



Energy research Centre of the Netherlands

E-MAGINING FUTURE ENERGY INFRASTRUCTURES IN THE DUTCH TRANSPORT SECTOR

**An analysis of stakeholder perspectives on
future energy infrastructures in the
transport sector**

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July 2005

ECN-C--05-051

Acknowledgement

This report could not have been written without the help of several stakeholders in the Dutch transport field. We are, in particular, very grateful for the time and commitment of Paul Langeweg, Bettina Kampman, Robert van den Brink, Ton van den Berk, Chris de Koning, Jan van Grondelle, Marten Janse, Jan van Dijke, Geert Verbong, Boelie Elzen, Roald Suurs, Alexander Hable, Dominic Boot, Martin Kroon, Sible Schone, and Herman den Uil.

The report is registered at ECN under project number 77584.

Abstract

The project aims to contribute to the development of a more sustainable transport sector by analysing existing end visions, necessary key changes to accomplish these visions and the necessary actors to undertake these changes.

Six sustainable end visions for the transport sector have been selected. These end visions were used as a starting point for interviews with relevant stakeholders in the Dutch transport sector. These stakeholders were asked to comment on the plausibility of the end visions, and more particularly on the likelihood of key elements of these end visions. Stakeholders were further asked to propose additional or alternative changes that might be needed to realise the end visions and the role actors would have to play in order to bring about the changes necessary.

This study aims at bringing together knowledge and ideas from various fields of expertise on visions on and key changes to a future sustainable transport sector. The objectives of this study are as follows:

- This study will offer insight in the perspectives of relevant stakeholders with respect to key elements of an end vision and with respect to possible necessary changes to realise a specific end vision.
- This study will also put special emphasis on the role of actors in overcoming barriers to ascertain the realisation of key changes.
- Another objective of this study is to identify possible conflicting and possible complementary elements in specific key changes and end visions.
- In addition we will discuss if key trends, as identified in the end visions and the interviews, are following current trends or would entail trend breaches.

Market actors and policy makers are expected to be able to use the outcomes of this study to facilitate further discussions on end visions and the possible accompanying key changes (constituting pathways). The results will offer insight in possible conflicts among relevant stakeholders concerning the likelihood and preferability of end visions or key elements of these end visions. And finally, this report will offer insight in the actors that were mentioned by relevant stakeholders as being responsible for undertaking actions on the short term to enable a transition towards a sustainable transport sector. One major conclusion on this report is that all stakeholders agree that sustainable end-visions focusing on behavioural changes are not realistic, and that sustainability must be achieved by means of technological development.

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Summary

S.1 Introduction

The current transport system cannot be considered sustainable since it contributes substantially to various environmental problems, such as polluting emissions (NO_x, VOC, SO₂, fine dust), noise emissions, and continuously increasing energy use and related CO₂ emissions. Furthermore, the energy supply to the transport sector may become uncertain in the future, due to its high dependence on imported oil from a limited number of (potentially politically unstable) countries. The problems associated with the current practice in the transport sector and the notice that radical measures might be necessary to curb existing trends, call for a transition towards sustainable transport.

This study aims to contribute to the development of a more sustainable transport sector by bringing together knowledge and ideas from various fields of expertise on end visions on and key changes to a future sustainable transport sector. The objectives of this study are:

- to offer insight in the perspectives of relevant stakeholders regarding to key elements of an end vision and possible necessary changes to realise a specific end vision,
- to assess the necessary role of actors in overcoming barriers to realisation of key changes,
- to identify possible conflicting/complementary elements in key changes and end visions,
- to discuss if key changes follow current trends or would entail trend breaches.

S.2 Methodology

In this study, six sustainable visions on how the future of transport might unfold in 2030 and 2050 (end visions) were selected from recently published studies that contained detailed technological and non-technological information on the energy infrastructure for the transport sector and strategies to achieve more sustainability, while taking the Dutch context as a starting point. The selected end visions can be characterised by an emphasis on either capacity constraint (or a high level of behavioural changes) or a high level of technological and infrastructural changes.

The six end visions were submitted to relevant stakeholders in the Dutch transport sector, in an attempt to make an inventory of stakeholder perspectives on key elements of these sustainable end visions. These stakeholders were asked to comment on the plausibility of the end visions, and more particularly on the likelihood of key elements of these end visions. Stakeholders were further asked to propose additional or alternative changes that might be needed to realise the end visions and the role actors would have to play in order to bring about the changes necessary.

S.3 Results

According to the stakeholders, the six end visions all shared many elements that, if implemented, would not lead to the lock out of particular end visions, but would support the achievement of all end visions. These elements are: introduction of car coupling systems, optimisation of transport flows (e.g. modal shifts), increasing vehicle efficiency and ICE improvement, introduction of a better and fine-meshed public transport system, and central production of energy carriers.

The end visions, however also conflicted strongly on two elements: the further improvement of the ICE towards a much more sustainable ICE and consequently a large role for the ICE and fossil fuels in 2030/2050 versus the increased role of other sustainable drive trains and fuels such as battery and fuel cell vehicles using hydrogen, electricity or biofuels. Another strong conflict dealt with the increase versus decrease of mobility demand. These conflicts would result in the lock out of end visions if others would be implemented. The end visions further con-

flicted to a lesser extent on elements such as battery versus fuel cell driven cars, biofuels versus hydrogen and public versus collective transport.

The stakeholders agreed that end visions consisting of radical behavioural changes (such as creating closed regional markets, relocating work and living environment, prohibiting long-distance travelling, demanding car sharing practices etcetera) are not likely to occur, and not a preferred option. To realise radical behaviour changes would require a very strong superimposing supranational governmental institute and cannot coexist with the free market paradigm. Sustainability would most likely be achieved by means of technological development.

Stakeholders further agreed that end visions that foresee a diversification of automotive fuels, vehicles types, and user practices are likely and also preferred. However, there should be a balance between diversification of fuel types, vehicles types and user practices on the one hand, but not too much fragmentation on the other hand, since this might lead to a situation with insufficient market share for specific promising options. The stakeholders demonstrate much disagreement on the potential role of hydrogen, biomass and fossil fuels as energy carriers in the future transport sector. If a transition to hydrogen is to occur, stakeholders argued that an evolutionary switch, using hybrid technologies and thus preventing the need for a totally new and large-scale infrastructure, is potentially most successful.

The stakeholders foresaw a great role for the (supra)national governments to play for creating the boundary conditions for a successful take-off of a transition towards a sustainable transport energy infrastructure. These governments would need to stimulate sustainable innovations by means of regulation, pricing of transport to decrease transport demand, technology agreements, internalisation of external costs, certification and standardisation actions. The governments should furthermore provide consistency and long-term security for alternative sustainable options to increase their market share sufficiently. NGOs supported by the government could try to increase the environmental awareness of consumers, and as such stimulate the emergence of a new market for more efficient and cleaner vehicles.

Finally, stakeholders mentioned that to realise many changes autonomously (without strong involvement of the government) a very strong sense of urgency with respect to emission reduction should develop through increased commitment to the Kyoto protocol, or due to increased scientific knowledge on climate change related issues and the political issue of security of supply. However, this sense of urgency is difficult to attain according to most stakeholders.

S.4 Recommendations

Based on this study, two research recommendations are given, i.e. the possible role of hybrid technologies, such as hybrid vehicles, within the context of infrastructural issues of a transition towards more sustainable transport, and the creation and management of niche experiments, preferably on a EU level. Moreover, this study shows that there potentially is a need for an action plan for coordinated cooperation between parties. This action plan can facilitate the discussion among stakeholders, and can inform particular stakeholders on the role other stakeholders expect them to play in a transition to a sustainable transport sector. Commitment of stakeholders is imperative for a successful start of a transition, and if stakeholders do not accept the role imposed on them by other stakeholders, this is expected to greatly hinder the take-off of a transition. Connected to this recommendation, vision forming processes could greatly benefit from the participation of stakeholders outside the transport sector, e.g. from the energy sector, the agricultural sector and the built environment. Finally, transitions are long-term processes that can only be achieved by long-term management, which takes into account a long-term vision while designing short-term policies.

1. Introduction

Both on national and international level the awareness has increased that the current transport system contributes substantially to various environmental problems and can therefore not be considered sustainable. Possibly, radical measures might be necessary to curb this trend. In the Netherlands, the fourth National Environmental Policy Plan (2001) of the Ministry of VROM built upon this notion, and the Ministry has set the stage for a transition towards sustainable mobility and a sustainable energy system. The Ministry states the following:

‘For solving large environmental problems, system innovation is needed, which can be shaped in different ways. For some of them, innovation will have to be shaped by means of a long-term societal transformation process (often taking more than one generation). This transformation includes technological, economical, socio-cultural and institutional changes that affect and must reinforce each other. The period in which this can be realised can be considered a transition.’ (VROM, 2001)

In its recent policy document on emissions from transport, the Ministry defines sustainable transport as follows:

‘Sustainability means that the mobility system meets the needs of people, does not harm the environment or the climate, is safe for both humans and animals, and offers opportunities to business and industry. Sustainability also means that the energy supply for the transport sector remains guaranteed for the longer term.’ (VROM, 2004)

Following this VROM definition, the current transport sector is not sustainable. In this report, first the current practice of the transport sector is described, followed by a discussion on the environmental problems related to this current practice and the need for a transition towards sustainable transport. Six different visions on how the future of transport might unfold in 2030 and 2050 (end visions) of a transport sector are discussed. These end visions have been submitted to relevant stakeholders in the Dutch transport sector, in an attempt to make an inventory of stakeholder perspectives on key elements of these sustainable end visions. Stakeholders not only gave their perspectives on the likelihood that these end visions or key elements of these visions could be reached. They were also asked what changes should necessarily occur to make the achievement of the end visions or key elements of the end visions possible. Some of the more trend-like changes mentioned by the stakeholders, were subjected to an external check to ascertain the general beliefs concerning the likelihood that these changes might actually occur. The results of this check can be found in the appendices.

1.1 Objectives of this study

This study aims at bringing together knowledge and ideas from various fields of expertise on visions on and key changes to a future sustainable transport sector. The study will not comment on the preferability of a specific end vision or pathway. The objectives of this study are as follows:

- to offer insight in the perspectives of relevant stakeholders with respect to key elements of an end vision and with respect to possible necessary changes to realise a specific end vision,
- to assess the necessary role of actors in overcoming barriers that hamper the realisation of key changes,
- to identify possible conflicting and possible complementary elements in specific key changes and end visions,

- to discuss if key trends in the different end visions and interviews follow current trends or would entail trend breaches.

Market actors and policy makers are expected to be able to use the outcomes of this study to facilitate further discussions on end visions and the possible accompanying key changes. The results will offer insight in possible conflicts among relevant stakeholders concerning the likelihood and preferability of end visions or key elements of these end visions. And finally, this report will offer insight in the actors that were mentioned by relevant stakeholders as being the party responsible for undertaking actions on the short term to enable a transition towards a sustainable transport sector.

1.2 Contents of this report

In the next chapter, Chapter 2, the current practice of the Dutch transport sector will be discussed, with special emphasis on the need for a transition towards a more sustainable transport sector. In Chapter 3 the methodological approach will be described. In Chapter 4 the selected end visions are discussed. In Chapter 5 the end visions are compared and analysed to identify possible conflicts but also possible cooperation between the different end visions. In Chapter 6 the likelihood of the different end visions is analysed following the comments made by the stakeholders. In Chapter 7, the detailed key changes necessary to reach specific end visions will be discussed. Finally, in Chapter 8, conclusions are drawn.

2. Current practice in the Dutch transport sector

On January 1st, 2003, there were 6.8 million passenger cars, about 1 million commercial vehicles, and almost half a million motorbikes in the Netherlands. In 2002, there were about 7000 inland ships (registered fleet), and ca. 2000 aircrafts (excluding balloons) (www.cbs.nl). Presently, automotive fuels derived from fossil oil dominate the energy infrastructure of the Dutch transport sector. Most passenger cars run on gasoline, but diesel cars have a large share as well (about one-third). The use of LPG, which is a by-product of production and processing of crude oil and natural gas, is limited to a few percent. Most vehicles for freight transport and inland ships run on diesel. The share of diesel for trains is very small; most trains run on electricity. Aircrafts use kerosene derived from fossil oil. In contrast to some other European countries, biomass-based fuels such as pure vegetable oil and biodiesel have so far (2004) only been applied in pilot projects in the Netherlands.

The production chain of oil-based fuels starts with the exploration and production of crude oil. Whether oil fields can be exploited economically is strongly influenced by current market prices and the costs of exploitation technologies. In Europe, the end-user price of oil among others consists of the import price, trade margins, refinery costs, and excise duties. The oil market involves a large number of market parties, i.e. producers, distributors and brokers. In the Netherlands, oil fields are located in South-East Drenthe (the Schoonebeek field), around Rotterdam and in the Dutch sector of the North Sea. The oil is transported to the refineries in Pernis. For transport of oil to refineries, pipelines, tankers, or trains are used depending on the location of the oil fields. At Pernis, the crude oil is converted into various products, including diesel, kerosene, gasoline and LPG. These fuels are then transported to distribution depots by truck tanks and inland ships, and sometimes pipelines. From these depots, the fuels are distributed further to refuelling stations. These fuels are stored in underground storage tanks. Automotive fuels sold on the European automotive fuel market have to meet the European standards on fuel quality. Fuel prices for gasoline and diesel are determined on Platt's in Rotterdam. In the Netherlands, excise duties and other taxes (e.g. VAT) constitute end-user prices of fuels. The Dutch gasoline and diesel market is dominated by a small number of large oil companies, which own most refuelling stations.

The main drive train technology is the internal combustion engine (ICE), which includes both Otto engines (or spark ignition engines) using gasoline, and diesel engines (or compression ignition engines). Other drive train technologies and concepts are being developed by car manufacturers and research institutes, but they are currently only applied in demonstration projects. The car industry is also still improving the internal combustion engine, stimulated by European standards on polluting emissions (EURO standards) and the negotiated agreement between the European car industry (ACEA) and the European Commission to reduce carbon dioxide (CO₂) emissions from passenger cars (www.nam.nl; Van Thuijl, 2002).

2.1 Why a transition towards sustainable transport?

Severe environmental problems are associated with the current practice in the transport sector (i.e. due to the share of diesel cars) and this calls for a transition towards sustainable transport. First, the transport sector in the Netherlands is responsible for a substantial contribution to harmful emissions, e.g. two-third of total national nitrogen oxide (NO_x) emissions. Together with other vehicle emissions such as VOC (Volatile Organic Compounds), sulphur dioxide (SO₂) and fine dust (from diesel engines), the NO_x emissions contribute to air pollution and thus to health problems, especially in densely populated areas along roads. They also contribute to the damaging of agricultural crops, buildings and nature and they contribute to the decline of biodiversity. Moreover, the transport sector currently has a share of almost 20% in total national

CO₂ emissions, which contribute to the greenhouse effect and thus to climate change (VROM, 2004).

Thirty years ago, the first policies were developed to reduce negative environmental impacts at their source, leading to many technological innovations. For example, fifteen years ago, the international introduction of catalysts led to a substantial reduction of air pollution of passenger cars. However, since the growth of transport activity is expected to continuously exceed the rate of improvements in vehicle energy efficiency, the energy use of both passenger and freight transport is expected to increase in the future, up to an expected 50% increase in the period 2000-2030 for road transport (RIVM, 2000). The related CO₂ emissions from transport are expected to increase accordingly, since they are directly related to the energy use of vehicles. The share of transport is expected to increase over time, which is in contrast to developments in polluting emissions. Another problem is the increasing noise from vehicles as a result of the strong growth of traffic. Substantial reduction of noise from vehicles and infrastructure is required to avoid exceeding maximum allowable noise levels at certain locations.

Another issue is the high dependence of the Dutch transport sector on imported oil. According to the General Energy Council in the Netherlands (AER, 1998) the national import dependency of oil is expected to increase to 96% in 2010. This development is due to a decreasing production of oil on the North Sea in combination with an increasing demand for oil, mainly due to the transport sector. Furthermore, the number of oil suppliers is limited and include some potentially politically unstable countries; the main exporters of oil to the Netherlands are the OPEC countries, and the United Kingdom, Norway, and Russia. This high dependency on imported oil from a limited number of (potentially politically unstable) countries possibly makes the Dutch transport sector vulnerable to oil price shocks and the energy supply to this sector may become uncertain in the longer term.

2.2 Why is this transition a challenge?

Based on the notion of the necessity of a transition towards sustainability, the fourth National Environmental Policy Plan of the Netherlands Ministry of Housing, Spatial Planning and the Environment (VROM, 2001) sets ambitious goals for reduction of polluting emissions in the next 30 years, aiming at a 'no effect' level (no negative impacts on public health and nature).

These goals are:

- Compared to 1990 levels, NO_x and SO₂ should be reduced by 80-90%, VOC by 75-90%, and fine dust by 85-95%, in 2030 and total CO₂ emission of 40-60% in 2030.

The transport sector should contribute proportionally to these goals. However, the CO₂ emissions from transport have shown an increase of ca. 20% since 1990. Due to the growth of transport activity and related energy use, substantial efforts are expectedly needed to curb this trend and make the transport sector contribute proportionally to the overall CO₂ emission reduction goals.

Possible options to achieve emission reductions from transport are to (Greene and Schafer, 2003):

- increase the energy efficiency of transport vehicles (including possible alternative drive trains such as hybrid, electric or fuel cell vehicles),
- substitute conventional automotive fuels by low or no carbon alternative fuels (e.g. LPG, natural gas, hydrogen, biofuels),
- increase the efficiency of the transport system (shifting to more energy-efficient modes; optimise transport routes, occupancy rates, maintenance and driving behaviour),
- reduce transport activity (e.g. by changing land use, spatial planning, adjust pricing to influence demand for transport).

Changes in the transport sector such as the ones mentioned above, are not easy to realise. This holds especially for radical changes in the transport system and associated product and fuel chains, and for changes in the transport sector, which imply accompanying changes in other sectors as well, for example agriculture, housing or the chemical industry.

