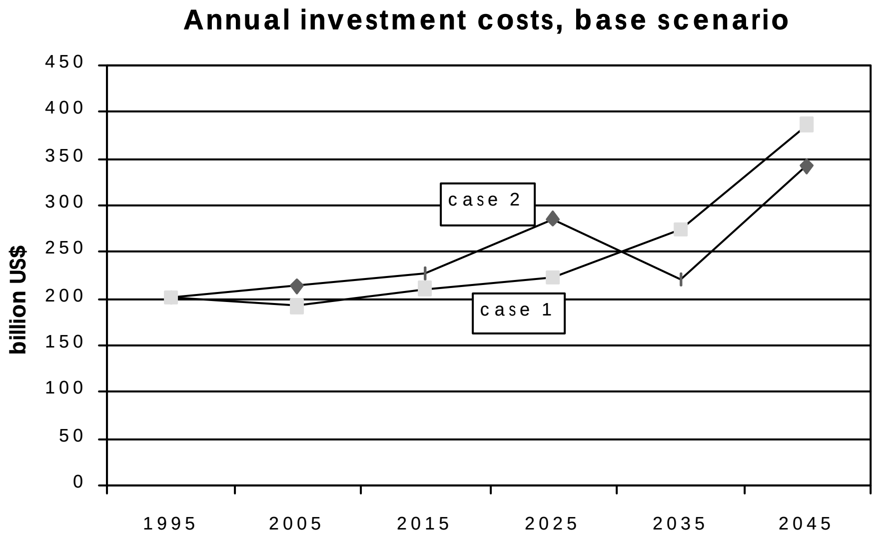


Figure 8. Modelling experiment: Total annual investments in the global electric system without (case 1) and with (case 2) learning investments in photovoltaics and fuel cells

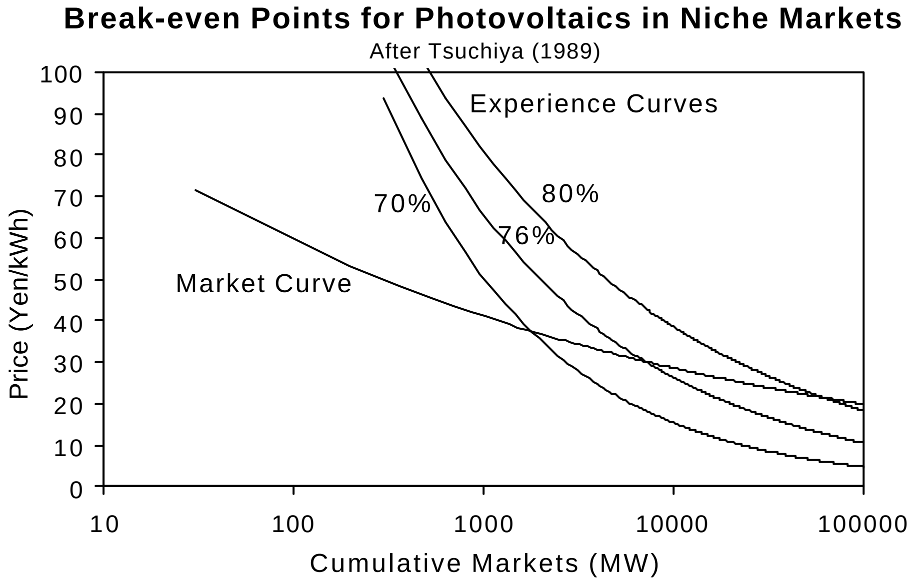


Figure 9. Niche markets for photovoltaics in Japan and break-even points for experience curves with progress ratios of 80%, 76% and 70%

The scale on the price axis is linear, which explains why the experience curves do not appear as straight lines in the diagram. Adapted from Tsuchiya (1989, full reference in footnote 4)

Table: The markets for photovoltaics in Japan

Electricity Supply Cost (Yen/kWh)		Market (MW)	Accumulated Market (MW)	Application
(Interval)	(Average)			
90-50	(75)	20-40	30	Substitute for Diesel-engine electricity in remote area
28-36	(34)	3600-5200	4430	Public use. Office building
27-31	(29)	17000-27000	26440	Residential use
15-29	(25)	10000-14000	38440	Industrial use

