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AUTHORS

Jens Schippl, Project leader,	(Institute for Technology Assessment and Systems Analysis (ITAS), Karlsruhe Institute of Technology (KIT))
Markus Edelman	(Institute for Technology Assessment and Systems Analysis (ITAS), Karlsruhe Institute of Technology (KIT))
Maike Puhe	(Institute for Technology Assessment and Systems Analysis (ITAS), Karlsruhe Institute of Technology (KIT))
Max Reichenbach	(Institute for Technology Assessment and Systems Analysis (ITAS), Karlsruhe Institute of Technology (KIT))

RESPONSIBLE ADMINISTRATOR

Peter Ide-Kostic
Science and Technology Options Assessment (STOA)
Directorate G: Impact Assessment and European Added Value
DG Internal Policies
European Parliament
Rue Wiertz 60 - RMD 00J016
B-1047 Brussels
E-mail: peter.ide-kostic@europarl.europa.eu

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Abstract

An affordable, efficient and clean transport system is a basic pillar for economic growth and the quality of life in European countries. However, transport is still accompanied by a broad range of negative impacts on human health and the environment. It is still using huge amounts of finite resources. Congestion is increasingly hampering the efficiency of the system. Transport volumes are expected to further grow in the future. So, a transition to a more eco-efficient transport system is needed to cope with recent challenges and anticipated future developments in the transport sector. Against this background, the STOA Project on "Eco-Efficient Transport" aimed at assessing to what extent different concepts and approaches can help to increase the eco-efficiency of the transport system. To allow the required systemic perspective, the assessment was supported by scenario building. The feasibility and desirability of the scenarios and their elements was the subject of a stakeholder consultation.

This report is the final report (Deliverable 5) of the project. It summarises the previous phases of the project and draws conclusions on that basis. The previous reports, Deliverables 2, 2b, 3, and 4, are available online on the STOA homepage at:

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Executive Summary

Transport is a key factor for economic development and wealth in modern societies. But at the same time, there are several reasons why there is an urgent need for eco-efficiency in transport. The transport system is facing serious challenges; among the most striking ones are surely the impacts of transport greenhouse gas (GHG) emissions accelerating climate change, the impacts on human health and the environment, oil dependency, and congestion.[1] The latter illustrates that the capacities of the transport networks are not able to deal with the growth in transport demand, at least not during peak hours. Regarding energy, almost 72% of the total oil product deliveries to the European Union (EU) are consumed by the transport sector, which is accordingly the largest consumer of oil products in the EU. Today, transport relies almost entirely on oil. Further challenges are emissions of noise and other pollutants. Particulate matter (PM) is an especially serious threat for human health. In addition, the production and disposal of transport-related products contribute to the ecological footprint of the transport system.

GHG emissions in the transport sector continue to grow, while they are decreasing in other sectors. Continuously increasing growth rates in the transport sector are a substantial driver behind the increases in energy consumption and GHG emissions. Statistics show that in Europe – apart from the period of the economic downturn in 2008 and 2009 – both passenger and freight transport have shown constant growth rates over the past decades. Between 1995 and 2009, the gross domestic product (GDP) grew annually by 1.8%, while passenger transport grew at an average of 1.4% and freight transport by 1.2%. For the future, a continuation of growth in the freight sector is expected; an increase in transport volumes is also assumed for the passenger sector, but with lower growth rates than in the freight sector. The reference scenario used in this project assumes a growth rate of 0.6% between 2010 and 2050 for the passenger sector and 1.8% for the freight sector.

A transition to a more eco-efficient transport system is needed to cope with the challenges and anticipated future developments in the transport sector. A wide range of technologies and concepts supporting eco-efficient transport are available and others are emerging, but are still at an early stage of development, with a low level of market penetration. However, there are different views on what desirable or feasible pathways to achieving an eco-efficient transformation of the transport sector could look like. Furthermore, given the complexity of the transport system, it is crucial to assess approaches towards eco-efficiency in a broader context: a systemic perspective is required.

Against this background, the Science and Technology Options Assessment (STOA) Panel's project "Eco-Efficient Transport Futures for Europe" aimed at highlighting and assessing the potentials of already established, emerging, and rather visionary technologies and concepts that could lead to a more eco-efficient transport system. In order to permit the required systemic perspective, the assessment was supported by scenario building. The feasibility and desirability of the scenarios and their elements was the subject of a stakeholder consultation.

The project is organised according to the following structure:

[1] See, for example, STOA (2007), STOA (2008), STOA (2009).

- deliverable 1 encompasses a survey of the field and a conceptualisation of eco-efficiency in the transport sector,
- deliverable 2 provides an overview of technological and organisational innovations in the field, accompanied by some stakeholders' statements on the pros and cons of these innovations,
- deliverable 3 illustrates scenarios for eco-efficient transport futures that have been developed in this project,
- deliverable 4 summarises the findings of the stakeholder consultation on the desirability and feasibility of the scenarios and their elements,
- deliverable 5 is the final report that summarises the previous phases of the project and draws conclusions on this basis.