Existing transport, energy and knowledge infrastructures cannot be changed overnight; this is a long-term process that needs to be managed (Rotmans e.o., 2000). Changes in the infrastructure will for example encounter resistance from actors with vested interests. In processes of change, some actors are expected to benefit from changes, although they cannot always influence them. On the other hand, actors that are able to influence changes may benefit from resisting these changes, for example because they face very long pay back periods for their investments in infrastructures ('sunk investments'). Moreover, resistance to change may be different depending on the kind of infrastructure that needs to be changed. The embeddedness of infrastructures (e.g. in regulation practices, user practices, investment practices) makes infrastructures inflexible to changes as well (Mourik, 2004). The flexibility of infrastructures depends on the possibilities for creating links with new technologies (either alternative or hybrid). However, lock-in situations may occur due to such links, i.e. when a short-term solution, which is easily implemented, hampers the achievement of long-term goals. Hybrid technologies may be applied. Hybrids are coupled technologies that can function as transitional technologies and that probably will not exist in this coupled form for a long time (Schot, Hoogma, Elzen, 1994), (Geels, 2002). These hybrids are different from hybrid cars such as the Toyota Prius, which aims at optimising the ICE car, and is not aimed at creating a transition to all-electric transport systems. The hybrids may either make use of the existing infrastructure or anticipate the creation of a new infrastructure. Because hybrids easily fit into the existing situation they may be economically attractive for business actors; after all, the investments in a new infrastructure can be deferred to long term. These hybrid technologies will be discussed in more detail in the concluding chapter.

The actions and key changes on the short term to facilitate this transition are, however, mainly unknown. This is the consequence of the current emphasis on the formulation of end visions that are supported by all relevant stakeholders in the transport sector, rather than identification of the different key changes that would create those end visions. As a consequence, the debates on the transition towards a sustainable transport sector are held anew every couple of years, and in the meantime the changes that do occur are more or less autonomous, the result of market mechanisms.

The changes that occur due to market mechanisms are aimed at optimising the existing transport system. However, to alter the present situation into a sustainable one, structural, radical, and above all, coordinated long-term actions aiming at increasing the possibility of unfolding sustainable end visions will be needed such as the built up of a new infrastructure. Relying on market mechanisms alone to create a more sustainable transport sector are likely not to be sufficient. Therefore it is imperative to translate long-term goals or targets (end visions) into short-term actions, since the transition needs to be managed. To be able to decide which actions are needed and preferred, it is important to identify all possible key changes and their technological, infrastructural, economic, socio-cultural and political consequences.

However, currently, when stakeholders do discuss different key changes, they usually only focus on their technical and economic characteristics. However, key changes also consist of many non techno-economic aspects and it is the interaction between these aspects and the consequences of these interactions that should be taken into account. Typically, however, these interactions between the different key changes and the consequences of specific (technological) choices have not been analysed so far. It is very likely that different possible key changes to a sustainable transport sector can be identified, all with their specific technological, infrastructural, economic, political and socio-cultural requirements. Facilitating the creation of one of these key changes might lead to the lock out of another pathway, because they require different characteristics. Therefore, it should be analysed what these interactions might be. In addition,

taking into account that the average time needed to change an existing (material and economic) infrastructure is at least fifteen years, but can amount to thirty to fifty years, contemplating on the consequences of certain technological choices is important.

3. Methodology

3.1 The societal embedding analysis (SEA)

This report makes use of a transition management instrument that aims at combining both fore- and back casting: the societal embedding analysis (SEA) (Kets, e.o., 2003). SEA builds strongly on the Socrobust methodology that was designed in the European Socrobust project to assess the potential for socio-economic success of innovations defined as radical (Laredo, e.o. 2002).

The SEA instrument is the basis for this analysis because its methodology facilitates the identification of both technological and non-technological elements of and changes towards an end vision, and also facilitates an analysis of relevant actors for each of these elements. A full SEA consists of several steps and accompanying instruments. In this report we only discuss the steps and instruments of relevance for this specific project. Within the project the following elements of the SEA methodology were used:

3.1.1 Selecting end visions

Typically, a SEA starts with the creation of a preferred end vision or set of end visions. In this project, it was not necessary to create end visions anew. The project team selected existing end visions from recent transport-transition reports that focused specifically on the Dutch situation. The selection criteria emphasised both technological and social aspects. The selection was based on the following criteria:

- *Time focus*: The end visions had to deal with at least mid-term (ca. 2030) and preferably long-term (ca. 2050) transitions.
- *Geographical focus*: The aim of this project was to analyse a transition towards a sustainable transport energy infrastructure in the Netherlands. The selected end visions had to take the Dutch context as a starting point.
- *Sustainable aim*: Visions that emphasised sustainability were selected, since those visions were most in line with the governmental focus on a more sustainable transport sector.
- *Focus on energy infrastructures*: The focus of this project was on the energy infrastructure ('from well to tank and tank-to-wheel'), not on vehicle assembly infrastructures and the energy required in that infrastructure. Therefore we focused on studies that emphasised the energy infrastructure of the automotive fuels and on the transport modality infrastructures.
- *Focus on all relevant dimensions*: Studies were selected that explicitly focused on technological (kind of cars, energy sources, modalities, innovation), infrastructural (modal shifts, occupancy rates, technological infrastructure) and non-technological aspects of energy infrastructures (actors, incentives, knowledge networks, socio-cultural and political-institutional aspects).

The project team selected six recently published sustainable end visions that contained detailed information on the energy infrastructure for the transport sector. These end visions are discussed in Chapter 4.

3.1.2 Description of end visions

The aim of a SEA is to formulate end visions as broadly as possible, focusing not only on the technological aspects of the embedding process of an innovation, but also on societal aspects. the project team used the concept of 'dimensions' to urge experts to view the end visions in a more schematic way. Within this project seven dimensions are used to describe the selected end visions. The dimensions are: technology, infrastructure, economy, ecology, political-institutio-

nal, socio-cultural and the geographical dimension. These dimensions are complementary; however, they sometimes overlap (e.g. the techno-economic dimension, or the socio-economic dimension). By focusing on all dimensions, a complete picture of an end vision is obtained, see Figure 3.1.

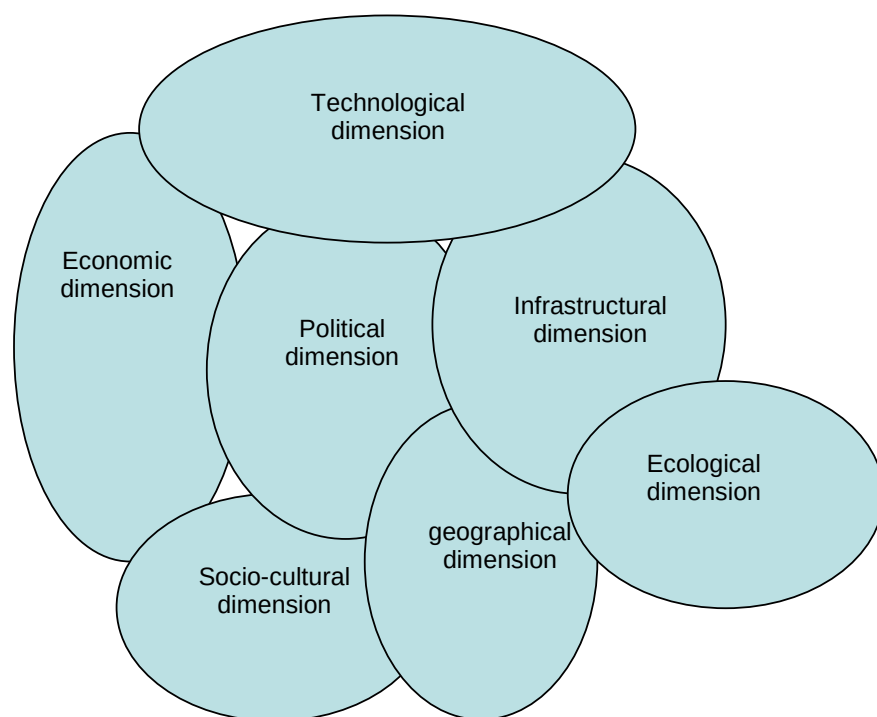


Figure 3.1 *Different dimensions constituting an end vision*

3.1.3 Description of key changes in end visions

The project team used the SEA concept of key changes to describe those elements that need to change to make the unfolding of an end vision actually possible. The project team first identified those elements of end visions that differed from the current practice. Then the project team submitted these elements to the interviewees for comments. In addition, during the interviews the stakeholders were asked to identify alternative key changes they thought were relevant to realise an end vision. For each key change the key actors required to undertake that change are identified. After the key changes typical for each end vision have been identified, the interaction between these changes can be analysed. Key changes for different end visions may be conflicting, neutral towards each other or perhaps even strengthen each other's development. By analysing the key changes necessary to realise end visions, it can be assessed if key changes necessary to achieve one end vision possibly lead to the lock-in or lock-out of elements of other end visions and as such might lead to lock out of alternative end visions.

3.1.4 Clustering end visions for further analysis

To facilitate the analysis of possibly conflicting end visions and their key changes, the project team clustered the end visions following different axes to see where they conflicted and where they complemented each other. The end visions proved to be difficult to divide. Many elements of the end -visions proved to be identical in all or almost all visions. This was explicitly the case for the following: all end visions included energy efficiency, public support for sustainability and environmental concern, more or less governmental influence, modal shifts towards collective transport, optimisation of transport streams. Most studies did not explicitly discuss drivers

such as internalisation of costs, CO₂ capture and sequestration, central or decentral production of carriers.

What remained as potential issues for a good distribution of the end visions in four quadrants were capacity constraint or the lack thereof and a high level of technological and infrastructural changes versus a low level of these. Additional differences between end visions within the same cluster were based on the used energy sources, carriers and drive trains. None of the end-visions that we analysed included both a high level of technological and infrastructural changes as well as a strong emphasis on capacity constraint. Such end-visions would probably include a very high level of sustainability but are highly unlikely. In addition, none of the end-visions included a low level of technological development as well as a lacking emphasis on capacity constraint. Such end-visions would likely not result in any sustainability, and therefore would not have been focus of analysis for this research. See Figure 3.2 below.

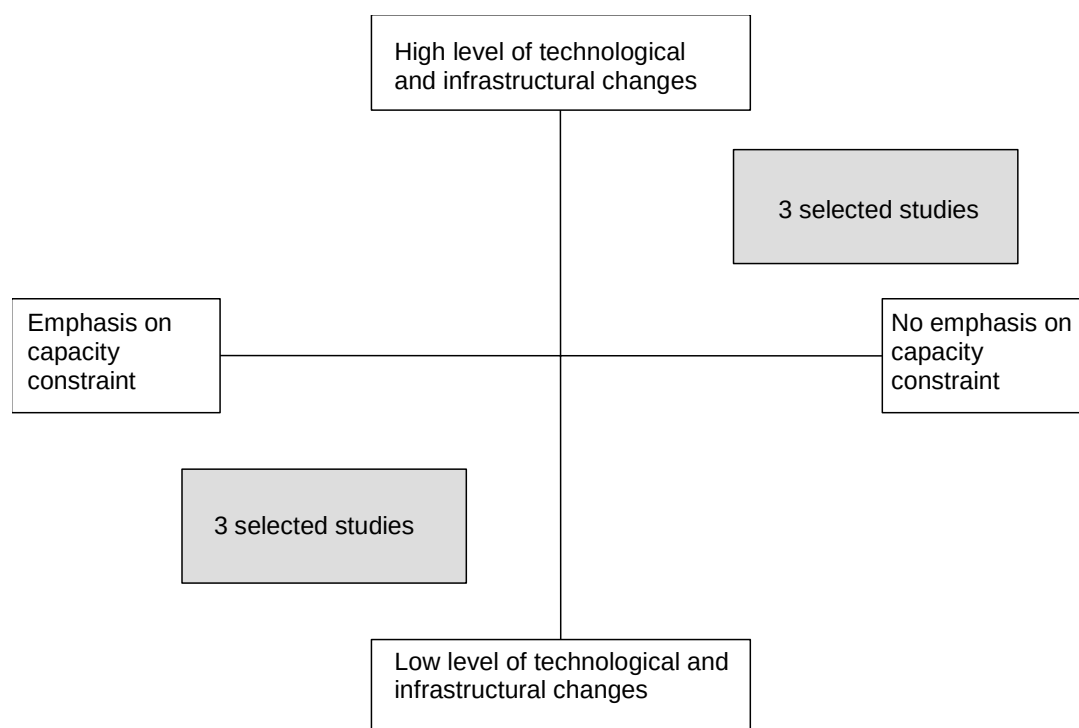


Figure 3.2 *Clustering the six end visions*

3.1.5 Selecting and interviewing representative stakeholders

The project team asked relevant stakeholders to brainstorm on these issues in a two-hour interview. It was decided to ask different representatives of actor groups, experts, to identify the key technological, infrastructural, economic, political, and socio-cultural changes with respect to the energy infrastructure. For each change the interviewees were asked to identify the party they believed should undertake that change.

3.1.6 External check

The project team performed an external check, which consisted of a search on the Internet. This search aimed to put the stakeholder perspectives about particular elements (key trends and key changes) of end visions into perspective by specifying alternative views and principal positions taken by other actors. During the interviews held for this project, the stakeholders mentioned

key trends and key changes that might be necessary (but not necessarily preferred or plausible) to accomplish an end vision of a more sustainable transport sector. The check involves taking one step back from the interviews, and testing the societal robustness of the perspectives on key trends and key changes as mentioned in the interviews. The result of the external check is a description of the state of the art viewpoints and knowledge of various relevant actors that were not involved in this research.

An important aspect of the external check is that one has to choose which perspectives have to be checked. Due to time constraints, not all perspectives can be checked. This choice is therefore biased. In addition, the translation of the perspective into key words with which the search can occur is also creating a bias since different key words might lead to alternative sources and consequently, relevant information may be overlooked. Typically, the external check includes both an Internet check and interviews with additional experts, relevant to the field of expertise of the interviewed stakeholder. This approach is time consuming and often consists of half of the project's budget. This research includes only an Internet check, to identify the possibilities to minimise the external check.

The external check should be viewed as a methodology to put the stakeholder perspectives about particular elements (key trends and key changes) into broader perspective by specifying alternative views and principal positions taken by other actors. However, only limited conclusions can be drawn on the merits (are they correct or faulty) of the stakeholder perspectives. The external check conducted in this research proved to be too limited to draw conclusions. Therefore the results of the check are discussed in an annex to this report.

For an overview of the different methodological SEA steps used in this project see Figure 3.3.

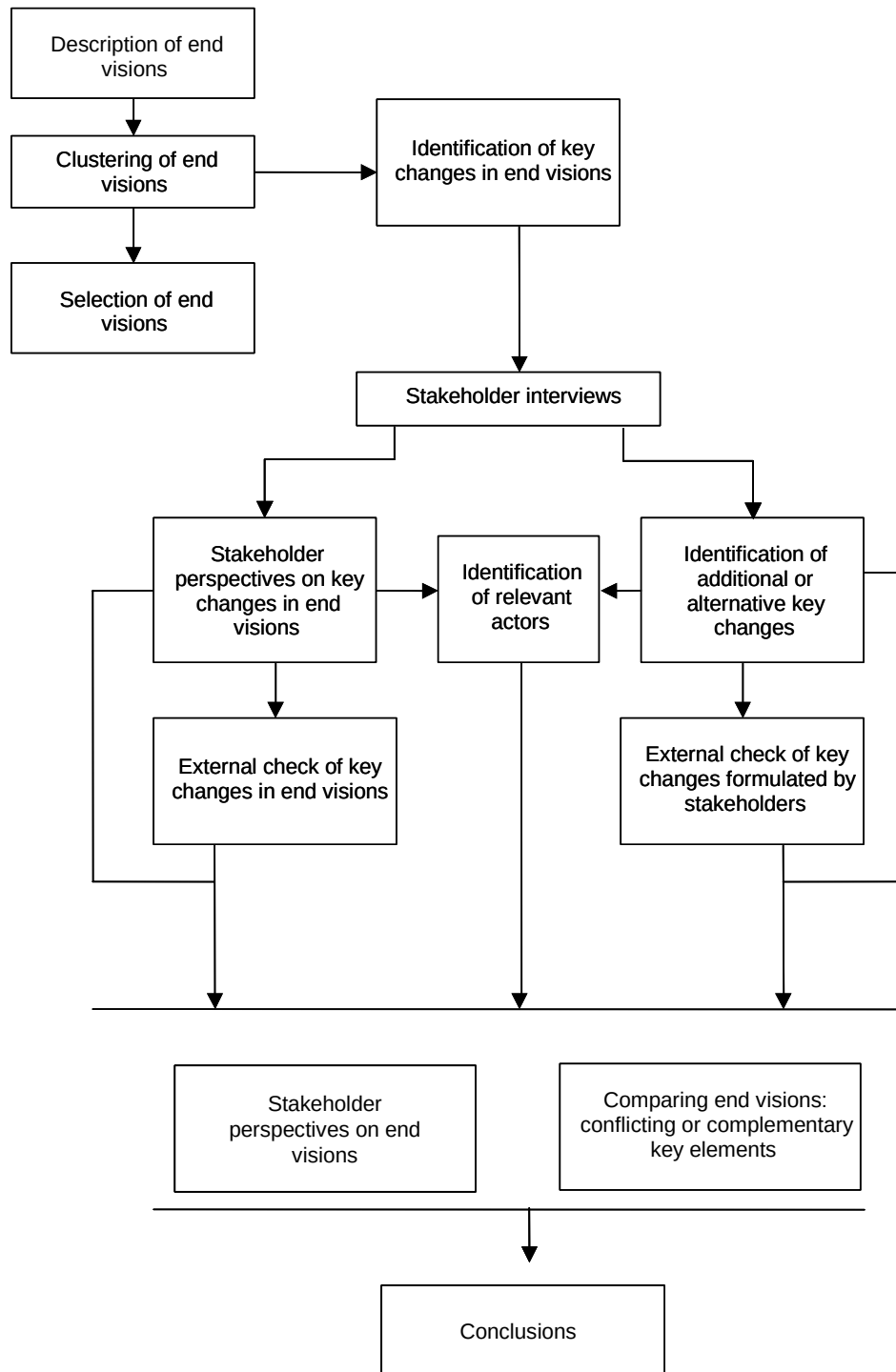


Figure 3.3 *Overview methodological steps*

4. End visions towards a more sustainable transport sector

In this section we discuss the six ‘sustainable’ end visions that were selected. The six end visions were retrieved from the 1999 OECD Environmentally Sustainable Transport project (Organisation for Economic Co-operation and Development, 1999), the 2002 Climate options for the long term COOL project (Tuinstra, W., e.o. 2002) and the 1998 SEP roadmaps to 2050: transport in the 21st century (van Gerwen, R., Toussaint, P., 1998). From each study we selected those end visions that aimed at achieving a more sustainable transport sector (in terms of far reaching emission reduction). For a detailed discussion of the background for each of the selected end-visions, see Appendix C.

The following six end visions are discussed in the sections below:

1. The 2030 OECD Capacity-Constraint
2. The 2050 OECD High-tech
3. The 2050 COOL A
4. The 2050 COOL B
5. The 2050 SEP Sustainable Balance
6. The 2050 SEP Sustained Growth.