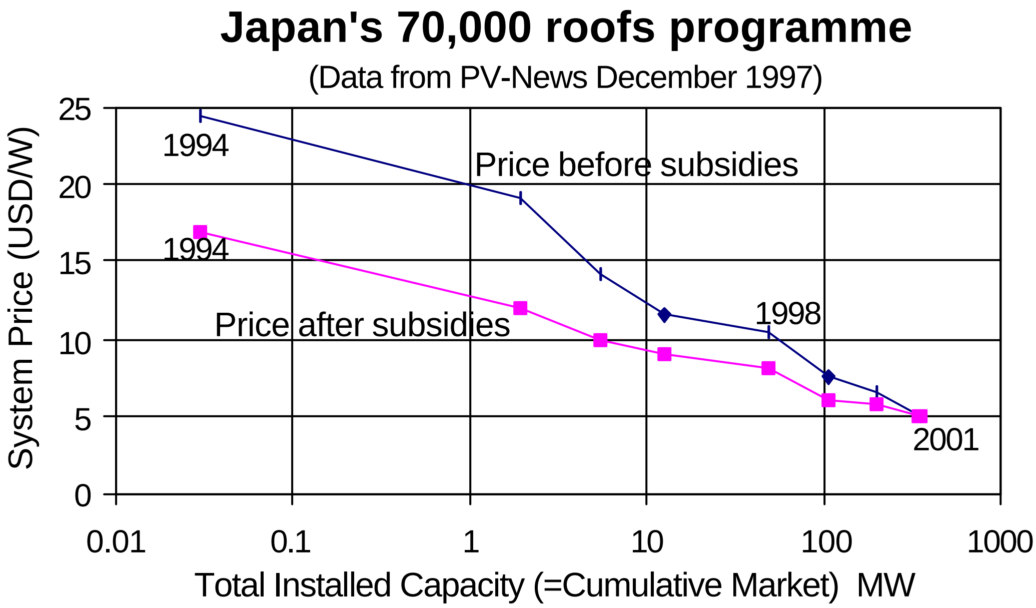


Figure 10. Prices before and after subsidies in Japan's 70,000 roofs programme

Attachment B:

Status, potential and costs of CO_2 removal in Europe in 2050

An interesting option to reduce emissions of CO_2 to the atmosphere is CO_2 removal, i.e. the use of fossil fuels with none or small emissions of CO_2. This option might especially be applicable in the short and medium term when renewable energy sources are developed and implemented. Whether or not CO_2 removal may play (still) an important role in 2050 depends, *inter alia*, on the successful implementation of renewable energy sources in the period towards 2050.

CO_2 removal can be done with commercial available technology. Nevertheless, substantial room for improvement for these technologies exists. Since 1996 there is a commercial removal project in Norway. In this project about 1 Mtonne of CO_2 is stored annual in offshore aquifers. The CO_2 is recovered from natural gas from a nearby gas field.

To determine whether CO_2 removal might contribute substantially to reduce CO_2 emissions, the following aspects should be considered:
- availability of fossil fuels
- availability of storage locations and potential of utilization
- costs of the removal process
- other aspects as safety and environmental impact

Availability of fossil fuels and required CO_2 emission reduction
The reserves of fossil fuels are large. According to a study of the Office of Technology Assessment (OTA, 1991) the carbon content of the reserves is estimated at 5,000 to 10,000 GtC. A substantial part can be recovered at costs below the 20 US$ per barrel oil equivalent. This amount is, however, much higher than is likely to be acceptable to use for climate change reasons. To reach a stabilisation of the CO_2 concentration in the atmosphere of 450 ppm, total emissions between 1990 and 2100 might not exceed the 550-750 GtC [IPCC, 1995]. The emission projection by ‘unchanged policies’ amount to 1450 to 2200 GtC. This implies that most probably between the 700 to 1650 GtC should be avoided. For Europe this may be between the 70 and 140 GtC.

In the case that CO_2 removal will play a major role in the reduction of CO_2 emissions towards 2050, a storage potential of at least some tens of GtC will be required.