Eco-efficient transport

For this project it is assumed that eco-efficient transport encompasses all approaches that help to reduce the ecological footprint of transport-related activities. The point of reference should be the amount of resources needed to fulfil a specific purpose (work, social contacts, production or purchase of goods; economic growth, etc.). In the scenarios, however, the focus is on emissions of pollutants/CO_2 as well as on energy consumption/intensity. Other aspects (for example, the toxicity of waste products or the environmental impacts of mining raw materials) are only mentioned briefly in the project. A broader, in-depth analysis including a life cycle assessment (LCA) of the various technologies that are relevant for eco-efficiency would have required a much more resource-consuming project design.

The way eco-efficiency is conceptualised above presents three basic strategies for achieving eco-efficiency in the transport sector:

- Cleaner modes: The individual modes/vehicles can be made cleaner. This involves approaches such as using cleaner fuels and propulsion technologies, lightweight construction, efficient design of vehicles and also soot filters or catalytic converters. Eco-efficient driving (or corresponding training) also belongs to this category.
- Modal shift: The idea is a shift to more efficient modes. This includes, for example, a shift from road to rail or, in the urban passenger sector, a shift from motorised modes to cycling.
- Reduction of transport volumes: This can be done by substituting trips, for example, by tele-working or video-conferencing. Additionally, this can be achieved by reducing the length of trips. The latter approach can be the result of land-use planning leading to a city of short distances (decentralised concentration).

From a user perspective the first strategy means that users and goods continue to employ the same modes, whereas in the second strategy, different modes are employed; in the third strategy users and goods have different points of origin and destinations.

Thus, there definitely is a broad range of available or emerging concepts and technologies that are relevant in the context of eco-efficiency. However, when looking at different studies, policy documents and statements of stakeholders, it becomes obvious that there are different views on the feasibility and desirability of these approaches. One important reason for this variety of opinions is surely that transport is a complex system with many mutual interdependencies between internal and external factors. This leads to a high degree of uncertainty regarding the potentials and the exact impacts of interventions in the system. Technologies and concepts need to be assessed in a broader context; thus, a systemic perspective is required.

In this project a set of scenarios dealing with eco-efficient transport futures were developed for the purpose of better understanding reasons for and assumptions about different assessments regarding the feasibility and desirability of different pathways or policy measures. The scenarios were used to trigger the debate among stakeholders. Furthermore, the scenarios provide a systemic perspective. These scenarios consist of qualitative storylines that are combined with quantitative calculations (with the transport model ASTRA (ASsessment of TRAnsport Strategies)).

It is not possible and it was not intended to deal with the whole range of potential future developments in a project like this. Therefore, the range of possible futures was limited by some general assumptions. Furthermore, the focus is on road, rail and waterborne transport (i.e., excluding aviation). The scenarios focus on three different basic strategies for achieving eco-efficiency:

- scenario I: making transport modes cleaner (while employing the same modes for users/goods),
- scenario II: changing the modal split (employing different modes for users/goods),
- scenario III: reducing growth rates in transport demand (different points of origin/destinations for users/goods).

REF – Reference scenario	External “business-as-usual” scenario used in the project GHG-TransPoRD; allows for easy comparison between the STOA scenarios and calculations made in other projects
AFS – Advanced framework scenario	Clearly optimistic, but not overly extreme, assumptions in relation to developments and technologies supporting eco-efficient transport; the other three scenarios are each implemented within the framework conditions of the AFS (i.e. AFS + Scenario XY).
Scenario I – Cleaner modes	Eco-efficiency of transport modes is pushed by extreme progress in technologies (e.g., energy supply, fuels and propulsion technologies, information and communication technologies (ICT))
Scenario II – Changing the modal split	Eco-efficiency is pushed by a combination of push-and-pull measures aimed at inducing an extreme modal shift
Scenario III – Reducing transport volumes	Eco-efficiency is pushed by a reduction of transport volumes (oil price of € 300 per barrel as a trigger)
“Full scenario”	Combination of all scenarios: AFS + Sc I + Sc II + Sc III

Table 1: Overview of the scenarios for 2050.

All three scenarios are embedded in the same set of general assumptions. These general assumptions are compiled in a so-called “advanced framework scenario” (AFS). Since the STOA panel deals with science and technology options assessment, it was decided to apply a rather optimistic approach regarding technology. Therefore, all scenarios intentionally assume high – sometimes extremely high –

rates of innovation and a very high pace of technological change and diffusion of new technologies in society. Scenarios I, II and III are each added to the AFS (scenario I = AFS + cleaner mode; scenario II = AFS + modal shift; scenario III = AFS + reduced volumes). Additionally, a reference scenario (REF) following a business-as-usual approach was used. An overview of the scenarios is provided in Table 1.