4.1 The OECD Capacity-Constraint end vision

In 2030 the transport system in the Netherlands has been changed radically. The efficiency of vehicles has been improved, such as the internal combustion engine, which is still the dominant drive train. Although the energy demand of the transport sector remains mainly fossil-based, the emissions of CO₂, NO_x and volatile organic compounds (VOC) have decreased enormously as a result of a much lower overall energy use due to increased efficiency of transport modes, efficiency of transport fuels and technologies (i.e. end of pipe cleaning) and due to the fact that mobility has reduced drastically too.

The overall mobility has been reduced due to relocation of different activities close to each other, regionalised production and consumption of goods, improved transport logistics, and improved quality of products. Close markets are developed on regional scale close to light rail systems. Most short distance mobility takes place by means of walking and cycling, and dedicated public transport with doubled occupancy rate through light rail. Vehicles having the lowest emissions meet remaining demand for long distance mobility. There are no motorcycles and mopeds. Buses are the main means of transport in less densely populated areas. Car use is restricted to special services such as transport for the disabled, ambulances, fire brigades and the police. The use of lorries in daytime is restricted. Air transport is replaced by telematics. Goods are transported by means of inland shipping, but international transport has decreased enormously.

4.2 The OECD High Tech end vision

In 2030, the energy use and emissions of CO₂, NO_x, and volatile organic compounds (VOC) of the transport sector are reduced substantially in the Netherlands as a result of a rapid introduction and diffusion of new, clean and highly efficient technologies and logistic optimisation in road and rail transport. In all transport modes, additional technologies are introduced to reduce noise emissions. Several technologies are used to increase energy-efficiency, such as the use of light materials and high-efficiency engines and re-use of brake energy. In private transport (cars, mopeds, motorcycles) there is a shift from internal combustion engines using petrol or diesel towards electric traction, based on electricity that is mainly produced from sustainable energy. For shorter distances electric cars run on batteries, for longer trips they are connected and run on rails using externally supplied energy. The coupling of cars, implemented in phases, results in

tripled capacity of drive lanes. Electricity that cannot be used immediately is stored in hydrogen at the central production plants. Thus hydrogen may be used in specific subsections of the transport sector.

In public and goods road transport (busses, vans and lorries), mainly a combination of both electric and hybrid LPG vehicles are used. Logistic optimisation is also used for buses, leading to a double average occupancy rate. In addition, public transport is made more flexible so that demand conforms better to supply. However, heavy lorries that are used for long-distance freight transport mainly use fuel cells in combination with sustainably produced hydrogen. This is also the case for inland ships, marine transport and international aircraft transport. Rigid airships (zeppelins) running on hydrogen are used for short distances and compete with air and rail transport.

4.3 COOL A end vision

In 2050, the transport sector no longer uses fossil petrol and diesel, but the energy supply is much more diverse and new technologies have been introduced to increase fuel-efficiency. In road transport, cars, vans and small trucks are equipped with fuel cells and hydrogen is stored on-board. They use refuelling stations that are provided with centrally produced hydrogen by means of truck lines. Because refuelling stations are not located within the built environment, large hydrogen storage tanks are required. The most important energy source for the production of hydrogen is biomass; the remaining part is produced from either coal or natural gas, and thus still largely fossil fuel based. CO₂ is captured and then sequestered, using an infrastructure to collect and store CO₂, mostly from and at large centralised power and hydrogen production plants. Biomass is also used for the production of synfuels (hydrocarbons) that are used in aircrafts, inland ships and trucks. This biomass originates from Eastern Europe, Latin America and sub-Saharan Africa. There is a tendency towards large-scale centralised production capacity.

Public or collective transport has grown substantially, at the expense of individual transport, especially in major urban areas. Freight transport has increased significantly in spite of the bundling of transport streams, and witnesses a modal shift from road to water transport after the water infrastructure has been improved by the government and after chemical plants have financed their own terminals. There is also a modal shift from air transport to transport by train. Overall, the demand for transport has increased which requires extensions of the transport infrastructure. Due to spatial scarcity the construction of infrastructures is expensive. In order to solve spatial scarcity issues, technologies are introduced to increase the efficiency of the transport system, for example magnetic coupling of cars and ICT.

4.4 COOL B end vision

In 2050, the demand for transport in the Netherlands is relatively low, which is mainly due to spatial planning policies that reduce commuter traffic and the partial replacement of mobility by ICT. Collective and bundled transport has gained importance, at the expense of individual transport. Overall, the energy-efficiency of the transport system has increased. In cars, trucks, and buses clean fuel cells are used, which mostly run on biofuels (mainly ethanol and methanol) and have a higher efficiency as compared to conventional cars using petrol or diesel. On global level there is sustainable production and distribution of all kinds of products from biomass, such as biofuels and hydrocarbons that serve as feedstock. CO₂ emissions are collected at bio refineries. The bio-alcohols used in fuel cell vehicles are converted to hydrogen on-board. For most public transport systems electricity is used. There is a strong increase of air transport but the energy efficiency of aircrafts is increased strongly and they run on synfuels (biomass-derived hydrocarbons). Short-distance air transport is largely replaced by rail transport. Trains and ships have gained importance as freight transport modes. A pan European network for underground transport will be implemented.

4.5 SEP Sustainable Balance end vision

In 2050, the internal combustion engine is still the dominant drive train in the transport sector, because, due to the introduction of advanced technologies, it can still comply with stringent energy use efficiency and emission standards. However, competing drive technologies have been introduced, i.e. electric vehicles using batteries or fuel cells, and hybrid electric vehicles. In individual passenger transport, a diversification of vehicle concepts has been realised as well. Downsized all-purpose vehicles that are either rented or shared are used in combination with a great variety of cars for city areas. Urban cars are mainly equipped with electric or efficient internal combustion engines. The mobility demand is still high.

In the transport sector, fossil fuels remain the most important fuels, although in the energy supply system fossil fuels are gradually replaced by energy carriers produced from renewable sources as a result of active governmental policies. Indigenous and imported biomass and solar energy (in the form of electricity or hydrogen) are important renewable energy sources. Electricity has gained a substantial share as energy carrier in transport, as well as biofuels that are used by fuel cell vehicles. In public transport diesel remains the most important fuel and it is used in vehicles with internal combustion engines and hybrid electric vehicles. In hybrid electric buses biofuels are used as well. Electric vehicles also have a share in public transport. The government support a fine meshed public transport system and contributes to the exploitation of demand-dependent transport that replaces non-rail public transport. The government also strongly promotes the use of bicycles and vehicle/bicycle concepts. For trucks, the internal combustion engine remains dominant, since the hybrid electric concept has little added value because trucks drive for long distances with constant speed. The diesel engines used in trucks have become much cleaner and they use biofuels or conventional diesel.

4.6 SEP Sustained Growth end vision

In 2050, despite stronger spatial concentration of houses, the lower share of paid labour and the CO₂ implications of transport, mobility has strongly increased due to high economic growth. Especially freight transport has increased enormously. The transport sector has witnessed a strong diversification in new, energy-efficient and environmentally friendly transport system and vehicle concepts and drive train technologies. For environmentally friendly vehicles there are separate high-tech lanes for the coupling of cars that guarantee a short travel time combined with automatic vehicles guidance. Moreover, differences between individual and public transport fade.

The diversification in vehicle types and drive trains occurs especially in individual passenger transport, in which small urban cars in city centres and urban areas have gradually replaced all-purpose vehicles and have become the dominant vehicle type. Long-distance vehicles are also used, but as second car, or shared or rented car especially for long-distance trips because they are more expensive. Passenger cars are mostly hybrid electric vehicles using biofuels or fossil petrol or diesel, and fuel cell vehicles using hydrogen. Electric vehicles using batteries also have a substantial share, which has led to a substantial extension of the number of recharging units, especially public recharging facilities. However, large extensions of the electricity grid have not been implemented. To avoid bottlenecks in recharging of battery electric vehicles different strategies are used, such as shifting of the load of battery electric vehicles to time periods in which the nation-wide electricity demand is low, or using batteries to store electricity from PV thus stabilising demand and supply of electricity from PV.

In public transport, the internal combustion engine still has a share but is mainly substituted by three types of traction. The first is hybrid traction vehicles using both a combination of electricity and biofuels or diesel. The second consists of fuel cell vehicles running on hydrogen and the third consists of battery electric vehicles. Most trucks are still equipped with internal combustion

tion engines using diesel, but fuel cell vehicles running on hydrogen become very important as well. Vans sometimes use electric engines combined with a battery.

Due to strong incentives for reducing CO₂ emissions, renewable energy sources and CO₂ capture and storage (in empty gas fields and aquifers) have become attractive technologies, which also applies to the transport sector, e.g. biofuels have become important energy carriers in transport. Biomass is also be used for other purposes, e.g. as a fuel for power plants and industrial installations. This large-scale application of biomass may result in large agricultural monocultures abroad, which may lead to other adverse environmental effects (due to the use of artificial fertilisers and pesticides). These effects will be avoided as much as possible but reduction of CO₂ emissions has the highest priority. Hydrogen and electricity are produced from natural gas (reforming and CHP) and coal (gasification combined with CO₂ storage) and renewable energy sources also gain importance here. CO₂ will be captured and stored at electricity and fuel production facilities.

5. Comparing end visions: Competitive and complementary key elements

In this report, a large number of stakeholders were asked to comment on six prior selected end visions of a sustainable transport energy infrastructure. In the current chapter, the possible complementariness or conflict between these six end visions (particularly their key elements) is discussed. The end visions may be complementary to each other if they share similar key elements. Conflict can occur when end visions do not share key elements, or when they consist of key elements that are opposed. In addition to this analysis of complementariness and conflict, the stakeholder perspectives on the plausibility of the key elements are discussed. For a detailed overview of shared key changes and changes that are particular for one end vision, see Figure 5.1.

5.1 Complementary key elements in the six selected end visions

As can be deduced from Figure 5.1, the six end visions all shared the following elements: the introduction of car coupling systems, an optimisation of transport flows (consisting of modal shifts towards inland shipping and rail transport of goods, and to a slighter extent air transport), an optimisation of ICE technologies and increasing the efficiency of vehicles, the introduction of a better and fine-meshed public transport system, and central production of energy carriers.

For all these elements, the stakeholders mentioned that they did not foresee severe hurdles in realising them. The critical notes concerned the optimisation of the ICE and the efficiency of vehicles. According to the stakeholders, this optimisation and efficiency improvement would not be able to solve all problems in the transport sector, such as congestion issues and emissions, and additional sustainable alternative automotive fuels and drive trains would be required.

It can thus be concluded that according to the stakeholders, these shared elements, if implemented, would not lead to the lockout of particular end-visions, but would support the achievement of all six end-visions.

Figure 5.1 demonstrates the different pathways to the different end visions. Each line corresponds to a different end vision. The figure does however not visualise which elements are possibly conflicting.

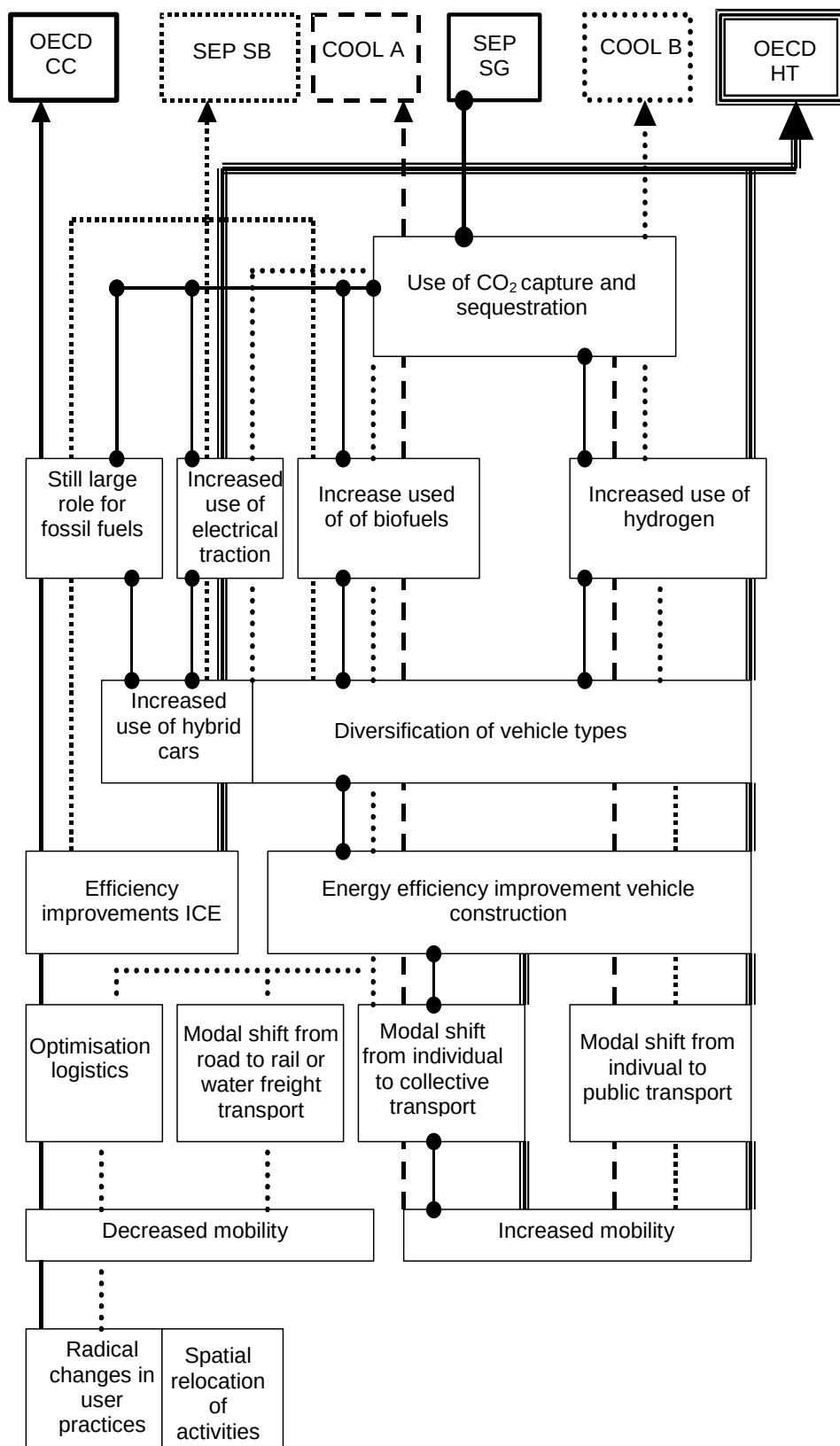


Figure 5.1 Overview of different pathways to the six different end visions

5.2 Conflicting key elements

As discussed in the section above, the six end visions shared many key changes. However, the stakeholders also mentioned elements that are in essence conflicting.

The possibly conflicting elements are fuel cell driven vehicles versus battery-electric vehicles, fuel cells using biofuels versus hydrogen-driven fuel cells, ICE improvements in energy efficiency and emission reduction versus other alternative sustainable drive trains, decreased or low mobility demand versus increased or high mobility demand. In addition the stakeholders mentioned that public transportation might conflict with collective (coupled car) transportation systems. Below the stakeholder arguments for the possible conflict are discussed, and then the different end visions are clustered in tables to demonstrate possible conflicting end visions. The inherent inconsistencies will be discussed as well.

The stakeholders made an additional very relevant general comment. They claimed that a balance should be found between diversification of fuel and vehicle types on the one hand, and the creation of sufficiently large market shares to secure the introduction of new sustainable options and the accompanying infrastructures on the other hand.

5.3 Possible conflicts between end visions and lock out of end visions

If different end-visions include of conflicting elements, the end visions might conflict. The occurrence of one end vision can then induce the exclusion of occurrence of another end vision. In some cases, conflicting elements occur within one end vision, and according to the stakeholders, therefore, this end vision demonstrates an inherent inconsistency.

Figure 5.2 demonstrates that many end visions may conflict with each other and possibly could lead to the lock out of certain other end visions, particularly concerning key elements such as increased versus decreased mobility and increased efficiency of the ICE versus increased use of other sustainable drive trains and automotive fuels. The conflict is also apparent, however less severe, with respect to collective versus public transport, battery-electric vehicles versus fuel cell driven vehicles and fuel cells on hydrogen versus fuel cells on biofuels. For a visualisation of the most severe conflicts see Figure 5.2.

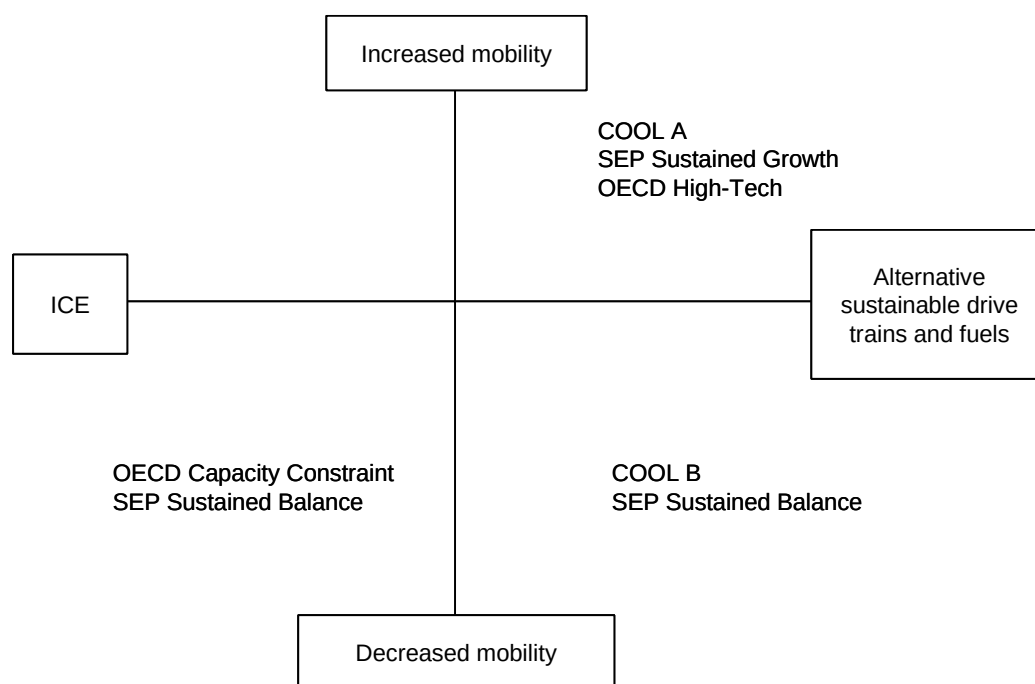


Figure 5.2 Overview of conflicting end visions. The SEP Sustained Balance end vision can be clustered in two areas because it emphasises both the use of ICE and alternative sustainable drive trains and fuels

The OECD Capacity Constraint, the COOL B and to a lesser extent the SEP sustained Balance end visions on the one hand conflict strongly with the OECD High-tech, COOL A, and SEP Sustained Growth end visions on the other hand. They demonstrate conflict on the following key elements: a decreased or low mobility demand versus an increased or high mobility demand. With the exception of the COOL B end vision, these end visions also conflict with respect to ICE improvements/large role of fossil fuels versus increased/large role of other alternative sustainable drive trains and automotive fuels. The COOL B end vision also envisions a large share of alternative sustainable drive trains and automotive fuels.