Availability of storage locations and potential of utilisation
Produced CO_2 should remain out or the atmosphere for at least several hundred of years. Storage locations should provide for at least 10-30 GtC of capacity to 2050. The following options can be distinguished:
1. Industrial application of CO_2
2. Enhanced Oil Recovery
3. Enhanced Coal Bed Methane Production
4. Storage in exhausted oil and natural gas fields
5. Storage in aquifers
6. Storage in oceans

Industrial application of CO_2
The potential to use CO_2 for industrial use is limited. An interesting option is the use in greenhouses, but this option is mainly limited to the Netherlands. Other uses might be the production of algae’s, that might be used as fuels for energy production. The CO2 is then used as a fertiliser to stimulate the growth of algae’s. This technology has been demonstrated in some projects.

Enhanced Oil Recovery

CO_2 can be used to enhance recovery of oil from oil fields. This is a proven technology, which can be applied to oil fields in the North Sea close the United Kingdom and Norway.

Enhanced Coal Bed Methane Production

Another option is to use CO_2 for recovery of encaptured methane in coal beds that are not exploitable. This is applied on small scale mainly in the United State and Canada. Research to this option, also for the European situation is ongoing. At this stage, it is difficult to estimate potential storage capacity of this storage location.

Storage in exhausted oil and natural gas fields

CO_2 can be stored in exhausted oil and natural gas fields. It has been estimated that about 10 GtC can be stored in the European Union and Norway [Holloway, 1996]. It may be possible to combine the storage of CO_2 with additional winning of natural gas.

Storage in aquifers

A very important storage location in terms of capacity is the aquifers. In a study for the EU for the Joule programme, it has been concluded that underground disposal is a perfectly feasible method of disposing of very large quantities of carbon dioxide [Holloway, 1996]. In the same study the potential for storage is estimated at about 60 GtC.

Storage in oceans

CO_2 can be stored by dissolving it in ocean water. The potential of this option is in principle very large, but many environmental related issues remain unsolved. Storage potential can therefore not yet be given for this option.

Cost of CO_2 removal

Costs of CO_2 removal are built up by costs for recovery, compression/transport, and disposal of the CO_2. Table 0.1 gives some typical high, medium and low costs figures for the various removal steps. The totals give therefore 'extreme values'. For a typical CO_2 removal process from flue gases the cost amounts to about 50-80 Euro/ton CO_2-avoided. For more 'specific' processes (e.g. CO_2 recovery by fuel conversion in an IGCC), the costs are typically somewhat lower: between 30-60 Euro/tonne CO_2-avoided. Recovery from sources with pure CO_2 (e.g. some hydrogen production plants) the cost may go down to 10-30 Euro/tonne CO_2-avoided.

The costs of CO_2 removal are likely to go down towards 2050. This will be caused by development of better and more efficient removal concepts and by the development of other energy conversion concepts. Especially, some types of fuel cells are very suitable for CO_2 recovery.

Table 0.1. Typical high, medium and low cost figures for CO_2 removal (Euro/tonne CO_2-avoided). Examples are given in italic.

	High	**Medium**	**Low**
Recovery	50 *recovery from flue gases*	25 *specific conditions present*	1 *pure CO_2 sources*
Compression & Transport	25 *distance: 300 km*	15 *100 km*	7 *0 km*
Disposal	10 *offshore*	5 *onshore (aquifer)*	2 *onshore (NG-field)*
Total	**85**	**45**	**10**

Safety and environmental aspects

CO_2 removal can only play a role when sufficient attention is paid to an environmental sound application of methods and technologies. Special attention is required to safety and environmental aspects.

In principle CO2 can be stored safely underground. Natural reservoirs do proof that. There is also experience with transport of large amounts of CO_2 by pipeline over long distances. Nevertheless, it can not be guaranteed beforehand that fast escape of CO_2 can not happen from aquifers. It is therefore required that (more) research will be done to safety aspects.

Conclusions

CO_2 removal may play a role in the transition of the energy system based on fossil fuel into a system based on renewable energy sources. CO_2 removal does have the potential to contribute substantial in the emission reduction of CO_2 emissions in 2050. It is estimated that there is at least a storage capacity of 70 GtC, but probably much larger. The required space for CO_2 storage towards 2050 will most probably not exceed this number. Safety remains an issue of concern. Research to underground storage and demonstration should proof that CO_2 can safely be stored underground.