The results from the quantification of the scenarios can be summarised as follows:

AFS: The overall result from this scenario is a significant reduction of CO_2 emissions (tank-to-wheel (TTW), upstream emissions are not considered) even if the modal split, the composition of the car fleet and mobility patterns do not change too much compared to today. Cars remain the most important mode in the passenger sector. The reason is that conventional cars become much more efficient and, therefore, also much cheaper. Nevertheless, CO_2 emissions are significantly reduced, as expected: down 50% until 2050 with respect to the reference case, which means a 38% reduction compared to 1990 (the White Paper of the European Commission sets a target of 60% reduction).

Scenario I: The results show the effects of the extreme technology development in the model simulations. In the year 2050 non-fossil-based fuels and propulsion systems dominate the car fleet. Other modes also become more efficient and, therefore, the CO_2 emissions reduction is substantial: down 75% with respect to the REF. This scenario simulation would meet the White Paper target.

Scenario II: Results of the modelling do not show changes in modal split that are as extreme as was expected. This is at least partly determined by the architecture of the model itself, which sets limits to the amount that can be shifted from the road to other modes. Therefore, the quantitative results of this scenario can be considered a conservative estimate of a mode-shift strategy. Nonetheless, a significant modal shift can be observed. A feebate scheme and high fuel duties eventually prove to be effective in supporting innovative vehicles, even without the additional technological investments assumed in scenario I. This scenario would also meet the White Paper target, as emissions are finally cut by 62% with respect to the level in the year 1990.

Scenario III: In this scenario, the total emission reduction is 73% with respect to the REF and 66% compared to the year 1990. This is mainly achieved by reducing passenger kilometres and tonne kilometres. Neither modal split nor fleet composition changes drastically with respect to the AFS. The reduction in CO_2 emissions is, to a large extent, achieved through the extreme reduction in transport-related energy consumption (93 Mtoe/y compared to 178 Mtoe/y in the AFS and 320 Mtoe/y in the REF).

"Full scenario": As expected, this is the most effective scenario. The simulations result in almost 80% less emissions than in the REF case, and nearly three quarters of the CO_2 tonnes are saved with respect to the year 1990. Also as expected, even this remarkable result is much less than the sum of the single scenarios, because some of the measures cancel one another out.

All three scenarios are able to reach the White Paper targets on CO_2 emissions but this is achieved in very different ways. Scenario I strongly relies on technologies. In scenario II cleaner technologies also play a significant role, but not as important a role as in scenario I; instead, modal shift is pushed strongly. Thus, in contrast to scenario I, changes that directly affect travel patterns are induced to a certain extent. Compared to the REF, other modes of transport have to be employed for goods and for passengers. Scenario II appears to be more flexible and "robust" compared to the first scenario, since there is greater variability in the choice of assumptions and measures. However, in both scenarios the reduction in CO_2 emissions depends heavily on developments in the energy sector. The provision of "clean" energy is crucial for the overall eco-efficiency.

Scenario III is of a very different character: here many parameters are similar to the AFS, but the demand for transport is heavily reduced. There is not very much focus on technological progress apart from the general optimistic assumptions about technological developments in the AFS. The reduction in CO_2 emissions is, to a large extent, achieved through the extreme reduction in transport-related energy consumption. Thus, the "success" of this scenario is not particularly dependent on developments in the energy sector. However, just reducing volumes would be a much too simplistic approach and not in line with the concept of eco-efficiency as it was applied in this project. Eco-efficient approaches are understood as gaining access to a specific activity/purpose (working, shopping, recreation, etc.) with a smaller ecological footprint. Economic wealth and the general quality of life should explicitly not be reduced. Thus, the desirability and acceptability of the scenario can be questioned, since the impacts on economic wealth and quality of life are difficult to assess and might also be rather negative. The crucial question that is revealed by this scenario is the extent to which transport can be avoided without endangering other societal goals. Some of the measures in this scenario illustrate how this might become feasible.

Stakeholder consultation

The stakeholder consultation was carried out in two steps:

- a survey was conducted to collect opinions related to feasibility and desirability and
- a workshop was carried out, which used the results of the survey to focus and to trigger debate.

The stakeholders invited were mainly organisations from the transport area based in Brussels, and the workshop was held in Brussels. For the survey, 14 theses on potential future developments in the transport sector were developed. The 14 theses can be allocated to the three scenarios. For each of the theses, questions related to feasibility and desirability were developed.