If the end visions that envision an increased role of alternative sustainable drive trains and automotive fuels are clustered according to battery-electric vehicles versus fuel cell driven vehicles, another possible conflict becomes visible, which is shown in Table 5.1. In this table, some end visions are mentioned on both sides, which demonstrates that they might experience inherent conflicts.

Table 5.1 Fuel cells versus battery driven cars/hybrids

Fuel cell	Battery driven cars/hybrids
SEP Sustainable Balance (biomass)	OECD High-tech
COOL B	COOL B (Public transportation)
	SEP Sustainable Balance (partly)
	SEP Sustained Growth

As discussed earlier in this chapter, the stakeholders claimed that fuel cell driven cars (particularly if implemented first) might compete with battery - electric cars. This would mean that the COOL B end vision might have to compete with the OECD high-tech and the SEP Sustained Growth and to lesser extent with the SEP Sustained Balance end visions.

According to the stakeholders, the COOL B end vision does not demonstrate inherent inconsistency, although both fuel cell and electric traction using batteries are envisioned. The different drive trains are envisioned for different sub sectors of the transport sector, and as such do not necessarily compete. The fuel cell driven vehicles would be implemented in private transportation, whilst the battery driven vehicles would be implemented in public transportation.

A possible inherent conflict with respect to battery driven cars versus fuel cell driven cars concerns the SEP Sustainable balance end vision, however. In this end vision both fuel cell driven and battery driven vehicles are envisioned. In the end vision, no separate niches are allocated to these different drive trains, and as such both drive trains would compete strongly for the same market share. Especially, since the ICE also still has a strong role to play in this end vision. If the technological problems of battery driven vehicles are not solved shortly, and if fuel cell driven vehicles are implemented first, with the accompanying infrastructure, the introduction of battery driven vehicles possibly might seriously be hindered. An additional inherent problem of this end vision, according to the stakeholders, is that fuel cell driven vehicles that are fuelled with biofuels is an unlikely occurrence due to their chain (in) efficiency.

Within the end visions that envision fuel cell driven vehicles, yet another possible conflict might occur. See Table 5.2.

Table 5.2 *Biofuel Fuel Cells versus Hydrogen Fuel Cells*

FC biofuels	FC hydrogen
COOL B (converted to hydrogen on board)	OECD HT (subsection; heavy lorries and airships)
SEP Sustained Growth	COOL A (from biomass not likely) SEP Sustained Growth

The COOL B and SEP Sustained Growth end visions might possibly conflict with the OECD High-tech and the COOL A end visions, with respect to the fuel used to drive the fuel cell. In addition, the SEP Sustained Growth end vision demonstrates some inconsistencies according to the stakeholders. In this end vision both hydrogen and biofuels driven fuel cells are envisioned. As mentioned in the paragraph above, the stakeholders did not consider biofuels driven fuel cells very likely, although hydrogen driven fuel cells also need to overcome several social acceptance barriers.

Finally the different end visions might conflict with respect to the mode of transportation. The OECD Capacity Constraint, the COOL B, and the SEP Sustainable balance end visions on the one hand might conflict with the OECD High-tech, and the SEP Sustained Growth end visions because they focus on possibly conflicting modes of transportation (if these modes are not implemented in different areas (e.g. rural versus urban transportation)). The COOL A end vision envisions both modes, which is possible if they are implemented in different areas. See Table 5.3.

Table 5.3 *Public versus collective transportation*

Public transportation system	Collective transportation system
OECD Capacity Constraint	OECD HT
COOL A partly	COOL A partly
COOL B	SEP Sustained Growth
SEP Sustainable Balance	

6. Stakeholder perspectives on end visions

In this chapter, the interviewee's perspectives with respect to the six end visions are given. Issues specifically related to energy infrastructure were already discussed in Chapter 5 separately. This chapter aims at reintegrating all these perspectives into general views on the likelihood of the six end visions.

6.1 Stakeholder perspectives on the OECD Capacity-Constraint end vision

The OECD Capacity-Constraint end vision consisted of radical changes. In 2030, improved efficiency of the ICE is responsible for its ongoing dominant role. Regional production and consumption of goods, logistic optimisation, spatial relocation efficiency improvements and a decreased mobility demand have led to enormous emissions reductions. Mobility consists mainly of walking, cycling and dedicated public transport. Car use is restricted.

The stakeholders all claimed that to realise this end vision, the government (national and international) would have to become a supranational, superimposing institution that imposed major behavioural changes on individual citizens. The government would need to superimpose relocation of activities by means of regulation, and would need to stimulate or superimpose transport logistics and the creation of regional markets by means of pricing of transport to decrease mobility. Finally, strict technology agreements and emission reduction targets would have to stimulate the development of a much more sustainable ICE. The stakeholders claimed that this end vision was not realistic. The stakeholders mentioned that the free market perspective counteracts a development towards such an extremely strong governmental role. Current trends such as globalisation, internationalisation and large-scale production counteract a decrease in mobility demand. In addition, the public would have to undergo a psychological shift from individualism towards a collective community sense. A modal shift towards widespread public transport is also problematic according to the stakeholders since it conflicts with the current trend towards more demand for individual transportation. The optimisation of the ICE, however, is likely to occur according to the stakeholders. The development of more efficient and sustainable ICEs will especially increase if the oil price increases. Stakeholders also claimed that optimisation of transport logistics is necessary and will occur on the short-term.

6.2 Stakeholder perspectives on the OECD High-tech end vision

In the 2030 OECD High-tech end vision, energy use and emissions of the transport sector are reduced substantially due to widespread use of new, clean and highly efficient technologies and logistic optimisation in road and rail transport. Mobility demand has increased but poses no problem. In private transport, electricity is the dominant automotive fuel either by means of batteries or through connection to rails using externally supplied energy. In public and goods road transport a combination of electric and hybrid LPG vehicles is used. Heavy lorries, inland ships, rigid airships, marine transport and international aircraft use hydrogen driven fuel cells.

The stakeholders commented that the OECD-High-tech end vision is not very realistic. The stakeholders claimed that the most important driver behind this end vision in 2030 would be a very strong 'sense of urgency' with respect to emission reduction. The stakeholders claimed that this sense of urgency is extremely difficult to achieve. An increased commitment to the Kyoto protocol, increased scientific knowledge on climate change and security of supply problems, in combination with a high increase in oil demand, would create a sense of urgency. According to the stakeholders, supranational governmental and NGO cooperation (at least on EU level)

would be required to develop and to implement strict emission reduction aims, in the form of either emission trading, pricing of transport to decrease mobility, energy efficiency standards and internalisation of external costs. This supranational governmental cooperation would also need to set boundary conditions for innovations in the transport sector and stimulate R&D experiments. In addition the stakeholders mentioned that it would be necessary to link the different sectors to achieve the best emission reduction and emission trading policies. The stakeholders further argued that the end vision was not very realistic because it was unlikely that fuel cell cars and battery driven cars would coexist, because both types would require extensive and different infrastructures. The stakeholders also claimed that battery driven cars still are quite expensive compared to fuel cell cars.

However, stakeholders argued that some aspects of the end vision are in line with current trends. Globalisation, internationalisation and large-scale production are in line with the expected increased mobility demand. All stakeholders agreed that the introduction and diffusion of clean, silent and efficient technologies is probable, although these are not necessarily the technologies described in the end vision. Many industries are already developing alternative fuels and drive trains. The population density of the European region would assure a sufficiently large market for these new drive trains and fuels. The diffusion of the innovations would benefit from globalisation and supranational cooperation.

6.3 Stakeholder perspectives on the COOL A end vision

In the 2050 COOL A end vision, cars, vans and small trucks are equipped with hydrogen driven fuel cells. Synfuels are used in aircrafts, inland ships and trucks. Hydrogen and synfuels are produced by biomass. Mobility demand has increased significantly in spite of the optimisation of transport streams. Public or collective transport has grown substantially, requiring different consumer practices.

The stakeholders had similar reactions to the changes in user practices described in this end vision as to the behavioural changes described in the OECD Capacity constraint end vision. They claimed these changes are not very realistic, although they are very important for increasing the sustainability of the transport sector in the short and mid term, since the free market counteracts the quick development and implementation of currently more expensive alternative technologies.

The stakeholders further mentioned that they did not deem fuel cell cars on biofuels likely due to their chain (in) efficiency. Using hydrogen is more likely, because hydrogen fuelled vehicles are quieter and smell less; hydrogen increases the security of supply on the short-term (because energy from intermittent sources can be stored) and on the long-term because hydrogen can be produced by a great variety of sources. On the other hand, the use of hydrogen faces public fear with respect to safety issues, whilst consumers perceive biofuels as more or less similar to the currently used fossil fuels.

The stakeholders further mentioned that the use of biomass for hydrogen production would probably not coincide with the production of biomass for synfuels because when synfuels and biofuels are produced efficiently, hydrogen from biomass (for transport) cannot compete. However, producing hydrogen from biomass offers the possibility of CO₂ sequestration and this results in negative CO₂ emissions.

In the long run, stakeholders argued, they expected technical solutions to increase the sustainability of the transport sector drastically. The stakeholders claimed that the government could take a facilitating role in the short and mid term to achieve this sustainability through behavioural changes, for example by means of pricing of transport to decrease mobility and by stimulating RD&D experiments. In the long run, the decreasing availability of fossil fuels, the need

for CO₂ reduction, the increased congestion and possibly increased negative health effects of small particles would become drivers for a transition towards this end vision.

6.4 Stakeholder perspectives on the COOL B end vision

In 2050, according to the COOL B end vision, mobility demand is low, due to spatial planning and the partial replacement of mobility by ICT. Collective transport is dominant. The energy-efficiency of the transport system has increased. Cars, trucks, airplanes and buses run on biofuels converted to hydrogen combined with fuel cells. Public transport is based on electricity.

The stakeholders commented that the COOL B end vision is not realistic. The stakeholders mentioned a very strong sense of urgency with respect to emission reduction would have to develop to set the realisation of the COOL B end vision in motion. And as mentioned in the discussion of the OECD High-tech end vision, stakeholders believed this to be unlikely.

The stakeholders also felt that the decrease in mobility demand is unrealistic. Stakeholders commented that mobility demand is strongly coupled to income, and to spatial planning policies. However, the stakeholders did not expect people to voluntarily decrease their mobility demand or relocate. In addition, stakeholders mentioned that tourism, increasing air traffic and the trends mentioned in the discussion of the OECD capacity constraint end vision lead to more mobility. Commuters and recreational traffic are only likely to decrease due to international conflicts (recreational traffic) or occurrence of shortages of automotive fuels due to supply problems. Supply problems could occur due to lacking technological developments in clean fossil solutions or due to problems related to the large-scale application of biomass. The stakeholders claimed that mobility demand is expected to decrease strongly only when people are facing economic crises or crises in energy supply, or when the government imposes a very strict pricing of transport to decrease mobility. These measures, combined with high quality public transport systems and high risks for congestion, might decrease the overall demand for mobility. In addition, the stakeholders claimed that the implementation of new fast driving lanes for coupled car systems would lead to increases in mobility demand. According to some stakeholders, the only way to create an urge to decrease demand is to couple the problem of congestion with the need to reduce emissions. All these measures, however, require cooperation at a supranational level and a very strong role of this supranational government in imposing measures.

As discussed earlier, stakeholders claimed that it was unlikely that fuel cell cars and battery-electric cars would coexist. The stakeholders further mentioned that they did not deem fuel cell cars on biofuels likely due to their chain (in) efficiency.

6.5 Stakeholder perspectives on SEP Sustained Balance end vision

In 2050, according to the SEP Sustained Balance end vision, the internal combustion engine is still the dominant drive train due to efficiency improvements and fossil fuels (diesel) remain the most important fuels. However, vehicles using electricity (batteries) or biofuels driven fuel cells, and hybrid electric vehicles with an efficient internal combustion engine (diesel or biofuels) are available as well. A fine meshed public transport system delivers demand-dependent transport.

The stakeholders claimed that overall, the end vision is quite realistic because the changes outlined are close to standard human behaviour. Several issues are of high importance in reaching this end vision: decreasing availability of fossil fuels, the need for CO₂ reduction, the increased congestion and possibly the increased negative health effects of small particles have to become key drivers towards this end vision. These drivers, however, are not sufficient for achieving this end vision, the stakeholders claimed. The government needs to assume a more active role, and increase the pressure on existing transport practices, implement pricing of transport to decrease

mobility, internalise external costs and the government could stimulate RD&D experiments to increase the possibilities for learning about the technologies (strategic niche management).

In addition the stakeholders claimed that, as mentioned before, it was unlikely that fuel cell cars and battery-electric cars would come to coexist, and that fuel cell cars on biofuels are unlikely due to their chain (in) efficiency. In addition, the stakeholders claimed that the improvements of the ICE and vehicles in general, might hinder (due to better cost performance ratios for both cost per kilometre and energy use) the introduction of new and more sustainable technologies such as fuel cell vehicles and battery driven vehicles.

6.6 Stakeholder perspectives on the SEP Sustained Growth end vision

In 2050, mobility demand has strongly increased. The transport sector has witnessed a strong diversification in new, energy-efficient and environmentally friendly transport system and vehicle concepts and drive train technologies. The coupling of cars guarantees a short travel time. Hybrid electric vehicles using biofuels or fossil petrol or diesel, and fuel cell vehicles using hydrogen are dominant. Electric vehicles using batteries and the internal combustion engine also have a substantial share.

The stakeholders commented that the SEP Sustained Growth end vision is both appealing and reasonably feasible. To realise this end vision, actually many current trends simply need to continue. For example, the use of hybrid drive trains is realistic to suppose. Governments already support the use of hybrid vehicles, and governments may steer these developments further e.g. by exempting/lowering excise duties and by setting stricter norms as to vehicle use and emission in urban regions. Local governments can for example compel the use of more environmental vehicles in city areas. The high growth in mobility is plausible. At present mobility demand grows, notwithstanding efforts of Ministry of Transport, Public works and Water Management to prevent this. The stakeholders claimed that since the government cannot pick a winning technology but could support potential sustainable innovations, it is realistic to assume that there is expected to be diversification in the drive trains used, and that consequently different energy infrastructures (including more decentral energy supply) are likely to coexist.

However, as mentioned before, the stakeholders claimed that battery-electric cars currently are quite expensive compared to fuel cell cars, and face many technical problems. In addition, the stakeholders claimed that both battery and fuel cell driven vehicles would require extensive and different infrastructures and that because of that it was unlikely that fuel cell cars and battery-electric cars would come to coexist. The stakeholders further mentioned that fuel cell cars on hydrogen were likely.

6.7 In conclusion

The stakeholders claimed that overall, due to the emphasis on a decrease in mobility demand and strict spatial planning, and due to the need for a supranational superimposing governmental institution, the OECD capacity constrain and the COOL B end visions were unrealistic. The stakeholders claimed that the OECD High-tech end vision was also unrealistic due to the emphasis on an unrealistic sense of urgency as the main driver behind the end vision. In addition, the diversification of vehicle drive trains and automotive fuels showed some inconsistencies. The stakeholders felt that the COOL A vision was not very realistic either, due to its emphasis on behavioural changes and due to inconsistencies in the implementation of diverse of vehicle drive trains and automotive fuels.

The stakeholders were quite enthusiastic about the SEP Sustained Balance and the SEP sustained Growth end visions because the changes outlined were close to standard human behaviour and coincided with current and expected trends. However, this end vision also demon-

strated some inconsistencies with respect to the different drive trains and fuels. One major conclusion on this report is that all stakeholders agree that sustainable end-vision focusing on behavioural changes are not realistic, and that sustainability must be achieved by means of technological development. However, the question what this technological development consists of is cause for disagreement among the stakeholders.

7. Stakeholder perspectives on Key elements of in the end visions

All six end visions of a sustainable transport sector discussed in Chapter 4 differ radically from the current transport practice. Many end visions share key elements, and to avoid repetition with Chapter 7, where stakeholder perspectives on the end visions were discussed, the following elements will be discussed separately in Chapter 8:

- Decrease in mobility demand
- Increase in mobility demand
- Optimisation of transport logistics
- Efficiency improvements
- Modal shift from individual to public transport
- Modal shift from individual to collective (coupled cars/shared cars) transport
- Modal shift from road to rail or water freight transport
- Diversification of vehicles types
- Diversification of drive trains and energy infrastructures
 - Fossil fuels
 - Electric traction
 - Biofuels
 - Hydrogen
- Use of CO₂ capture and sequestration.

7.1 Decrease in mobility demand

The interviewed stakeholders claimed that a decrease in mobility demand is unrealistic. A decrease in mobility demand firstly presumes a trend towards a system of regional trade, and this would entail a trend breach since the current trend is towards globalisation, internationalisation and large-scale production of goods.

The stakeholders claimed that the only way to breach that trend would either be through a crisis on world scale, or by means of strict international regulation of trade leading to closed markets. This strict regulation would demand a very stronger role of the government, both on a national and international level. Governments would have to implement measures aiming at increasing costs of mobility and simultaneously implement regulation aimed at restriction of mobility, and the government would have to implement measures aiming at relocating people to live near their working environment.

However, stakeholders claimed, this strong governmental role and the accompanying protectionism is not allowed in the current EU legislation and different (oil product) industries are expected to attempt to counteract such developments, since in that case their markets and export possibilities would decrease and the industries' dependence on local feedstocks would increase. And according to the stakeholders, although these closed and regional markets might lead to increased employment they might also be inefficient in terms of total energy demand on a macro scale. Stakeholders therefore claimed that this change, with the accompanying breaking down of institutions and regulations allowing international trade, is not probable.

The public would also have to undergo a psychological shift from individualism towards a more collective perspective. In addition, several taboos would have to be broken. A decrease in mobility would imply a society in which economic growth is not the highest priority and people have no long distance social contacts.

Current trends are internationalisation, globalisation and the accompanying worldwide travel. At most, these trends might create the need to optimise the transport logistics and as such might lead to a bundling of transport systems. However, most stakeholders expected that this would not decrease mobility demand. Especially, since travel time is of more importance than travel distance, the implementation of faster transport modes is expected to lead to longer travel distances.

