Future Images for 2050
Transport

Climate OptiOns for the Long term

COOL Europe

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

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

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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 the transport sector. The image is based on the input of the participants during the first workshop. In a separate document the future image for the energy sector is described.

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

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

1. GENERAL ASSUMPTIONS

1.1 Introduction

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

1.2 The energy supply and demand system

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

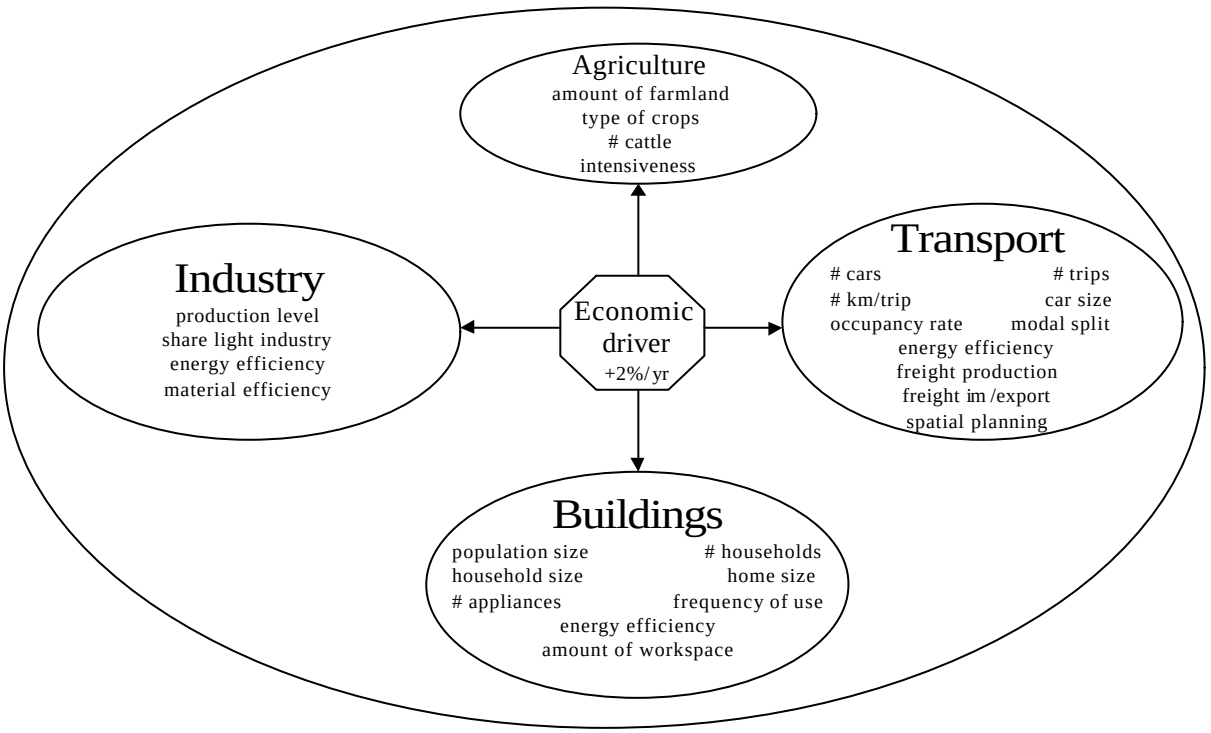

Figure 1: A schematic representation of the economy by sector and important drivers of energy consumption.