Some of the interesting findings that originated with the stakeholder consultation were the emphasis on looking beyond the technological scope in order to move towards a more eco-efficient transport system in Europe. At the workshop the stakeholders were asked which scenarios they found most attractive and realistic. There was overall agreement on focusing on core elements in scenario II as the most robust scenario – in combination with mobility elements in scenario III. In the discussion, it was more or less taken for granted that the technical developments sketched in scenario I would be realised in the mid to long term; these technical approaches were understood as something that is needed anyway to cope with future challenges. However, the elements and approaches described in scenario II were also needed, according to the stakeholders. In addition, many stakeholders emphasised the need for a mobility management that tries to actively influence the number, length and distribution of trips. In other words: technologies were understood as a necessary, but not as a sufficient requirement for a transition to an eco-efficient transport system. Many saw mobility management based on information and communication technologies (ICT) as an opportunity to achieve more eco-efficient transport, as it could help in integrating different transport modes and making the use of these modes more effective. They felt that an eco-efficient development in transport required that the individual citizens change their transport behaviour. The stakeholders/respondents stressed that a massive investment in public transport was needed in order to achieve this development. The general message was that incentives are needed in order to change people's transport behaviour.

It was said that the EU needed to focus more on the implementation of the EU strategies on eco-efficient transport and on finding ways to encourage implementation at the member state level. At the workshop it was addressed that there is a gap between policy and reality. It was not only at the European level that uncoordinated institutional actions/responsibilities hinder a more eco-efficient transport; at the level of member states the lack of coordination between different operators of public transport has also led to a public transport system that is not easy to use, flexible, convenient, or accessible. This is supported by the results of the survey: uncoordinated action and a lack of political vision were mentioned quite often as obstructive factors. Further, there was agreement about a lack of coordinated/comparable data on transport at a European level, which hinders comparison, common debates and initiatives. This lack of data also dominates in regard to knowledge of consumer behaviour and preferences. It can be concluded that corresponding research is needed for the successful design of policy measures supporting eco-efficient transport.[2]

As a supplement to the project, the survey was also filled out by 35 transport-related scientists. These results are, of course, not relevant to the stakeholder consultation (scientists are not stakeholders). However, it is a good point of reference for further discussion of the results of the project, and it helps in identifying and specifying crucial research questions.

Based on the screening for innovative approaches potentially supporting eco-efficient transport (cf. deliverable 2), based on the scenarios (cf. deliverable 3) and based on the stakeholder consultation (cf. deliverable 4), a number of key areas have been identified by the project team. These key areas are regarded as crucial for a transition to a more eco-efficient transport system. The following key areas were selected:

- Energy system
- Cleaner cars
- Cleaner trucks
- Smart logistics
- Automation
- Integrated ticketing
- Access instead of ownership
- Shift to rail
- Shift to short sea and inland shipping
- Awareness of/making use of habit and attitude changes
- Urban design
- Mobility pricing

Thus, it can be concluded that the stakeholders considered scenario II to be the most promising. The development of alternative fuels and propulsion technologies was considered to be desirable and also feasible. However, since this is not enough, the modal shift approach of scenario II is also important for robust strategies towards achieving more eco-efficient transport. There was also broad consensus that a shift to rail is desirable, but the feasibility was assessed as rather low by several participants. Furthermore, several stakeholders argued that other measures from scenario II were also needed, and there was a broad consensus that mobility management is crucial. However, there were definitely different opinions among stakeholders on how mobility management might look. One of the main controversies emerged regarding measures restricting car transport in urban areas. This was mainly

[2] see STOA (2012) as an example of such an approach

triggered by thesis 3, on zero-emission zones, as well as by thesis 6, which assumes a modal share of 75% for non-car-based modes in urban areas in 2050. A majority welcomed these approaches but there were very critical voices as well, pointing out negative consequences for accessibility and for the economy. Controversial opinions related to desirability and impacts were also characteristic for thesis 7, on the road-charging system. It can thus be concluded that there was a broad consensus on the need for mobility management, but there was no clear consensus on how it should be applied.

A range of more general conclusions can be drawn for the scenarios and the stakeholder consultation:

- Basic research: there definitely is a need to push forward the development of technologies. For example, basic research is needed regarding the development of technologies for mobile energy storage as well as new options for generating biofuels. The commercialisation of alternative fuels and propulsion technologies was assessed as desirable in the stakeholder consultation.

- Regarding technologies, more attention should be paid to the development and application of ICT. There is huge potential to further improve eco-efficiency with the support of ICT. It is an extremely dynamic area. The potentials in this field are far from being fully tapped. ICT can be an enabler for new businesses and more flexible mobility patterns, but also for electric mobility.

- In order to assess eco-efficiency, systemic perspectives are needed. There is a need for LCA, in order to assess the full ecological footprint of individual technologies or approaches. But systemic perspectives that assess the relevance and impacts of approaches in a broader context are also needed. For example, an assessment of new energy carriers needs to also take into account their potential role in the energy system. The linkages between different technology fields need to be addressed. This could mean developing cross-cutting roadmaps that cover development in the energy, transport and ICT sectors.