If, in spite of the arguments mentioned by the stakeholders, mobility would decrease anyway, for example through strict relocation of people and activities, ICT possibilities and strict trade regulation leading to closed markets, stakeholders believed that this might lead to a life with less transport related stress and a better living environment.

7.2 Increase in mobility demand

The stakeholders believed that an increase in mobility demand is realistic as it complies with the current trends. However, the government does attempt to counteract this growth in demand.

7.3 Efficiency improvements of vehicle and combustion technologies

The stakeholders claimed that the introduction of techniques to optimise the efficiency of vehicles' traction systems is likely. A decrease in emissions is considered probable. Noise reduction is also feasible by means of development of low noise or noise absorbing bitumen.

According to the stakeholders, it is unlikely that the public will accept the banning of inefficient motors, mopeds and cars. Hence, efficiency optimisation is expected to only occur if governments start to stimulate these innovations by means of regulation, pricing of transport to decrease transport, and technology agreements. In addition, a higher oil price is expected to drive developments to increase the demand for higher efficiency of vehicles. The stakeholders claimed that once the European Union has implemented regulation and pricing policies that stimulate efficiency innovations, globalisation combined with the role of the EU as a large market is expected to facilitate the diffusion of new efficient technologies. Still, NGOs supported by the government could try to increase the environmental awareness of consumers, and as such stimulate the emergence of a new market for more efficient and cleaner vehicles.

Stakeholders were, however, critical about this optimisation of the efficiency of vehicles. They claimed that this higher efficiency probably would not solve problems on a global scale, for example because the vehicles that are built are increasingly heavier and equipped with more energy consuming gadgets. The stakeholders claimed that it is unclear how much energy efficiency improvement can be achieved. In addition, the improved efficiency and sustainability of the ICE might hinder the development of other sustainable alternatives.

7.4 Optimisation of transport modes

Most stakeholders claimed that logistic optimisation is necessary and if implemented, it is expected to lead to more decentral production of goods, and thus lead to more regional markets. However, this is not likely to substitute the global market. To optimise the transport of persons and goods, stakeholders claimed that several technological developments would have to occur. First, a good information system needs to be developed and implemented, transferia need to be built, a better integration of functions (living, working, shopping) needs to be realised. Buses and trains should drive more frequently. The stakeholders claimed that other non-technological developments also have to occur for optimisation of transport modes to occur. Congestion needs to increase drastically, the costs of all transport should be increased, and governments should internalise external costs. This optimisation may only be started (in terms of economics) at

places where many people have to be transported. The western part of the Netherlands may be considered to be one agglomeration in which public transport can be used. The stakeholders also claimed that to realise optimisation of public transport, the public should feel safe (from accidents) using the optimised transport modes. This feeling of safety should be taken as a starting point in developing alternative optimised transport systems such as coupled car systems.

7.5 Modal shift from individual to public transport

The stakeholders claimed that the development of a widespread (optimally organised) public transport system is not likely, since current trends show a development towards increased individual transport. Such a large-scale public transport system is only expected to develop autonomously, if the physical space for further development of individual transport is no longer available. The stakeholders claimed that the government could stimulate the development of a widespread optimally organised public transport system by means of regulation, pricing of transport to decrease mobility, internalise external costs, subsidies for consumers to increase their demand for more sustainable technologies and public transport, implement codes and norms and make technology agreements aimed at facilitating the development of a public transport system, and the government could stimulate technological developments by ensuring continuity in governmental policies.

According to the stakeholders, cities are the starting point for changes from individual transport by car to public transport because of the low accessibility for cars and expensive parking in urban regions.

Stakeholders claimed that a further development of public transport would have many advantages. Besides possible environmental advantages (if sustainable fuels and drive trains are used), a large public transport system is expected to lead to a decrease in demand for individual mobility and to an increased social cohesion.

Stakeholders believed that it is likely that public transport will couple to private transport. The implementation of transferia is a first step. Some stakeholders claimed that collective private transport (with individual cars coupled) is expected to emerge instead of public transport (see Section 5.6). According to the stakeholders a system of collective private transport is expected to be technically feasible soon, but some institutional barriers (dealing with issues of responsibility and liability) have to be solved first. In addition, ICT may have a large impact on transport according to the stakeholders. ICT may contribute to the self-organisation of transport, route information; ICT may facilitate the change from a product orientation to a service orientation in public transport.

Stakeholders claimed that the further large-scale development of a carpooling system is not probable. Stakeholders claimed that car sharing or renting might increase in popularity, if the government actively stimulates this development. The government could apply regulation or pricing that increases the costs of car possession. However, stakeholders claimed that the automotive industry could be strongly opposed to this development, which reduces the probability of the occurrence of this change. In addition, stakeholders referred to the fact that the cultural role of cars is expected to be a hurdle to car sharing. Consumers are expected to prefer the private owning of a car above sharing one. Consequently, car-sharing systems would only be used when financially necessary.

7.6 Modal shift from individual to collective individual transport systems

Stakeholders claimed that the widespread implementation of collective private transport systems (automatic car guidance or car coupling systems) is perhaps too ambitious for 2030. According to the stakeholders, these systems are expected to develop from the already optimised public

transport systems. Modal shift could also start from cities. People in cities already adapt their transport patterns to the accessibility of the city and cost of private transport. Demonstration projects and experiments and consumer technologies might prepare future users. Technologies such as cruise control and automatic proximity warning systems to increase road capacity already prepare people for the loss of control, which is inherent to coupled car systems. Some of these technologies can already be found in some luxury cars. NGOs supported by the government could try to increase the environmental awareness of consumers and as such also promote the coupled cars systems.

Current trends (e.g. our network society induces many travels for work and social activities) lead to a bundling of collective transport systems, although different collective systems can co-exist. Thinking in terms of a mobility market where a great variety of mobility services replace the individual ownership of a car is increasing. A number of mobility suppliers that fulfil consumers' needs but use one infrastructure might develop.

The stakeholders were optimistic with respect to the public acceptance of coupled car systems. They believed consumers will accept these coupled car systems and the accompanying loss of control because the consumers see the coupled car systems as consisting of normal cars and because their use is advantageous since it solves congestion problems. When mobility demand is low, these coupled car/truck systems may be used for the transport of goods. To increase efficiency of these collective systems even more, systems could be used more evenly over the day.

To realise a modal shift to this collective private transport, however, the quality of the transport should be guaranteed. Consumers should be able to trust the reliability and safety of the systems. In addition, passengers should not be responsible when their vehicle is coupled to the system: the transporters or the manager of the infrastructure should be responsible. The system is expected to lead to changes in the legal system: producers of technologies to facilitate the system and infrastructure managers are expected to become liable. Moreover, if cars are able to drive in two modes (hybrids), one of them a coupled car mode that for example uses electrical traction, this is expected to enhance social acceptance. To increase transport efficiency in certain areas, only the coupled car mode may be used. Road infrastructures could be adapted to facilitate that possibility for different vehicle types to use the infrastructures.

The national governments could make the system compulsory, and stimulate codes and standards development for such couple car systems. Government could furthermore introduce market thinking in the sector by differentiation in pricing of transport to minimise transport; and the government could own the rail network. This governmental role is conflicting with the liberalised market system, and would entail a stop to liberalisation.

Coupled car systems do not necessarily need a different energy infrastructure. And it is expected that the fuel used in these systems will depend on market developments, but the stakeholders claim that it is likely that electricity or hydrogen will be used as fuels in these coupled car systems. But even when the system does not make use of sustainable fuels, the coupled car systems may lead to increased sustainability. Since coupled car systems can be safer, material use decreases, and cars are expected to be lighter, leading to lower fuel use. In addition implemented systems might increase the efficient use of fuels.

7.7 Modal shift in freight transport from road to rail or water

The stakeholders claimed that it is unlikely that a modal shift in freight transport will occur on a large scale. Stakeholders claimed that if a modal shift in freight transport from road to rail took place, this would result in a relatively fast mode of transport, however, it would be accompanied by high costs in the beginning due to the building up of the infrastructure. Transport by inland shipping would be rather slow compared to road transport. Stakeholders argued however, that

inland shipping might be combined more easily with road transport to create a fine meshed network of freight transport.

Stakeholders agreed that, as long as oil is still widely available, (however, the peak might be reached in 2050) a modal shift in freight transport might only occur if governments use regulation, pricing of transport to decrease transport, and technology agreements aiming to increase the costs of road transport. Governments could also stimulate a modal shift from road to rail or water by regulating the hours available for freight transport by road. Another, more autonomous driver for a modal shift in freight transport is, according to the stakeholders, the increasing congestion of roads.

7.8 Diversification of vehicle types

Stakeholders agreed that diversification of vehicle types for long distance and urban functions, is likely. The number of cars per family is increasing, which might pave the way for diversification. Many families now own a large car for trips and kids, and a smaller one for urban shopping. Another aspect that favours the diversification in the use of vehicle types is that industrial strategies aim for diversification to a certain degree.

7.9 Diversification of drive trains

Stakeholders agreed that diversification of vehicle drive trains is likely. They referred to a corresponding trend in the USA, where hybrids are gaining in market share.

However, stakeholders claimed that too much diversification inherently poses an infrastructural problem. If the market share of particular drive train technologies is too small, the fuel infrastructure required to sustain that option is expected to be either too costly to implement, or too costly to maintain. One possible solution opted for by the stakeholders is to develop infrastructures that are so flexible that different fuels can be transported.

The government has a key role in realising this diversification of drive trains. Emission trading is not enough incentive, because of the relative costly measures in the transport sector. Therefore specific emission reduction targets for the transport sector are necessary. According to the stakeholders, internalisation of external costs is better and more efficient than the use of subsidies to induce this diversification of drive trains. These external costs should include noise production and use of space for both public and private transport. Regulation may make the use of environmental friendly engine compulsory in urban areas. Financial support and subsidies favouring hybrid cars is yet another policy that can contribute to this change. In addition, to ensure the right level of diversification (to prevent the market shares from becoming too small for infrastructures to be built) governments could set boundary conditions that on the one hand do not favour one option, but on the other hand, provide enough consistency and long-term security for a few options to increase their market share sufficiently.

The support of NGOs and the industry is also imperative. The industry needs to feel a sense of urgency in creating a more diverse transport system and the NGO's needs to stimulate the public to support hybrids and other alternative more sustainable drive trains.

7.9.1 Electrical traction

The stakeholders claimed that it would be difficult to achieve a substantial market share for electrical traction combined with on board electricity storage using batteries. First there are the present technological problems. The battery technique needs to improve strongly. The charging of the batteries poses a problem; it is too slow, the load capacity is too small and the efficiency

and consequently the possible driving range are insufficient. Users should also be allowed to use the electricity grid to recharge their batteries. Charging at night could be made advantageous to avoid necessary extensions of the electricity grid.

The stakeholders foresee no social acceptance issues as long as the technical problems mentioned above are solved. However, they foresee problems related to the distribution of renewable electricity among sectors. Stakeholders commented that sustainable electricity, because it is difficult to produce enough electricity to cover the demand of the whole transport sector, could better be used first in other sectors than the transport sector.

The stakeholders believed that a transition to electrical traction would lead to radical long-term changes in society. A complete transition towards a sustainable electricity transport system is difficult to achieve, among others, due to the costs of a possibly needed new electricity infrastructure (although night charging might prevent this need). To legitimise these costs, a sense of urgency would have to exist among industry and the public. This sense of urgency can emerge when problems in security of supply arise due to a decreasing availability of fossil fuels. To induce this sense of urgency among both the industry and the public, stakeholders foresee a key role for NGOs supported by the government.

Stakeholders claimed that technical measures probably could not solve all problems associated with transport (CO₂, congestion, use of space, negative effects production, small particles etc). However, battery electrical vehicles can use the existing infrastructure and they are easy to use. Therefore it is likely that they will soon be used in niches such as urban transport where zero emission vehicles are promoted.

Stakeholders argued that electrical traction is expected to never suffice to cover the high mobility demand that is expected to exist in the future. Electrical traction in battery electric vehicles is expected to therefore face competition with fuel cell vehicles using biofuels. The stakeholders claimed that, in addition, the ICE is expected to continue to play a role in the transport sector, especially because improvements in the ICE are likely to lead to CO₂ emission reductions and reduction of other emissions such as noise and small particles.

If the ICE is made to use alternative fuels such as biofuels, its emissions may be lowered strongly, it may become a strong competitor to the introduction of electrical traction. Particularly if electricity is produced in a sustainable manner, the introduction of electrical traction depends mainly on the internalisation of external costs. Moreover, the success of the introduction of electrical traction depends on the sustainable production of electricity and on the performance of the electrical battery.

To create a larger market share for electrical traction, stakeholders claimed that governmental support is imperative. Not only could the government stimulate the uptake of electrical traction by means of internalisation of external costs, pricing of transport to decrease mobility, and subsidies to induce a demand for alternative automotive fuels and drive trains. The national governments could also facilitate experiments and the creation of small grid infrastructures. Consensus and cooperation among ministries and ministerial departments is needed. Moreover, governmental policy should be consistent and aiming at the long-term. National and regional governments could also force the use of electrical traction by demanding zero emission vehicles in urban regions.

A section of the stakeholders mentioned that a transition to a sustainable transport sector in terms of energy infrastructure would probably be an evolutionary process. The government cannot choose winners, both with respect to technologies and fuels. In addition, normal strategy for companies is to invest in a larger number of options, and according to these stakeholders, a probable development is that industries are expected to invest in technologies that combine the best attributes of both the existing system and the new technology. Another important issue is

that many parties are against radical changes in the existing infrastructure because of the vested interests.

According to some stakeholders, optimisation (efficiency improvements, strong reductions of emissions through existing technologies) of the existing transport system is still possible, and new systems are deemed too expensive.

Stakeholders therefore claimed that hybrids are a good transition technology if developed in such a manner that the existing infrastructure can also be used by the alternative additional traction and fuel in the hybrid. In time, stakeholders believed that infrastructures are expected to blend and perhaps become flexible, so that different vehicle types using different fuels can use the same infrastructures. The question remains what kind of hybrids would be suitable for this kind of infrastructure.

7.9.2 Fossil fuels

A majority of stakeholders claimed that the use of conventional vehicles and energy sources is inconsistent with the huge changes needed to not only meet the increased worldwide energy demand in a sustainable manner but reduce emissions as well. Therefore these stakeholders claimed that a large share of fossil fuels in the future transport energy infrastructure is improbable or at least highly undesirable.

Reason for a large share of fossil fuels would be that high efficiency improvements of the ICE would have been achieved, or that new fossil sources would have been discovered, or that exploitation costs of fossil sources would have decreased enormously. The majority of the stakeholders consider all of these reasons improbable. For example, even if the ICE becomes much more efficient, the energy demand would still increase due to all gadgets that are put in a car, or because the size of the cars continuously increases, the number of cars increases and the total mobility demand increases. Other reasons for a continuing large share of fossil fuels could be that accidents with hydrogen, or ethical issues concerning the use of energy plants create an opposing social stand for these alternatives.

If in a future transport system the ICEs using fossil fuels are still dominant, stakeholders claimed this would be due to the use of hybrids. With respect to the particular fossil fuels used, stakeholders mentioned that the use of LPG is unlikely, since there are no real environmental advantages connected to its use. The use of diesel is more likely, also because it could be easily mixed with bio diesels, and because many technological improvements can still be made to reduce emission of diesel driven ICEs.

However, there are also stakeholders that believed that fossil fuels are expected to still be dominant in 2030 or even 2050. CO₂ capture and sequestration will contribute to substantial emission reduction and ICE and vehicle efficiency improvements are likely to reduce emissions as well, which reduces the need for the application of alternative drive trains and fuels.

7.9.3 Hydrogen

The stakeholders did not agree on the possible use of sustainably produced hydrogen as a dominant fuel in the transport sector. Some of the stakeholders claimed that implementing a hydrogen infrastructure is not expected to pose a problem. The infrastructure can be implemented gradually. The first refuelling stations are likely to be implemented by means of lighthouse projects (high profile demonstration projects) in densely populated areas. When problems with the storage of sustainable electricity cannot be solved, the use of hydrogen is expected to be a solution that increases the security of supply on the short-term. These stakeholders further claimed that hydrogen could become a key energy carrier because it can be produced, stored, distributed

and used in many different ways. Finally these stakeholders pointed at the car and oil industry that have enormous influence on future fuel choice. They claimed that at present it seems that the industry embraces the possibilities of hydrogen.

On the other hand some of the stakeholders claimed that the introduction of hydrogen in the transport sector is not probable. According to these stakeholders the implementation of a new infrastructure with sufficient refuelling stations is difficult to accomplish in the Dutch planning climate and very expensive. Safety issues are also likely to contribute to the costs. These stakeholders claimed that hydrogen refuelling is expected to only be allowed outside cities, and this means that the vehicles will need a hybrid fuel system or that vehicles are not often used in cities. In addition, they claimed, storage of renewable energy (wind/solar) in the form of hydrogen is not probable, because it is too expensive. Furthermore, these stakeholders expect strong opposition from the oil companies.

The stakeholders all agreed that if hydrogen is to become a widely introduced transport fuel, it is likely to require many governmental actions. The government would first need to introduce zero emission vehicle regulations. The government also has a role in counteracting rebound effects of the ICE efficiency improvements (reduce growth in size of cars, the number of gadgets in cars etcetera). The government should strive towards internalisation of external costs, including noise and other environmental costs. The government could attempt to create a sense of urgency, for example by referring to issues of security of supply and the advantages of diversification of energy sources. The governments could further facilitate experiments. Interdepartmental consensus is needed as well as long-term consistency in policy.

If a transition to hydrogen is to occur, stakeholders argued that an evolutionary switch (using yet another kind of hybrids and not changing the existing infrastructure too much) to hydrogen as a by-product of refineries is probably the easiest way. A possible pathway to implementation is the use of dual fuel vehicles driving on gasoline and hydrogen, as a precursor for fuel cell cars. Dual fuel vehicles are expensive if they need two fuel tanks and a reformer (to use gasoline for input for the fuel cell). Dual fuel vehicles can also use an ICE using both hydrogen and gasoline, and then they do not require a reformer. This option would however, not promote the use of hydrogen and fuel cells. Another possibility mentioned by the stakeholders is to introduce fuel cell cars with reformers because then refuelling stations for hydrogen would not be necessary. Although this option is not expected to lead to a hydrogen infrastructure, it may lead to the acceptance of fuel cells. Also reforming at refuelling stations is possible. However, to implement this option, the government should decrease excise duties for hydrogen in order to decrease the price of hydrogen. If this hydrogen is made from natural gas, this also implies the building of an additional infrastructure to transport the natural gas, and again this would counteract the implementation of a hydrogen infrastructure.