Within the energy supply system various sources (e.g. wind, biomass, coal) basically deliver a limited number of energy functions or energy carriers. In Figure 2 we distinguish electricity, heat (low temperature, high temperature and steam) and fuels. With fuels we

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

Basic assumptions in our future images:

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

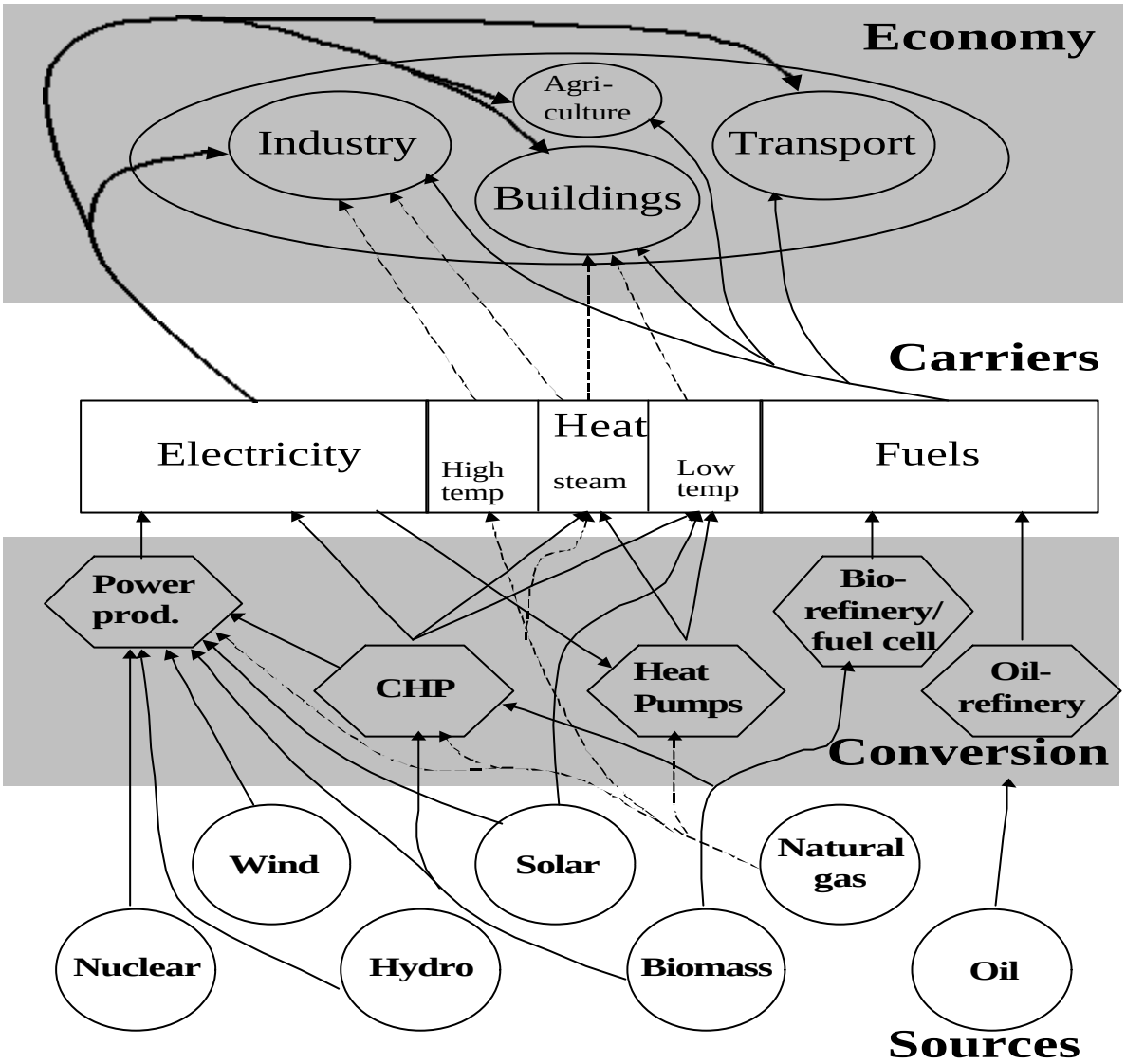

Figure 2: The future image of the energy supply and demand system in 2050.