- The scenarios and the stakeholder consultation illustrate that many developments are impeded because of uncoordinated political actions and a lack of political visions. It was underpinned that in many cases, it is non-technical factors that hamper the success of eco-efficient transport. A striking example is the shift to rail, which was assessed by the stakeholders as highly desirable but hard to realise. Harmonised standards and regulations are needed in various fields.

- One highly crucial issue for optimising transport in the long term is a better integration of land-use planning and transport planning. It was highlighted in the key area on "urban design" that this is particularly true for urban agglomerations.

- Furthermore, it was highlighted several times that there is a need to better understand the customers/users of the transport system. There was a broad consensus at the stakeholder consultation that the measures of the scenarios do not suffice. This means that, to a certain extent, behavioural changes will be needed to achieve sustainable transport. It was illustrated in one of the key areas that mobility patterns and related preferences and attitudes are not static but display dynamics. It is crucial to more effectively take these dynamics into account in scenarios on the future of European transport, but they also need to be more effectively taken into account as part of transport policy strategies. A basis for that could be provided by more research on the dynamics of users and customers' transport-related perceptions and attitudes.

Last but not least, it should be emphasised that new and emerging technologies need to be taken into account: thus, foresight processes accompanied by technology assessment are needed in order to scan the development of new and emerging technologies and concepts, particularly when they have the potential to become relevant on a systemic level. There is definitely a need for further science and technology options assessment within the field of transport and beyond.

Contents

General information

An affordable, efficient and clean transport system is a basic pillar for economic growth and the quality of life in European countries. However, transport is still accompanied by a broad range of negative impacts on human health and the environment. It is still using huge amounts of finite resource; congestion is increasingly hampering the efficiency of the system. Transport volumes are expected to further grow in future. So, a transition to a more eco-efficient transport system is needed to cope with recent challenges and anticipated future developments in the transport sector. Against this background, the STOA Project "Eco-Efficient Transport Futures for Europe" aimed at highlighting and assessing the potentials of already established, emerging, and rather visionary technologies and concepts that can lead to a more eco-efficient transport system. To allow the required systemic perspective, the assessment was supported by scenario building. The feasibility and desirability of the scenarios and their elements was the subject of a stakeholder consultation.

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1. Introduction

1.1. A need for governance and research

The transport sector faces a dilemma. On the one hand, it aims to ensure efficient, safe, and affordable mobility for people and goods and, thus, to enable freedom of movement and trade; on the other hand, it has to deal with negative externalities. Besides concerns about the sector's dependence on oil, there are worries about the impact of transport on climate change and about problems related to traffic congestion, noise, pollution, and health hazards. These externalities incur high costs and they become increasingly subject of public debates and policy actions. The recently published White Paper on Transport also emphasises that greater efforts are needed: "A reduction of at least 60% of GHG by 2050 with respect to 1990 is required from the transport sector, which is a significant and still-growing source of GHGs. By 2030, the goal for transport will be to reduce GHG emissions by around 20% from their 2008 level. Given the substantial increase in transport emissions over the past two decades, this would still put them 8% above the 1990 level."[3] This will require significant efforts related to all modes of transport. One of the key challenges outlined in the 2011 White Paper "is to break the transport system's dependence on oil without sacrificing its efficiency and compromising mobility."[4]

At present, most vehicles on European roads still operate on the basis of internal combustion engines (ICE), mainly using gasoline or diesel oil. Almost 72% of the total oil product deliveries to the EU are consumed by the transport sector, which is accordingly the largest consumer of oil products in the EU. Today, transport relies almost entirely on oil; in 2006, almost 97% of the energy used in the EU-27 (i.e. including data from all present members of the EU, regardless of when they became members) for transport (including all modes) was based on petroleum products. Only 1.7% of the energy came from electricity, 1.5% from renewables and 0.2% from natural gas.[5] The transport sector's share of the final energy consumption was around one third (31.5%), gone up from 26.3% in 1990. The main contributors to this increase have been growing freight and passenger vehicle fleets and a strong rise in air transport. Road transport is the most energy-consuming mode of transport, while aviation shows the fastest growth rates. 82% of the total energy used in transport can be attributed to road transport.[6] Passenger cars account for 55.9% and trucks for 39.4% of the total energy consumption in road transport.[7]

GHG emissions in the transport sector continue to grow, while they are decreasing in other sectors. In 2006, the transport sector in the EU-27 accounted for around 23% of carbon-dioxide (CO_2) emissions and is thus the second largest emitter of CO_2 (after the energy industry).[8] The transport sector is the only sector that has not shown reductions in emissions. During the period from 1990 to 2006, it actually showed average annual growth rates of 1.5%[9] and thus cancelled out the reductions of emissions in all other end-use sectors.[10]

[3] CEC (2011a), p. 3.

[4] CEC (2011a), p. 5.

[5] See Eurostat (2009).

[6] See Eurostat (2009).

[7] See CEC (2008).

[8] See Eurostat (2009).

[9] See Eurostat (2009).

[10] See CEC; DG Energy and Transport (2008).