7.9.4 Biofuels

Part of the stakeholders claimed that biomass certainly is a potentially important energy source for transport. However, they also state that the availability of biomass is limited and is expected not to be sufficient to cover a large-scale worldwide implementation in all sectors. In 2050 large-scale use of biomass is possibly enough to cover the demand of a few sectors per country, e.g. transport and chemical production (if the production becomes more energy efficient).

These stakeholders further believed that biomass is an important source because it can be used for the flexible production of electricity and hydrogen, in addition to biofuels and syngas. However, these stakeholders acknowledge that biofuels are expected to only become a widespread energy carrier in the transport sector, if the use of biofuels and the accompanying drive trains is cheaper (due to subsidies or exemption of excise duties) or have higher or equal energy density than fossil fuels. In addition, stakeholders mentioned that the problems with the efficiency of biomass production would have to be solved first.

The stakeholder claimed that biomass will most probably be produced abroad and not in the Netherlands. Wood is expected to be transported to the users; other biomass sources are likely to be produced and converted on location. Certification is necessary to ensure environmentally friendly production. Biomass production may occur in more countries than oil production, and consequently, a biomass OPEC is possibly needed. The stakeholders claimed that although the use of biomass is expected to lead to monocultures in the beginning, that this is likely to solve itself.

Mixing coal and biomass could be the starting point for a biomass market, according to these stakeholders. They claimed that CO₂ sequestration is not necessary, but might be economically attractive when emission-trading system is put in place.

However, another part of the stakeholders claimed that they could not foresee a very large role for biomass. They believed that biomass is expected to be one of the energy sources to be used. Moreover, they believed that biomass is more of a transitional energy source towards a hydrogen economy. Biomass has a chance when the availability of fossil fuels is low and the sense of urgency (in terms of securing energy supply) is high. These stakeholders acknowledged that biomass has potential, however, they claimed that biofuels are expected to have a limited role in 2050 due to the increased role of other alternative automotive fuels and accompanying drive trains. One of the main barriers impeding the introduction of biomass is legislation dealing with the production of biomass. These stakeholders claimed that the production of synfuels is problematic. First a huge area of land is necessary for wide scale production. Furthermore, biomass storage capacity should be developed.

However, all stakeholders agreed that to implement changes large changes in policy are needed. Strict emission targets in transport may be reached when fuel cells fuelled with biofuels are used. Emission trading is not enough to stimulate the uptake of biofuels because of the relative costly measures for reducing CO₂ emissions in transport. The government could stimulate the uptake of biomass by implementing a CO₂ emission dependent tax for fuels. Issues such as security of supply and emission reduction may play a favourable role for the introduction of biomass in the transport sector. Policy aiming at internalisation of external costs in the transport sector must also include noise and other environmental costs, otherwise energy efficiency improvement of the ICE might increase the competitiveness of fossil fuels compared to biofuels. The government could further set goals to create acceptance of biomass and to stimulate the industrial development of sustainable (biomass) technologies. The government could for example create opportunities for the development of a market share that is large enough (e.g. by creating environmental zones). Finally stakeholders stated that policies should be consistent and that there should be an international perspective on environmental policy making. Globalisation combined with the role of the EU as the largest market is expected to also add to the diffusion of the new biomass technologies. NGOs supported by the government may also contribute to an increasing environmental awareness of consumers by means of education and information.

7.10 CO₂ sequestration

Most stakeholders claimed that the use of CO₂ sequestration is most likely to be a central aspect of a transition to a sustainable transport sector's energy infrastructure. When a CO₂ emission reduction of 20-50% is required in 2030, the use of renewable energy without sequestration might be necessary, however, for further reductions e.g. 80%, stakeholders claimed that CO₂ sequestration is necessary. Depending on the timescale for the reduction different combinations are possible according to the stakeholders. When CO₂ emissions should be strongly reduced in a short time period, biomass and CO₂ sequestration should be combined because this creates negative CO₂ emissions.

Stakeholders believed that energy companies are expected to cooperate to enable CO₂ sequestration. The Netherlands may use empty oil and gas fields for the storage of CO₂. Another positive aspect is that NGOs accept CO₂ sequestration as a temporary solution towards a sustainable energy system.

Since the possibilities for CO₂ sequestration depend on local circumstances, stakeholders claimed that the Dutch government could have a role in steering the developments on CO₂ sequestration. Emission trading is not sufficient because of the relatively costly measures to reduce CO₂ emissions in the transport sector, and this should therefore be combined with internalisation of external costs, pricing of transport to decrease transport, and technology agreements.

7.11 In conclusion

The stakeholder perspectives demonstrate consensus on many key elements of the end visions, but also show some discrepancies.

The stakeholders were mostly in agreement (given that a minority of individual alternative perspectives exist as well) on the following key elements:

- A decrease of mobility is not likely, an increase in mobility is likely.
- Efficiency improvements of vehicle and combustion technologies are likely.
- Optimisation of transport modes is likely.
- A modal shift to widespread public transport is unlikely.
- A less widespread shift in combination with individual transport is likely.
- A modal shift to collective individual transport is likely, but not before 2030.
- A modal shift in freight transport from road to inland shipping and rail transport is expected to partly occur.
- Diversification of vehicle types and diversification of drive trains and automotive fuels is likely to occur.
- CO₂ sequestration and capture is likely to occur.
- It will probably be difficult to achieve a substantial market share for widespread use of electrical traction due to technological problems, costs of a new infrastructure and competition with fuel cell vehicles and biofuels driven vehicles.
- Some stakeholders mentioned that hybrid vehicles are very promising.

The stakeholders disagreed on the role of fossil fuels in the transport sector. Some stakeholders claim that fossil fuels are expected to still play a large role in 2030/2050 due to the efficiency improvements in vehicle and combustion technologies. Other stakeholders claimed that fossil fuels will probably have largely been replaced by (more) sustainable fuels. The stakeholders also demonstrated disagreement on the possible role of hydrogen. Those stakeholders that claimed a large share of hydrogen in the transport sector is unlikely, base this on the high costs of a new hydrogen infrastructure. Stakeholders also disagreed on the role of biomass/biofuels/synfuels. Some stakeholders expected biofuels to become a widespread energy carrier in the transport sector, if the use of biofuels and the accompanying drive trains becomes more efficient than the use of fossil fuels. Other stakeholders claimed that biomass would become one of the many energy sources used, and that biomass is more of a transitional energy source towards a hydrogen economy.

8. Concluding remarks and recommendations for future research

With the results of the analysis in Chapter 5, 6 and 7 conclusions can be drawn on what elements of a sustainable energy infrastructure were considered likely and perhaps even preferred by relevant stakeholders, and which elements were considered unlikely or even not preferred. The possible complementarity or conflict between end visions (particularly their key elements) was also discussed. With these three chapters as base, conclusions can be drawn on possible barriers to a transition to a sustainable transport energy infrastructure. These conclusions are first summarised. The report then concludes with recommendations for further research.

8.1 Conclusions

The six end visions all shared many elements. According to the stakeholders, these shared elements, if implemented, would not lead to the lockout of particular end-visions, but would support the achievement of all six end-visions. It concerns the following elements: the introduction of car coupling systems, an optimisation of transport flows (consisting of modal shifts towards inland shipping and rail transport of goods, and to a slighter extent air transport, an optimisation of ICE technologies and increasing the efficiency of vehicles, the introduction of a better and fine-meshed public transport system, central production of energy carriers.

The end visions, however also conflicted strongly on two elements: the further improvement of the ICE towards a much more sustainable ICE and consequently a large role for the ICE and fossil fuels in 2030/2050 versus the increased role of other sustainable drive trains and fuels such as battery and fuel cell driven vehicles that drive on hydrogen, electricity or biofuels. Another strong conflict dealt with the increase versus decrease of mobility demand. These conflicts would result in the lock out of end visions if others would be implemented. The end visions further conflicted to a lesser extent on elements such as battery versus fuel cell driven cars, biofuels versus hydrogen and public versus collective transport.

The stakeholders agreed that end visions consisting of radical behavioural changes (such as creating closed regional markets, relocating work and living environment, prohibiting long-distance travelling, demanding car sharing practices etcetera) are not likely to occur, and not a preferred option. To realise radical behaviour changes would require a very strong superimposing supranational governmental institute and cannot coexist with the free market paradigm.

Stakeholders further agreed that end visions that foresee a diversification of automotive fuels, vehicles types, and user practices are likely and also preferred. First, such diversification corresponds with the free market paradigm. Second, such diversification does not require the government to pick a winning technology or fuel.

The stakeholders stated that there is a need for a balance between diversification of fuel types, vehicles types and user practices on the one hand, but not too much fragmentation on the other hand, since this might lead to a situation with insufficient market share for specific promising options.

If a transition to hydrogen is to occur, stakeholders argued that an evolutionary switch is potentially most successful. Stakeholders did not deem extreme trend breaches feasible or likely. A continuation of existing trends with coordinated management to stimulate certain options and discourage others would secure a start towards a more sustainable future.

Such an evolutionary perspective would start with the use of hybrid technologies in an attempt to prevent the need for a totally new and large-scale infrastructure. With hybrids, users may get

accustomed to a new technology, resulting in technology pull, while at the same time, investors can slowly de-invest in the existing dominant infrastructure and start to invest in new infrastructural (mini) grids.

The stakeholders, however, also remarked that too much of an evolutionary approach to a transition to a sustainable transport energy infrastructure may also diminish the market introduction opportunities of alternatives. For example, if the widespread introduction of electrical traction (combined with sustainably produced automotive fuels) builds on the internalisation of external costs, the emission reduction improvement of the ICE is expected to make ICE more economically competitive. This competitiveness might hamper electrical traction.

The stakeholders demonstrate much disagreement on the potential role of hydrogen, biomass and fossil fuels as energy carriers in the future transport sector.

The stakeholders demonstrated remarkable consensus concerning the party responsible for creating the boundary conditions for a successful take-off of a transition towards a sustainable transport energy infrastructure. All actors foresaw a great role for the national and supranational governments to play. These governments would need to stimulate sustainable innovations by means of regulation, pricing of transport to decrease transport demand, technology agreements, internalisation of external costs (including noise and health issues), certification and standardisation actions. Government could furthermore introduce market thinking in the transport sector by differentiation in pricing of transport to decrease transport, and stakeholders also mentioned that privatising infrastructure might also contribute to a more sustainable transport sector. Regulating the hours available for freight transport by road is yet another option mentioned by the stakeholders. Regulation can in addition make the use of environmental friendly engine compulsory in urban areas. Financial support and subsidies favouring the dual mode cars is yet another policy that can contribute to a sustainable transport sector. In addition, to ensure the right level of diversification (to prevent the market shares to become too small for infrastructure to be built) governments could sketch boundary conditions that on the one hand do not favour one particular option. The governments should furthermore provide consistency and long-term security for alternative sustainable options to increase their market share sufficiently. Another action that could induce sustainable innovations could be to facilitate experiments and the creation of small grid infrastructures. Creating a dialogue among the relevant stakeholders, including the automotive manufacturers would also contribute to the creation of a shared sustainable end-vision.

Stakeholders also mentioned that NGOs supported by the government could try to increase the environmental awareness of consumers, and as such stimulate the emergence of a new market for more efficient and cleaner vehicles.

Finally, stakeholders mentioned that to realise many changes autonomously (without strong involvement of the government) a very strong sense of urgency with respect to emission reduction should develop through increased commitment to the Kyoto protocol, or due to increased scientific knowledge on climate change related issues and the political issue of security of supply. This sense of urgency might also be created due to particle matter issues and due to political instability in oil producing countries in combination with a high increase in oil demand, which in turn is expected to create security of supply issues and is likely to foster the urge to become independent of oil. This sense of urgency is difficult to attain according to most stakeholders.

8.2 Further recommendations

This report started with the statement that both on national and international level the awareness has increased that the current transport system contributes substantially to various environmental problems and that therefore the Dutch Ministry of Housing, Spatial Planning and the

Environment (VROM) set the stage for a transition towards sustainable mobility and a sustainable energy system.

The purpose of managing a transition is to shift from the present undesirable situation, for example an energy system with undesirable high emission of green house gasses, NO_x and particle matters, to a desirable future, for example towards a sustainable energy system. Managing a transition, and not leaving it to be solely the result of market mechanisms is essential (Jeeninga and Mourik 2004). Market mechanisms might not take into account the societal and long-term (economic and societal) benefits of sustainable technologies and fuels, and as such not lead to the creation of the required drivers.

New sustainable fuels and vehicle technologies have to compete with the dominant and fully functional current mix of energy carriers and energy related technologies and face problems of cost reduction. In addition, to secure the widespread implementation of new (more) sustainable fuels and vehicle technologies, it is likely that new infrastructures will have to be built. Investors face the risk that the new infrastructure is hardly used. Consequently, actors that have the capacity to invest in the required radical new technological concepts or systems that are needed to start the lengthy process of change are possibly not willing to commit themselves, especially when they have vested interests in the old system. As a consequence a status quo emerges, based on short term economic calculations: investments in a new infrastructure are expected to only be made if there is a demand (end-users), and because of the lacking infrastructure, there are no end-users. This status quo might seriously hamper the introduction of hydrogen and needs further research.

Research into the infrastructural issues of a transition towards a more sustainable transport sector could take into account the possible role of hybrid technologies, such as hybrid vehicles. Hybrid technologies are coupled technologies that function as transitional technologies and that probably will not exist in this coupled form for a long time (Geels, 2002). The hybrids can either make use of the existing infrastructure or anticipate the creation of a new infrastructure. In case of hydrogen hybridisation can occur in two ways: a new technology is introduced (fuel cell hybrid cars) that does not immediately require a new hydrogen infrastructure, but facilitates the gradual build up of a hydrogen infrastructure. The function of this first form is to create a demand, without the immediate need for a new and costly infrastructure, because the existing infrastructure can be used temporarily. Or, hybridisation can occur in the following way: vehicles can be introduced with an ICE on hydrogen or an ICE bi-fuel that immediately requires a new infrastructure. This design however does compete with the existing technological systems, in the sense that an ICE on hydrogen is different than an ICE for petrol and diesel. This type of hybridisation creates an infrastructure from the onset, that later can be used for other hydrogen-related technologies as well (i.e. hydrogen fuel cell vehicles).

Hybridisation involves the coupling of niche and existing technologies or systems that are either similar or different. The coupling results in a variety of different interactive relationships to offer either an optimised or new functionality. The need for coupling of the new technology is often related to its need for growth (of its market share), whilst the need for coupling of the existing technology or system is often based on a need for optimisation and stabilization, and need for added functionality (often following a change in user demands the existing practice). The key to a working hybrid is that the technologies that are hybridised are interlocked in mutual interdependence, and that both their survival (economy and scale) depends on this coupling.

It is important to acknowledge that the hybrids discussed above are different from hybrid cars such as the Toyota Prius, which aims at optimising the ICE car, and is not aimed at creating a transition to all-electric transport systems.

Another aspect that needs further research relates to the creation and management of niche experiments, preferably on a EU level (Schot, Hoogma, Elzen, 1994) (Geels, 2002), (Rotmans,

Kemp, van Asselt, Geels, Verbong, Molendijk, 2000). This management should be the result of coordinated active and motivated involvement of all relevant stakeholders (Rotmans, 2003). To interest these stakeholders, governments, investors, industry, and the market should be assessed to decide which large-scale, representative demonstration projects might be created. At present this occurs in the HyCom initiative of the EC. In addition it should be assessed which actors might be motivated to start up these new niches, and what incentives can (positively) influence the success of these demonstration projects (Kets, Mourik, 2003). Finally all the barriers (institutional, political, socio-cultural, technological, infrastructural) should be assessed for all possible options and the interaction (complementariness and conflict) of different options should be assessed (Mourik, Burger, 2003), (Mourik, 2004).

A last recommendation is that there potentially is a need for an action plan for coordinated co-operation between parties. This action plan can facilitate the discussion among stakeholders, and can inform particular stakeholders on the role other stakeholders expect them to play in a transition to a sustainable transport sector. Commitment of stakeholders is imperative for a successful start of a transition, and if stakeholders do not accept the role imposed on them by other stakeholders, this is expected to greatly hinder the take-off of a transition. As such, fine-tuning of expectations between stakeholders can occur, thus facilitating the creation of a transition perspective that can count on the commitment of the relevant stakeholders. Connected to this recommendation is the fact that such a stakeholder analysis would benefit from the involvement of more than just stakeholders in the transport sector. The vision forming processes could greatly benefit from the participation of stakeholders from the energy sector, the agricultural sector and the built environment. Finally, as mentioned in the introduction of this report, transitions are long-term processes that can only be achieved by long-term management. And for a radical system change to occur in the transport sector in 2030, short-term policy should be influenced by the long-term vision.

9. References

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List of interviewees

The persons listed below participated in this research on personal title. Their perspectives do not represent their company's perspective in whatever manner:

- Ton van den Berk - SenterNovem
- Dominic Boot - Vereniging voor de Nederlandse Petroleum Industrie (VNPI)
- Robert van den Brink - Rijksinstituut voor Volksgezondheid en Milieu (RIVM)
- Jan van Dijke - TNO Wegtransportmiddelen (TNO WT)
- Boelie Elzen - Technische Universiteit Twente (UT)
- Willem Jan van Grondelle - Stichting Natuur en Milieu (SNM)
- Alexander Hable - Ministerie Verkeer & Waterstaat
- Marten Janse - TNO INRO
- Bettina Kampman - CE
- Chris de Koning - Shell Hydrogen
- Martin Kroon - Ministerie VROM
- Paul Langeweg - ANWB
- Sible Schone - Wereld Natuur Fonds (WNF)
- Roald Suurs - Universiteit Utrecht (UU)
- Herman den Uil - ECN Biomassa.
- Geert Verbong - Technische Universiteit Eindhoven (TUE)

Appendix A External check of additional or alternative key changes formulated by the stakeholders

In the interviews, stakeholders mentioned that several changes and elements might be necessary (but not necessarily preferred or plausible) to accomplish a sustainable transport sector. For a selection of the key elements, an external check was conducted on the Internet, to make an inventory of additional perspectives. These changes were subjected to an external check to ascertain the principal external positions concerning the likelihood of occurrence of these changes. In this chapter we discuss the outcomes of this external check. The objective of this external check was to put the interviewees' assumptions about future developments and trends into perspective. The external check was performed using sources on the Internet. The Internet search identified the principal external positions with respect to the assumptions and as such demonstrates whether the identified trends in the interviews were either in line with or opposed to current trends.