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. TRANSPORT IMAGE FOR 2050

In this chapter an Image of the transport system 2050 is outlined. It is based on the assumptions regarding energy supply and emission levels specified in the Introduction to this paper. The Transport Image is described as regards the overall picture (2.1) and four specific elements that contribute to the "solution". These main elements are *Fuel Substitution* (2.2), *Improved Efficiency* (2.3), *Structures and Patterns* (2.4) and *Awareness, Values and Lifestyles* (2.5).

Improved energy efficiency and new fuels directly affect emissions (emissions per unit of transport), while new patterns of human activities and values and life-styles mainly have an impact on transport volumes. For each element the achievements (for example, the level of efficiency improvement for different vehicles) are specified in a box and factors that would make these possible are outlined. Finally, a *Profile of the Image* (2.6), i.e. how much each element contributes to the solution, is outlined in a table.

In order to ensure that the image is consistent and meets the CO_2 target, some calculations have been made concerning the use of different kinds of fuels and energy-saving techniques as well as transport volumes – a kind of transport energy balance. The methodology for this was developed in a Swedish transport futures study and has also been applied in the EU Fourth Framework Programme project Policy Scenarios for Sustainable Mobility (POSSUM).[1]

2.1 Introduction: An Overview of the Transport System in 2050

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

The energy efficiency in the transport sector is high. On average 25 per cent less energy is used per person-km compared to 1995, including energy for production of fuels (i.e. gross energy use). For freight the corresponding figure is 20 per cent less energy per ton-km than 1995. The efficiency improvements of vehicles – i.e. excluding energy used in the production of fuels – are even better, on average 40 per cent for both passenger vehicles and freight vehicles.

The volume of short everyday trips is less than in 1995, due to "decentralised concentration" and the use of IT as a substitute for commuting to work. IT shopping is also widespread. Long-distance journeys are well above the figures for 1995, especially those by air.

All this has resulted in more efficient, flexible and cleaner passenger transport.

Also, when it comes to *freight transport*, inter-modality is widespread, which has led to an increased share for fast trains. Dematerialisation and structural changes in industry have led

[1] 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.

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.

2.2 Fuel Substitution

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

Box 2. Fuel mix in 2050

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

Context

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

2.3 Improved Efficiency

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

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

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

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

Context

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

2.4 Structures and Patterns

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

Box 4. Increase in transport volumes 1995–2050

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

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

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

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

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

Context

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

Modal split

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

Residential patterns and urban form

The degree of structurally enforced travel, which was considerable in 2000, is reduced due to the residential pattern and the large amount of telecommuting and tele-shopping. Everyday short-distance travel has decreased, especially by car. Also, a considerable shift from private cars to public transport and bicycle has taken place. However, this does not hold to the same extent for non-urban car travel.

People to a large extent live in urban centres or sub-centres that are more self reliant than they were in the year 2000 ("decentralised concentration"). The supply of services is good and these centres can easily be reached by public transport. New residential areas are usually situated along public transport corridors or in city centres. Existing sub-centres are being upgraded to a higher degree of self-reliance with a rich supply of workplaces, goods and services. In many of these centres there are well-equipped "tele-cottages", making it possible for people to work in the vicinity of their residences. Tele-shopping in combination with electric delivery vehicles has cut trips to market stores considerably. This possibility also makes it possible to do without a car in many urban areas.

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

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

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

Industrial structure and patterns of trade

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

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

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

2.5 Awareness, Values and Lifestyles

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

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

40 per cent of the European population use computer-based programmes to define their individual carbon budgets. More than half of the consumers 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.

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 cooperative attitude among world leaders.

Changes in values and lifestyles cannot be enforced, but education, information and opinion-forming campaigns may help.

2.6 Profile of the Image

Table: Overview of the main elements of the transport image

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

values ▪ Green consciousness and support for policy measures	Very important as a precondition for the other improvements	Curricula for civic values and environment at schools and universities, information campaigns	Materialistic values