Continuously increasing growth rates in the transport sector are a substantial driver behind the increases in energy consumption and GHG emissions. According to the International Transport Forum (ITF), air transport, international maritime transport, and road freight transport are showing particularly substantial growth rates while passenger transport is increasingly showing saturation.[11] However, statistics show that in Europe — apart from the period of the economic downturn in 2008 and 2009 — both passenger and freight transport have shown constant growth rates over the past decades. Between 1995 and 2009, the GDP grew annually by 1.8%, while passenger transport grew by an average of 1.4% and freight transport by 1.2%. In a document related to the 2011 White Paper on transport the Commission assumes: "Without policy change, total transport activity is expected to continue growing in line with economic activity. Freight transport activity is projected to increase, with respect to 2005, by around 40% in 2030 and by little over 80% by 2050"[12].

When looking at these recent and anticipated challenges of the transport system, it becomes obvious that more eco-efficiency is needed to cope with these challenges: There is a need to increase awareness for these challenges and for potential solutions, and there is a need for governance and research activities aiming at increasing eco-efficiency in the transport sector. Action is needed to attenuate transports impacts on the environment and on human health.

Furthermore, increasing the eco-efficiency is often related to the commercialisation and market penetration of innovative technologies and concepts. There is a relation between eco-efficiency, innovations, and the global competitiveness of European economies.[13] The relation between competitiveness and innovations is emphasised in the 2011 White Paper on transport and it is, of course, deeply embedded in the EU framework programme for research and innovation that is named "Horizon 2020".

1.2. Conceptualisation of eco-efficient transport

Many concepts or technologies supporting eco-efficient transport can be found in literature. According to the World Business Council for Sustainable Development (WBCSD), which initially coined the term in 1992, eco-efficiency is primarily a business approach and a way that businesses can contribute to sustainable development. It can be achieved through the delivery of goods and services that satisfy human needs and bring quality of life, while at the same time reducing ecological impacts (such as waste and pollution). In other words, the WBCSD objective is to create more goods and services with less impact.[14] Similarly, the European Environmental Agency (EEA) understands eco-efficiency as "a concept and strategy enabling sufficient de-linking of the use of nature from economic activity, needed to meet human needs *(welfare)*, to keep it within carrying capacities; and to allow equitable access to, and use of the environment, by current and future generations."[15] Even though both conceptions of eco-efficiency are quite similar, the WBCSD places a stronger focus on eco-efficiency as a technical challenge, where solutions need to be found in technological and scientific innovations in order to gain competitive advantage. The EEA understands eco-efficiency as a necessary, though not sufficient, condition for achieving sustainability and more strongly emphasises

[11] See International Transport Forum (ITF) (2008).

[12] CEC (2011f), p. 12.

[13] See Beise & Rennings (2005).

[14] See WBCSD (2000).

[15] EEA (1999), p. 4.

that behavioural changes leading to absolute reductions in transport volumes are needed to achieve a sustainable transport system. However, both definitions are applying a rather broad perspective by using economic growth and the quality of life or welfare as a point of reference (which goes beyond the pure resources input per person kilometre / tonne kilometre). This broader conceptualisation will be used as a basis in this project.

In this project, we assume that eco-efficient transport encompasses all approaches that help to reduce the ecological footprint of transport-related activities. Eco-efficient transport is understood in a broader sense

- By using economic growth and the quality of life (welfare) as a point of reference (one which goes beyond the pure resources input per person per kilometre / per metric ton per kilometre).
- By focussing not only on technologies but also on organisational measures and behavioural changes.

In principle, three basic strategies can be applied to increase the eco-efficiency of the transport system:[16]

- Cleaner modes: The individual modes/vehicles can be made cleaner. This involves approaches such as cleaner fuels and propulsion technologies, lightweight construction, and also soot filters or catalytic converters.
- Modal shift: The idea is to shift trips to more efficient modes. This includes, for example, a shift from road to rail or, in the urban passenger sector, a shift from motorised modes to cycling.
- Reduced volumes: The reduction of trip lengths and the avoidance of trips fall into this category. This can be the consequence of a virtualisation of activities: Tele-working offers a prominent example. It can also be the result of land-use planning strategies that try to avoid extreme suburbanisation processes and instead promote the city of short distances (decentralised concentration).

These strategies have different implications for user behaviour. The first strategy can be realised without any significant changes for the users. It is basically about substituting existing technologies by cleaner ones but in most cases the mode of transport as well as the origins and destinations remains unchanged. Of course, users have to buy and use cars with new technologies or they have to learn and get used to an eco-efficient style of driving. But all that does not necessarily change the modal spilt, number of trips, or transport volumes.

The second and the third group of measures definitely mean a change in mode, in purpose, or in destination. This measures lead to a change in transport volumes and/or in modal shift. Many studies show that the first strategy does not suffice to achieve far-reaching eco-efficiency. For example, Skinner et al. (2010) illustrate that by applying technological measures only half of the CO_2 reductions the EU aims to reduce can be achieved until 2050. Further reductions make changes in modal share and transport volumes inevitable.