As mentioned before, the external check is biased and relevant information may be overlooked. The external check should therefore be viewed as a methodology to put the stakeholder perspectives about particular elements (key trends and key changes) into broader perspective by specifying alternative views and principal positions taken by other actors. The results of the external check do not represent the standpoint of interviewed stakeholders or the authors. Below the suppositions and the results of the external check are discussed

A.1 External check on assumptions on transport modes

An Internet search was conducted on the assumption that there is a trend towards the optimisation of transport flows as a means to increase the sustainability of the transport sector. A note of caution on this assumption is necessary: this trend may develop in two directions. Flows of transport can either be minimised by reallocation of the elements house-work-recreation and by joining production and consumption in the same location. The capacity of the infrastructure can also be enlarged in order to meet the growing demand for mobility. The result of this check demonstrates that the transport sector is dealing with a lot of problems concerning congestion. This is particularly the case for road transport. This trend induces a call for 'sustainable logistics' that focuses on transport efficiency as well as transport prevention. Due to this development, enterprises feel a strong incentive to optimise and reduce transport movements. This incentive, combined with the integral approach that is used by these enterprises often has a positive effect on the environment and sustainability. The national and international focus on reduction of emissions also contributes to the optimisation of transport flows and thus to the creation a more sustainable transport sector.¹

An Internet search was also conducted on the supposition that future infrastructures are expected to be built in such a way that they can be used more flexibly in the future, e.g. they can be used for different transport systems. The result of this check demonstrates that, there is no clear indication that a more flexible infrastructure is going to be built. More information was found concerning energy housekeeping. Due to liberalisation of the energy market and technological development, in combination with decreasing costs, consumers have more freedom to choose their energy housekeeping. Therefore, project developers and architects will have to adapt houses to meet the increased public demand for freedom of choice with respect to the en-

¹ The conclusions are based on: Report IG & H - Raad V & W - Managementsamenvatting - Report NIDO - 'Duurzame logistiek...anders, slimmer, beter.' <http://www.nido.nu/image/publicatie/bestand/1036680106.pdf>. And: Dutch ministry of Environment (VROM) - Nederland in de EU: de Europese milieu-agenda - www.vrom.nl/get.asp?file=docs/milieu/Nederland_in_de_EU_de_Europese_milieuagenda.pdf.

ergy housekeeping. Several reports claim that local and national governments have to stimulate this development.²

A.2 External check on assumptions about the modal shift from individual to public transport

An Internet check was conducted on the supposition that long-distance passenger transport by train will increase, as travelling by train is likely to have advantages compared to travelling by car or plane (travel time, price, comfort etc). No clear arguments were found that confirmed this supposition. Nevertheless, two sources (the Fifth Environmental Action Programme 'Towards Sustainability' and the European Commission) indicate the importance of (long-distance) passenger transport by train in solving problems like congestion and environmental deterioration. In the Netherlands, trains might be an attractive alternative to cars and airplanes when capacity and quality is guaranteed on both national and European level. The Fifth Environmental Action Programme 'Towards Sustainability' focuses on the emissions from transport and the consequences for the public health. Therefore, the Commission wants to encourage the use of trains instead of airplanes in passenger transport for distances up to 1500 kilometres.³

A.3 External check on assumptions concerning the development of hybrids

An Internet check was also conducted on the assumption that around 2050, there will be cars that can drive in two modes: ICE and electrical traction (hybrids). The first mode is a mode for areas where local emissions form less of a problem and the second mode is aimed at use in areas (especially in and around cities) where reducing local emissions has the highest priority. This statement seems to be confirmed by the new cars Toyota Prius. Many car manufacturers and developers aim at this new dual technology. What has been found in several sources is that the car as a transport mode will become more environmental friendly over time. This will be the most important technological challenge for the coming few decades. Nevertheless, this will remain a big challenge since it is expected that there will be a shift towards faster modes of transport, which means an increase in energy intensity and an increase in emissions if sustainable fuels are not used.⁴

A.4 External check on supposition on battery electrical vehicles

Due to the time constraint, the check was only conducted for suppositions on battery electrical vehicles. Fuel cell vehicles were not considered

Some of the stakeholders claimed that improvements in batteries are of utmost importance for the development and deployment of battery electrical vehicles. In addition they expected that the quality of batteries would improve drastically, and consequently allow for long driving distances and short loading times.

² These conclusions are based on the following sources: ECN Report - Flexibele energie-infrastructuur in woningen - Menkveld e.a. - 2002 - <http://www.ecn.nl/docs/library/report/2002/c02014.pdf>. And: ECN Report - Energie-infrastructuur van de toekomst - Seebregts e.a. - 2002 - <http://www.ecn.nl/library/reports/2002/c02014.html>.

³ These conclusions are based on: Brochure Mobiliteitsgroei vraag om rail - Pleidooi om tijdens de kabinetsperiode 2002-2006 een investeringsvisie te ontwikkelen voor rail vanaf 2020 - Railforum Nederland. - http://www.railforum.nl/publicaties/brochure_nwe_visie.pdf. And: Website 'The European Union and the Environment' - http://europa.eu.int/comm/publications/archives/booklets/move/15/txt03_en.htm.

⁴ These conclusions are based on: Modeling global mobility - world passenger transport through 2050 - Andreas Schafer - MIT - 2000 - <http://scitech.dot.gov/policy/vision2050/docs/andreasschafer.ppt>. And: GITAGE-project - report TBM Web TU Delft - Section 9 Probable Innovative Developments - <http://www.tbm.tudelft.nl/webstaf/jann/git9.htm>.

Little alternative or additional perspectives could be found on the Internet concerning the statement that improvements in batteries are of utmost importance for the development and deployment of battery electrical vehicles. Concerning the quality of batteries, several key limitations are mentioned on the Internet. The most important limitations mentioned are the low energy density compared to gasoline, a slow recharging time compared to a quick stop to fill a tank, a small driving range for an electrical vehicle, limitations due to weather conditions and the high price of a battery in relation to its lifetime. Due to technological developments the energy density, driving range, recharging time and lifetime have improved over time. On the Internet expectations are expressed that this technological process will continue, leading to further improvements of the quality of batteries for electrical vehicles.⁵

A.5 External check on assumptions on biofuels

An Internet check was conducted on the supposition that first generation biofuels (biodiesel, and ethanol) will not be used due to their high costs. The results of this check show that at this moment biofuel production costs are very high, in relation to fossil fuels. There is much discussion about the possible contribution to CO₂ reduction of first generation of biofuels. There is however agreement that the first generation of biofuels is more sustainable than fossil fuels. Second generation biofuels are expected to become more CO₂ efficient and cheaper to produce.⁶

A.6 External check on assumptions regarding role of government

Stakeholders mentioned that they expect the Dutch and European government to be able and willing to steer the sustainable development of (transport) systems or technologies. The result of the external check showed that partly due to the European policy concerning the reduction of CO₂-emissions, the Dutch government is focusing on a (more) sustainable transport sector. Besides the harmful emissions, congestion is an important issue in the Netherlands. Mobility demand is linked to economic growth. In order to deal with these problems the Dutch government monitors international technological developments and stimulates national projects concerning a more sustainable transport sector. The ministries of transport and the environment recently published an important document on mobility issues.⁷

Another assumption the stakeholders mentioned was that in order to stimulate sustainability the government should promote the development of new technologies in niches by a strategic approach towards experimenting with new options. (This approach does not only comprise the promotion of experiments, but also learning from experiences world-wide, linking experiments, and building future experiments upon past experiences.) The result of the external check shows that technological innovations in the transport sector are necessary in order to achieve a more sustainable transport sector. Due to the small size of the Dutch automotive sector there is a focus on niches, which eventually leads to products with a broader application. Subsidies are given to extend the level of basic research. Normally, the subsidy stops once the technology has reached the phase of market implementation, but the stakeholders that deal with engineering and

⁵ These conclusions are based on the following sources: Article MIT - The Future of Solar And Electrical Vehicles - De La Paz, C.A., e.a. - <http://web.mit.edu/course/3/3s32/www/delapaz.html>.

⁶ These conclusions are based on: Report to the European Commission on Directive 2003/30/EC (Covering the year 2003) - http://europa.eu.int/comm/energy/res/legislation/doc/biofuels/member_states/2003_30_nl_report_en.pdf. And: Boerrigter H., Hans Peter Calis, Dennis J. Slort, Herman Bodenstaff, Gas cleaning for integrated biomass gasification (BG) and Fischer-Tropsch (FT) systems: experimental demonstration of two BG-FT systems, 2004 - <http://www.ecn.nl/docs/library/report/2004/rx04041.pdf>.

⁷ These conclusions are based on the following sources: Ministry of Environment (VROM) - Nederland in de EU: de Europese milieu-agenda - 2004. www.vrom.nl/get.asp?file=docs/milieu/Nederland_in_de_EU_de_Europese_milieuagenda.pdf. And: ICIS - Van individueel autogebruik naar mobiliteit op maat - Maastricht - <http://www.icis.unimaas.nl/projects/transitions/examples.html>.

testing claim that to reach the level of widespread application and production, a longer period of subsidies is necessary.⁸

Stakeholders mentioned that they expect that the European government could challenge the industry to reduce energy use and emissions by setting clear efficiency standards and develop emission reduction policies. The result of the external check demonstrates that the European government has set targets for saving energy and for switching to more environmental friendly sources. The reductions of pollution and energy efficiency have become a priority in the industrial sector. The Emission Trading System started in 2005, which results in a limit on the amount of CO₂ that EU industry can emit. Companies who exceed their emissions allowance will have to trade with others with spare allowance. This measure is important to reach the goal set by the Kyoto protocol. The trading system fits into the new energy framework of competition, ruled by the process of liberalization and market economy. Industrial organisations have to compete in terms of achieving sustainable energy use and a reduction of emissions.⁹

The stakeholders further mentioned to expect the Dutch and EU government to internalise direct and indirect costs in the transport sector. The external check showed that since 1995 the European Commission is already working on the internalisation of external costs of transport. The publication of the European Commission White paper 'Fair payment of infrastructure use' in 1998 has stimulated the set-up of a framework to internalise both direct and indirect or external costs. In this White paper the European Commission focuses on the idea that the 'polluter needs to pay for the (societal) costs of his pollution'. Societal costs are among other things the direct costs of infrastructure and the indirect costs of environmental damage. The Dutch minister of Traffic and Water management has adopted this policy.¹⁰ This is published in the Green Paper 'Towards fair and efficient pricing in transport - policy options for internalising the external costs of transport in the European Union'. The most recent report is the White Paper of 2010: 'European transport policy for 2010: time to decide'. This paper describes the need for pricing policy in order to solve the problem of congestion and to enhance quality of living environment. This is partly done by taking external costs into account when charging for infrastructure use. The Dutch government is working on the implementation of pricing in the transport sector.¹¹

The stakeholders further claimed that the government should demonstrate consistent policy by maintaining concrete (financial) incentives and sending a clear message to the public emphasising the importance of sustainability. The external check demonstrated that the government is working on policies to stimulate developments towards a more sustainable transport sector. Concerning other sectors the Dutch government does not seem to be very consistent in the field of sustainability. For example, several measures aiming at long-term sustainability have been abolished (for example VAMIL). On the other hand, an initiative like 'the sustainable suitcase'

⁸ These conclusions are based on: Federatie Holland Automotive - De groeipotentie van Automotive Nederland - Een visie op de internationale ontwikkelingen en de toekomstige rol van Nederland in de automotive industrie, Juni 2004 - [http://www.atcentre.nl/Downloads/Groeipotentie_van_Automotive_Nederland_\(hoofdtekst\).pdf](http://www.atcentre.nl/Downloads/Groeipotentie_van_Automotive_Nederland_(hoofdtekst).pdf). And: De Vaan, M.J.M. and H.A.M. Weken, Onderzoek strategie automotive industrie - rapport fase A. Managementsamenvatting, Utrecht, juni 2000 - <http://www.unie.nl/content/files/download/FierEindrapportOnderzoekStrategie0600.pdf>.

⁹ EU guides - Energy Policy in the European Union - <http://www.eubusiness.com/guides/energy>. And: The Northern Dimension of European energy policy - <http://europa.eu.int/scadplus/leg/en/lvb/l27031.htm>.

¹⁰ These conclusions are based on: SER - Samenvatting Advies 99/01- Doorberekening van maatschappelijke kosten bij verkeer en vervoer - January 1999 - <http://www.ser.nl/publicaties/default.asp?desc=b17185>. And: Ministry of Traffic and Water management - budget 2000 - International <http://www.verkeerenwaterstaat.nl/?lc=nl&page=659>.

¹¹ These conclusions are based on: Directorate General National Water Management - Commission Traffic and Transport - "Europees beleid voor stedelijk verkeer en vervoer" - www.kenniscentrumgrotesteden.nl/.../file=Europees_beleid_stedelijk_verkeer_-_vervoer.pdf?textonly=148324. And: Ministry of Housing, Spatial Planning and the Environment - 'Nederland in de EU: de Europese milieu-agenda' - www.vrom.nl/get.asp?file=docs/milieu/Nederland_in_de_EU_de_Europese_milieuagenda.pdf. And: European Commission - A transport policy for Europe's citizens (press release for 'European transport policy for 2010: time to decide') - http://europa.eu.int/comm/energy_transport/library/communi-presse-lb-en.pdf.

is a good practice example of government and citizens working together to create sustainable policy. The 'suitcase' contains ideas and proposals from citizens, organisations etcetera for sustainability. These recommendations are taken along in the new policy for the coming year.¹²

The stakeholders mentioned that in order to achieve a diminishing market share for fossil fuels in the transport sector, a new independent institution could be established. This institution could promote this change and be able to break down existing institutions, such as governmental structures. In order to pressure actors towards sustainable behaviour, a more authoritarian power on international level could be institutionalised. The external check showed that different sources demonstrate that there are several initiatives for institutionalising an influential international approach towards sustainability. For example the United Nations World Summit on Sustainable Development (WSSD) in Johannesburg in 2002 has resulted in more policy by national governments that focus on sustainable development, for example to decrease air pollution. Another movement is initiated by the European Union. Already in 2001 the goal was set to implement a sustainable policy. A final example is the World Health Organisation (WHO) that recommends certain values concerning air pollution.¹³

The American Council for the United Nations University worked on a study focusing on 'environmental security'. This is defined as 'the relative safety from environmental dangers caused by natural or human processes due to ignorance, accident, mismanagement or design and originating within or across national borders'. The change of the current system from fossil fuels to biofuels may be part of environmental security. An international panel was asked who could be responsible for assuring the environmental security. The answer 'new institutions' was an option. It was stated that 'a new institution is probably not needed', but that this statement needs reviewing.¹⁴

The stakeholders also claimed that a trend towards more decentralised environmental governance should provide local governments (provinces and municipalities) with the opportunities to implement policies aiming at a more sustainable transport sector. The result of the external check demonstrates that this trend of decentralisation is already going on for a few years in the Netherlands. For example, concerning passenger transport, the government has delegated most of the policy to local authorities. Concerning environmental policy the process of decentralisation of policy has led to increasing tensions between Dutch local and national governments and between the Dutch government and the European parliament. Local governments have freedom to a certain extent but the national governments are responsible for certain targets that have been set by the European Commission. It is mentioned that local authorities should obtain more knowledge concerning the execution of national and international environmental policy.

The stakeholders also mentioned that pricing policies will stimulate sustainable mobility patterns such as the use of public transport and the decreased use of transport and the type of vehicles used. The external check demonstrated that pricing policies aim at reaching emission reduction targets and internalising external costs. The latter may lead to a high increase of prices in the transport sector, for example, 10% for transport by trucks and up to 70% for public transport. Furthermore, the demand of road transport has a relatively high price-sensitivity. For example, when the price of road transport rises with 1%, the transport volume decreases by 0.6%

¹² Ministry of VROM - Ontvangst van het duurzame koffertje - <http://www.vrom.nl/pagina.html?id=18445>.

¹³ These conclusions are based on the following sources: Website 'Bond Beter Leefmilieu Vlaanderen' - De Europese duurzaamheidsstrategie en Europese Grondwet, Göteborg 2001 - <http://www.bondbeterleefmilieu.be/theme.php/2#mondiale%20aspecte>. And: Website Federal Department of the Environment - http://www.environment.fgov.be/Root/tasks/atmosphere/atmopol/Beleid/Int/BeleidInt_nl.htm.

¹⁴ ACUNU - The Millennium project - global futures, studies & research - Chapter 5 'Environmental Security study' - <http://www.acunu.org/millennium/es-5pol.html>.

to 0.9%. Half of this is a net decrease, which means less demand. The other half is a change in transport mode. So, pricing policies may be effective in reaching their goals.¹⁵ The stakeholders further claimed that (Urban) environmental and quality of living problems, for example congestion, emissions of CO₂, NO_x, and noise will create a sense of urgency to install a more sustainable transport sector. The external check showed that congestion, emissions of greenhouse gases and of noise have become major issues in urban regions. On European level as well as national level, policy supports the development to a sustainable transport sector, namely policy concerning emissions of gases and noise and the effort to diminish congestion. The defined problems are also present in the city areas. Local authorities are aware of this and are participating in programs in order to solve these problems. One initiative is Civitas. Civitas is a European project in which 19 cities participate. The goal is to achieve a significant change in the modal shift towards sustainable transport modes, in order to make cities cleaner and increase their accessibility. Civitas carries out this objective through the combination of technology and policy based strategies.¹⁶

The European Commission has defined that by the year 2010, 22% of the consumed electricity should be generated by means of renewable energy sources. On a global level an important example is the Kyoto-protocol imposing a reduction of CO₂ emission reduction targets. The protocol is an important commitment between countries towards the process of climate change. Europe has an Emission Trading System, starting from January 2005. This system should reduce emissions of greenhouse gases by the trade of the emissions.¹⁷

Finally, the stakeholders mentioned that globalisation and the increasing European market will contribute to fast diffusion of sustainable innovation. The external check showed no statements under scribing that globalisation results in a *fast* diffusion of sustainable innovations. Sources mentioned that globalisation and deregulation have led to new market structures and changes in the framework for competition and innovation. Another source indicates that innovation occurs mainly at company level and that innovative behaviour is driven by the quality of the business environment they face. Due to the competitiveness resulting from globalisation companies have to work very efficient which might induce innovation.¹⁸

A.7 The external check: in conclusion

The stakeholders mentioned several actions that the government could undertake to secure a transition towards a more sustainable transport sector. Stakeholders first mentioned the internalisation of direct and indirect costs in the transport sector, the setting of clear efficiency standards, pricing policies to stimulate sustainable mobility patterns, and targets for emission reduction. Stakeholders furthermore mentioned the stimulation of national projects and experiments,

¹⁵ These conclusions are based on the following sources: Report CE - Efficiënte prijzen voor het verkeer; raming van maatschappelijke kosten van het gebruik van verschillende vervoermiddelen - Dings, ir J.M.W. e.a. - Delft, 1999 (October) - www.ce.nl. Via 'publicaties' naar het rapport uit 1999. And: Report CE - Prijselasticiteiten in het goederenwegvervoer (Hoofdrapport) - Dings, ir J.M.W., e.a. - Delft, 1999 (December) - www.ce.nl. Via 'publicaties' to reports from 1999. And: Report 'Verkeer en vervoer in hoofdlijnen - Capita Selecta - Deel 1: Prijsbeleid in verkeer en vervoer' - Bert van Wee e.a. - <http://www.coutinho.nl/verkeer/prijsbeleid.pdf>.

¹⁶ The conclusions are based on: Novem, Gave project - Wijkman speech at Conference, Stockholm, June 2004 - http://gave.novem.nl/novem_new/index.asp?id=25&detail=223. And: Website city of Rotterdam. <http://www.rotterdam.nl/smartsite2004777.dws?MainMenu=267127&Menu=267127&SubStyle=251100>. And: Website Civitas - <http://www.civitas-initiative.org/civitas/home.cfm>.

¹⁷ These conclusions are based on: Corbey e.a. - 'Domestic action' na de domper van Den Haag (11-04-2001) - Vrijblijvendheid voldoet niet - Staatscourant, Spring 2001 - <http://www.corbey.nl/print.php?id=4>. And: Website GroenLinks - Europa neemt voortouw vermindering CO₂ - 17 maart 2004 - <http://oudesite.groenlinks.nl/partij/europa/dossier/klimaat.html>.

¹⁸ These conclusions are based on: DIW Berlin (German Institute for Business Research) - Research Programme - Towards a sustainable transformation of the electricity system: Governance and diffusion of innovation in large infrastructure / technology systems in the context of social-ecological dynamics and development - http://www.ioew.de/governance/english/veranstaltungen/Int_Tagung/Praetorius.pdf. And: Ketels - The impact of globalization - http://www.insme.info/documenti/future_innovation_03_1.pdf.

the institutionalisation of an influential independent international approach towards sustainability, and the stimulation of more decentralized environmental governance. The stakeholders also mentioned that (urban) environmental and quality of living problems, and globalisation would contribute to fast diffusion of sustainable innovations. Finally, the stakeholders mentioned consistent short and long-term policy. The external check shows that these efforts are indeed taking place, although some notes of concern were found with respect to the issue of consistency.

Appendix B General description of end visions

B.1 OECD visions

B.1.1 Introduction

In this section we discuss the OECD Project on Environmentally Sustainable Transport. And we focus specifically on the 'Individual project Case Studies. Annex Volume to the Report on Phase II. Transport Scenarios for the Netherlands for 2030. A description of the scenarios for the OECD project 'Environmentally Sustainable Transport'. The OECD investigation was performed by order and for the account of the Directorate-General for Environmental Protection of the Ministry of Housing, Spatial Planning and Environment, The Netherlands, within the framework of the project Traffic and Transport no. 773002 National Institute of Public Health and the Environment, P.O. Box 1, 3720 BA Bilthoven, The Netherlands, tel. +31-30-274 9111, fax +31-30-274 4417. The researchers were G.P. van Wee, K.T. Geurs, R.M.M van den Brink J. van der Waard. December 1996. Report no. 773002009.

The overall purpose of the OECD EST project was to establish guidelines for the development of policies that would result in the achievement of EST in the Netherlands. The report describes four transport scenarios for the OECD project on Environmental Sustainable Transport (EST) for the Netherlands for 2030:

- Business-as-usual scenario (BAU): continuation of present trends in transport, moderated by likely changes in legislation and technology. This scenario does not necessarily conform to current governmental policies in the Netherlands.
- High-technology scenario (EST1): only technical measures to meet EST criteria,
- Capacity-constraint scenario (EST2): contains reductions in the volume of passenger and goods transport (behavioral adaptations) to meet the EST criteria. Assumes increases in efficiency of passenger transport and the transport of goods.
- Optimum-combination scenario (EST3): contains a package of measures from the high technology and capacity-constraint scenarios to meet EST criteria.

B.1.2 General assumptions and criteria

- Reduction of CO₂ by 80%, NO_x by 90%, VOC by 90% between 1990 and 2030,
- Particulate matter: 90% less PM10 emissions between 1990 and 2030,
- Noise: a negligible level of serious noise nuisance in 2030,
- Land use: stabilization of direct land use for transport outside urban areas between 1990 and 2030; a good living climate inside urban areas in 2030, indirect land use in 2030 represents half the 1990 level.
- Economic growth is supposed to be about 2 - 2.5% per year.
- A constant growth factor (growth per year) for the period up to 2030.
- Demographic growth: between 1995 and 2030 population growth is 13.7%. The percentage of the population under 20 years decreases from 24.3% in 1990 to 21.9% in 2030, whereas the percentage 65 and older increases from 13.1 to 24.4%. Annual growth rates of total population are 0.57% for the period 1995-2010, 0.27% for 2010.

B.1.3 Methodology

For this study several scenario studies were used that in recent years have been carried out for the Dutch transport system. For the high-technology, the capacity-constraint and the optimum-

combination scenario, several changes, compared to the Business as Usual (BAU) scenario are described. The reductions in emissions refer to comparisons with the BAU scenario (and not with 1990 levels). For the base year (1990) data from the Dutch Central Bureau for Statistics as reported in several documents was used.

B.2 COOL visions

B.2.1 Introduction

The overall purpose of the COOL project in which the two end visions described below have been developed, was to explore routes towards far-reaching CO₂ emission reduction. The emission target chosen was an overall CO₂ emission reduction of 80% in 2050 as compared to 1990 emissions. The dialogue within the COOL project was focused on the question on how CO₂ emissions of the transport sector can be reduced by 80% in 2050 as compared to 1990, not on the necessity of an 80% reduction.

The COOL project was an interactive project in which two general end visions on national level, image A and B, were developed. Both end visions lead to the 80% reduction desired. Four dialogue groups on four different sectors (Built environment, Industry and Energy, Agriculture and food and transport) have formed their own future images based on the two future images A and B.

The dialogue group transport has developed:

- Two future images of a society in which an 80% CO₂ emission reduction in the transport sector is possible. The end visions are based on the national end vision A and B. End vision Free roads ('vrij baan') is based on Vision A and custom made transport ('Transport op maat') is based on Vision B.
- A description of possible routes for CO₂ reduction. The routes are 1) the use of CO₂ neutral fuels, 2) technological solutions leading to reduction of energy demand per vehicle km, 3) reduction of demand for transport and 4) modal shift.

Furthermore the dialogue group has back casted the development and implementation of several technological options such as fuel cells for the two end visions. The back casting of technological options was based on end visions A and B.

The dialogue was not aimed on developing an unequivocal approach to reach the 80% emission reduction desired. The relations between the end visions A and B, the end visions 'Free roads' and 'custom made transport', and the options and routes back casted are therefore not completely clear; the visions are however strongly interrelated. For the description of the COOL end visions therefore a combination of sources were used: either the end visions 'COOL A' and 'free roads', possible routes and technological options back casted for the description of COOL A (Section 4.3) or the end vision 'COOL B' and 'custom the description of COOL B (Section 4.4). For both descriptions the underlying spreadsheet ¹⁹is used.

B.2.2 General assumptions

The most important general assumption is the 80% CO₂ emission reduction in 2050 as related to CO₂ emissions in 1990.

¹⁹ Based on the spreadsheet developed by P. Kroon for the Cool project, January 2001.

B.2.3 Methodology

The overall purpose of the COOL project was to explore routes towards far-reaching CO₂ emission reduction. A number of dialogue groups have been set up to explore possible routes for emission reduction on global, European and national level. On national level two general end visions were developed: end vision A and end vision B. On national level four dialogue groups on four different sectors (Built environment, Industry and Energy, Agriculture and food and transport) were formed. Each of these dialogue groups formed their own future images based on the two end visions. Based on these end vision for the transport sector the dialogue group has back casted the possible routes leading to CO₂ emission reductions. Furthermore the dialogue groups has back casted possible technological option based on the end visions A and B. A team of experts that supported the dialogue groups: they answered questions of group members and calculated resulting emission reductions for the technological options or routes.

B.2.4 COOL A

In 2050, the transport sector no longer uses fossil petrol and diesel, but the energy supply is much more diverse and new technologies have been introduced to increase fuel-efficiency. In road transport, cars, vans and small trucks are equipped with fuel cells and hydrogen is stored on-board. They use refuelling stations that are provided with centrally produced hydrogen from refineries by means of truck lines. Because refuelling stations are not located within the built environment, large hydrogen storage tanks are required. The most important energy source for the production of hydrogen is biomass; the remaining part is produced from either coal or natural gas. CO₂ is captured and then sequestered, using an infrastructure to collect and store CO₂, mostly from and at large centralised power and hydrogen production plants. Biomass is also used for the production of synfuels (hydrocarbons) that are used in aircrafts, inland ships and trucks. This biomass originates from Eastern Europe, Latin America and sub-Saharan Africa. Biomass and other renewable energy sources, as well as nuclear energy, play a moderate role in power production; coal is the preferred source for power generation. There is a tendency towards large-scale centralised production capacity.

Public or collective transport has grown substantially, at the expense of individual transport, especially in major urban areas. Freight transport has increased significantly in spite of the bundling of transport streams, and witnesses a modal shift from road to water transport after the water infrastructure has been improved by the government and after chemical plants have financed their own terminals. There is also a modal shift from air transport to transport by train. Overall, the demand for transport has increased which requires extensions of the transport infrastructure. Due to spatial scarcity the construction of infrastructures is expensive. In order to solve spatial scarcity issues, technologies are introduced to increase the efficiency of the transport system, for example magnetic coupling of cars and ICT.

B.2.5 COOL B

In 2050, the demand for transport in the Netherlands is relatively low, which is mainly due to spatial planning policies that reduce commuter traffic and the partial replacement of mobility by ICT. Collective and bundled transport has gained importance, at the expense of individual transport. Overall, the energy-efficiency of the transport system has increased. In cars, trucks, and buses clean fuel cells are used, which mostly run on biofuels (mainly ethanol and methanol) and have a higher efficiency as compared to conventional cars using petrol or diesel. On global level there is sustainable production and distribution of all kinds of products from biomass, such as biofuels and hydrocarbons that serve as feedstock. CO₂ emissions are collected at biorefineries. The bio-alcohols used in fuel cell vehicles are converted to hydrogen on-board. For most public transport systems electricity is used. There is a strong increase of air transport but the energy efficiency of aircrafts is increased strongly and they run on synfuels (biomass-derived hydrocar-

drocarbons). Short-distance air transport is largely replaced by rail transport. Trains and ships have gained importance as freight transport modes. A pan European network for underground transport is expected to be implemented.

B.3 SEP visions

B.3.1 Introduction

The visions have been developed within the project ‘Transport in the 21st century’, which was performed in 1997 for the Samenwerkende elektriciteitsproductiebedrijven (SEP, Co-operating Electricity Production Companies) in the Netherlands. The project consists of five partial studies by six institutes (TNO, University of Twente, ECN, KEMA, CE, Technical University of Eindhoven). The project started with a partial socio-economic scenario on ‘transport demand and transport systems’, that describe future developments in demographics, spatial planning, infrastructure, socio-economics, socio-cultural aspects, technology, pricing and regulation regarding the transport sector. The socio-economic scenarios from this study have been integrated with outcomes from the other partial studies on new drive train technologies, strategies for innovation, passenger transport and lifestyle, and the energy infrastructure for transport. This approach resulted in four scenarios, which integrate all the aspects mentioned above.

B.3.2 General assumptions

The time focus of the end visions is 2050, but key changes have been described for the intermediate years 2005 and 2020. Developments in the transport system are described for the Netherlands, whereas the identification of potentially successful drive train and vehicle concepts and the description of energy scenarios are based on international developments.

The scenarios contain some general assumptions, for example for the availability of fossil energy sources. The proven reserves of fossil fuels are high and new wells are still being discovered, reserves that currently cannot be exploited economically are expected to be used in the future due to developments in exploitation technologies and cost reductions. World energy prices are expected to not increase drastically. Therefore, there it is not expected that there will be any scarcity of gasoline and diesel. Gasoline and diesel are expected to remain very important in the fuel mix. Energy saving in transport is mainly realised by increasing conversion efficiencies instead of changing lifestyles and consumption patterns. Furthermore, diesel engines are assumed to become much cleaner in the future.

Alternative energy carriers concern electricity, hydrogen, natural gas, and biofuels. In all four scenarios, there is an increasing diversification of drive train concepts and vehicle concepts in passenger transport on the road. The internal combustion engine remains the dominant drive train (direct or hybrid). However, competing drive technologies are likely to be introduced, i.e. hybrid electric vehicles, and electric vehicles equipped with either fuel cells or batteries. Electric traction occurs in every scenario. In vehicle concepts for individual transport, the diversification is expected to be realised through the introduction of all purpose vehicles, long distance vehicles (which are larger and more comfortable than APV), and dedicated vehicles (for special uses and target groups such as compact cars, urban cars, and fun cars). The extent of this diversification is high in scenarios with higher incomes. In ‘Sustained Balance’ it is high as well because transport must be sustainable. In all scenarios, most changes occur in road transport, whereas hardly any changes are assumed for other modes of transport. Inland ships are expected to continue to use diesel and trains mainly run on electricity. Aviation is also considered similar to the current practice.

B.3.3 Methodology

The four scenarios are built around two dimensions of possible future developments, i.e. high versus low economic growth (and technological development) and little versus much emphasis on sustainability. In this section only the visions with much emphasis on sustainability are discussed, 'Sustained Growth' (high economic growth) and 'Sustainable Balance' (low economic growth). In general, environmental issues in the scenarios mainly concern emissions and energy use (extension of the infrastructure as a result of increasing mobility and its impacts is not discussed).

The study distinguishes between several levels within the transport sector. For each scenario, there is one 'transport system' that consists of several 'transport concepts' (the way one or more vehicles concepts are used, for example shared cars, 'transport on demand' or automatic vehicle guidance systems). The 'transport system' also refers to the logistic organisation and the transport infrastructure. 'Vehicle concepts' that are included in 'transport concepts' denote all transport modes that are used, such as cars, trains, buses, ships, trucks. A 'vehicle concept' can use various 'drive concepts' such as the internal combustion engine or an electric engine combined with a fuel cell.

The end visions of the energy infrastructure for transport have been created combining the outcomes of the various partial studies, i.e. the socio-economic scenarios combined with developments in drive train technologies and in the overall energy system. In the scenarios, the role of various actors is discussed explicitly, not only for the end vision in 2050 but for the intermediate years as well. The actors that are taken into consideration are: governmental bodies (on local, national and international level), the car producers, producers of traffic telematics, the battery industry, the oil industry, energy companies, transport companies, consumers, and environmental organisations. For each group of actors, their interests, attitudes, and roles are briefly discussed.

B.3.4 Sustainable Balance SEP

In 2050, the internal combustion engine is still the dominant drive train in the transport sector, because, due to the introduction of advanced technologies, it can still comply with stringent energy use and emission standards. However, competing drive technologies have been introduced, i.e. electric vehicles using batteries or fuel cells, and hybrid electric vehicles. In individual passenger transport, a diversification of vehicle concepts has been realised as well. Downsized all-purpose vehicles that are either rented or shared are used in combination with a great variety of cars for city areas. Urban cars are mainly equipped with electric or efficient internal combustion engines.

In the transport sector, fossil fuels remain the most important fuels, although in the energy supply system fossil fuels are gradually replaced by energy carriers produced from renewable sources as a result of active governmental policies. Indigenous and imported biomass and solar energy (in the form of electricity or hydrogen) are important renewable energy sources. Electricity has gained a substantial share as energy carrier in transport, as well as biofuels that are used by fuel cell vehicles. In public transport diesel remains the most important fuel and it is used in vehicles with internal combustion engines and hybrid electric vehicles. In hybrid electric buses biofuels are used as well. Electric vehicles also have a share in public transport. The government supports a fine meshed public transport system and contributes to the exploitation of demand-dependent transport that replaces non-rail public transport. The government also strongly promotes the use of bicycles and vehicle/bicycle concepts. For trucks, the internal combustion engine remains dominant, since the hybrid electric concept has little added value because trucks drive for long distances with constant speed. The diesel engines used in trucks have become much cleaner and they use biofuels or conventional diesel.

B.3.5 Sustained Growth SEP

In 2050, despite stronger spatial concentration of houses, the lower share of paid labour and the CO₂ implications of transport, mobility has strongly increased due to high economic growth. Especially freight transport has increased enormously. The transport sector has witnessed a strong diversification in new, energy-efficient and environmentally friendly transport system and vehicle concepts and drive train technologies. For environmentally friendly vehicles there are separate high-tech lanes that guarantee a short travel time combined with automatic vehicles guidance. Moreover, differences between individual and public transport fade.

The diversification in vehicle types and drive trains occurs especially in individual passenger transport, in which urban cars in city centres and urban areas have gradually replaced all-purpose vehicles and have become the dominant vehicle type. Long-distance vehicles are also used, but as second car, or shared or rented car especially for long-distance trips because they are more expensive. Passenger cars are mostly hybrid electric vehicles using biofuels or fossil petrol or diesel, and fuel cell vehicles using hydrogen. Electric vehicles using batteries also have a substantial share, which has led to a substantial extension of the number of recharging units, especially public recharging facilities. However, large extensions of the electricity grid have not been implemented. To avoid bottlenecks in recharging of battery electric vehicles different strategies are used, such as shifting of the load of battery electric vehicles to time periods in which the nation-wide electricity demand is low, or using batteries to store electricity from PV thus stabilising demand and supply of electricity from PV.

In public transport, the internal combustion engine still has a share but is mainly substituted by hybrid electric vehicles using biofuels or diesel, fuel cell vehicles running on hydrogen and battery electric vehicles. Most trucks are still equipped with internal combustion engines using diesel, but fuel cell vehicles running on hydrogen become very important as well. Vans sometimes use electric engines combined with a battery.

Due to strong incentives for reducing CO₂ emissions, renewable energy sources and CO₂ capture and storage (in empty gas fields and aquifers) have become attractive technologies, which also applies to the transport sector, e.g. biofuels have become important energy carriers in transport. Biomass is also be used for other purposes, e.g. as a fuel for power plants and industrial installations. This large-scale application of biomass may result in large agricultural monocultures abroad, which may lead to other adverse environmental effects (due to the use of artificial fertilisers and pesticides). These effects are expected to be avoided as much as possible but reduction of CO₂ emissions has the highest priority. Hydrogen and electricity are produced from natural gas (reforming and CHP) and coal (gasification combined with CO₂ storage) and renewable energy sources also gain importance here. CO₂ is expected to not be captured and stored at end-use of a fuel in a car but at electricity and fuel production facilities.