Moreover, the three strategies (cleaner technologies, modal shift, reduced volumes) do not only touch upon the modal choice and choice of destination of users but as well on users' and stakeholders' political support for or against certain planning strategies. For example, building infrastructures for public transport or achieving a city of short distances are long-term projects that need political, and

[16] See STOA (2008).

thus, public commitment. More generally spoken, users and stakeholders contribute to the formation of public opinion in elections and elsewhere which is often formative for activities on a political level: "Public acceptability drives political acceptability and it is only when there is sufficient public support for change that action will take place"[17].

So, to assess the potentials of technological and organisational approaches for increasing the eco-efficiency of the transport system, a broader, systemic perspective is needed. The transport system as whole with its technologies, actors, institutions and customers needs to be taken into account for understanding barriers and success factors of different pathways towards eco-efficiency.

1.3. Objectives and approaches

Against this background, the STOA Project "Eco-Efficient Transport Futures for Europe" aimed at highlighting and assessing the potentials of already established, emerging, and rather visionary technologies and concepts that can lead to a more eco-efficient transport system. To allow the required systemic perspective, the assessment was supported by scenario building. The feasibility and desirability of the scenarios and their elements was the subject of a stakeholder consultation.

The project was organised along the following structure:

- Deliverable 1 encompasses a scoping of the field and a conceptualisation of eco-efficiency in the transport sector (see section 1.2 of the report at hand)
- Deliverable 2 provides an overview on technological and organisational innovations in the field accompanied by some stakeholder statements on the pros and cons of these innovations (see section 2)
- Deliverable 3 illustrates scenarios for eco-efficient transport futures that were developed in this project (see section 3)
- Deliverable 4 summarises the findings of the stakeholder consultation on the desirability and feasibility of the scenarios and on their elements (see section 4)
- Deliverable 5 is the final report that summarises the previous phases of the project and draws conclusions on that basis (see sections 5 and 6).

In deliverable 1 of the project the concept for eco-efficiency is introduced. Deliverable 2 illustrates that a huge variety in technologies and concepts do exist that have the potential to contribute to eco-efficiency. It is also indicated that an assessment of a specific approach's ecological footprint can be difficult to perform. Actually, a LCA would have been needed for each single technology. As far as possible and useful LCA-related results were indicated in deliverable 2 (for example for battery electric vehicles (BEVs)). In the scenarios, however, the focus is on emissions of pollutants/CO_2 as well as on energy consumption and on energy intensity. Other aspects (for example the toxicity of waste products or environmental impacts of the mining of raw materials) are only mentioned briefly. A broader in-depth analysis, including LCA, of the various technologies that are relevant for eco-efficiency would have needed a much more resource consuming project design.

The project shows that there is definitely a broad range of concepts and of technologies available or emerging that are relevant in the context of eco-efficiency. However, different assessments of the potential impacts of these approaches on eco-efficiency exist. When looking at different studies, policy documents and statements of stakeholders it becomes obvious that there are different views on the feasibility and desirability of these approaches. An important reason for this variety of opinions is that

[17] Banister (2008), p. 76.

transport is a complex system with many mutual interdependencies amongst factors in the system and external factors. This leads to a high degree of uncertainty regarding the potentials and the exact impacts of interventions in the system. Technologies and concepts need to be assessed in a broader context, thus, a systemic perspective is required.

In this project, a set of scenarios on eco-efficient transport futures were developed with the purpose to better understand reasons and assumptions for the different assessments on the feasibility and desirability of different pathways or policy measures. The scenarios were used to trigger the debate with stakeholders. Furthermore, the scenarios provide a systemic perspective. These scenarios consist of qualitative storylines that are combined with quantitative calculation (with the transport model ASTRA).

The stakeholder consultation was carried out in two steps:

- A survey was conducted to collect opinions related to feasibility and desirability
- A workshop was carried out. The results of the survey were used to focus and trigger the debate in the workshop.

The invited stakeholders were mainly organisations based in Brussels in the transport area and the workshop was held in Brussels. For the survey, 14 theses on potential future developments in the transport sector were developed. The 14 theses can be allocated to the three scenarios. Each thesis was accompanied by questions regarding the feasibility and the desirability of this development.

Based on the screening of innovative approaches that are potentially supporting eco-efficient transport (DEL 2), based on the scenario (DEL3) and based on the stakeholder consultation (DEL 4) a number of key areas were identified by the project team. These key-areas are regarded as being crucial for a transition to a more eco-efficient transport system. The key-areas are described in section 5. Further conclusions are drawn in section 6.

2. Technologies and concepts for eco-efficient transport

Deliverable 2 of the project provides an overview on technologies and concepts supporting eco-efficiency in the transport sector. The content is briefly summarised here.

Fuels and propulsion technologies are one of the most important approaches for eco-efficiency of the transport system. A broad range of rather different approaches exist. It becomes obvious that the eco-efficiency of all the alternatives to oil-based fuels is strongly dependent on other developments in the energy sector. Biomass can be used in stationary as well as in mobile applications; the same is true for hydrogen, and, of course, also for electricity and natural gas. For electric engines the most open questions – in terms of eco-efficiency - are related to the production of electricity or hydrogen as well as to the integration of these production pathways into the energy system. Thus, the integrated perspective on the transport and the energy system is becoming highly relevant.

It can be observed that more and more car manufacturers start the commercialisation of BEVs. Weak points compared to the conventional ICE are the low ranges, whereas the lower energy density is not expected to be improved too quickly. Furthermore, there are longer charging times, higher prices as well as open questions concerning reliability. This needs to be balanced by higher efficiency, lower energy cost per kilometre and, thus, by beneficial total cost of ownership. In terms of eco-efficiency, the whole life cycle needs to be considered. Assessments show, that the environmental impact of both BEV and ICE is dominated by the operation phase. Electric propulsion also plays a role in many hybrid concepts.

Cars with hydrogen and fuel cell (FC) technology use an electric engine for propulsion. Prototypes are tested in pilot projects, ranges around 400 km are possible, commercialisation seems to be close. However, the crucial issue is how the hydrogen is produced. The route via electrolyses allows for a high flexibility in terms of feedstock; for example wind power or photovoltaic can also be used. But this means that electricity is used to produce hydrogen and then, in the car, hydrogen is used to produce electricity again. This process is leading to considerable losses in usable energy. Some observers argue that BEVs could be used for shorter distances and hydrogen cars with FCs could be used for longer distances. Because of low energy density and low storage capacities both batteries and hydrogen are not suitable for trucking and aviation. For these modes, biofuels are an alternative. However, biomass as feedstock is critically discussed for several reasons, amongst them competition with food production and the direct or indirect land use changes (e.g. deforestation). Other options are gaseous fuels such as natural gas. Its main component, methane, could also be produced by alternative methods on the basis of renewable feedstock. Again it is crucial to consider the energy balance carefully.

Further, there are different approaches for improving vehicles and infrastructures. In particular lightweight materials are getting increasingly important. Improved aerodynamics for trucks can bring significant benefits for eco-efficiency. Also for trains, approaches to improve eco-efficiency are discussed. In aviation, the so-called flying wing is discussed as completely new and more energy efficient design of aircrafts. Eco-efficiency in maritime shipping is subject of an extra deliverable (2b) of the project.

The second highly important technological strand are the developments related to the progress of ICT in the transport system. Such applications are often subsumed under the title Intelligent Transportation System (ITS). Deliverable 2 highlights that ICT is playing an increasingly crucial role for the transport system, and many of these applications have the potential to improve the eco-efficiency of the system. This can be done by reducing the need to travel (reducing volumes) or by increasing the competitiveness of more efficient modes or vehicles. ICT can improve the availability of information on public transport; it can facilitate the access to public transport with handy ticketing or integrated ticketing; it enables advanced car-sharing or bike-sharing services; it can support a more efficient use of infrastructures; it can substitute travel by enabling tele-working or video conferencing. However, the overall effects of these approaches are difficult to assess since it is also possible that so-called rebound effects occur: ICT-based applications might generate additional trips when capacities are enlarged or when travelling becomes easier and more enjoyable.

In the freight sector, a great impact is expected from progress in ICT applications. ICT plays a major role for the continuous and immediate exchange of information, tracking and tracing of goods, in enabling new concepts for production and services, for performances on time aspects and in determining shipment sizes. It helps to increase the reliability of transport chains. Increasing the load factors is a crucial issue. The capacity of transportation systems can be made more efficient by an integrated use of ITS. As it is the case for passenger transport, ICT might increase the transport distances. Four key areas for ITS in freight transport can be subdivided: pre- and on-trip travel information, cargo and vehicles tracking and tracing, cooperative systems and advanced urban logistics.

Deliverable 2 further illustrates that organisational innovations are strongly enabled by progress in the ICT sector. Organisational innovations have the potential to improve the efficiency of mobility patterns by making them cleaner (e.g. better load factors, more efficient usage of infrastructure), they help to shift loads (e.g. by making public transport and freight rail more attractive) and they can help to reduce volumes (e.g. tele-working; video-conferencing). Prominent examples are carsharing and bike sharing schemes. It can be assumed that both approaches would not have such significant growth rates in several European countries without sophisticated ICT applications that allow for easy booking, easy access and easy charging. It is interesting to observe that several car manufacturers recently started to test own approaches that are similar to carsharing. One reason for these surely is, that the younger generation, in particular in urban areas, seems to be less interested in ownership than the generation before.[18] Again it is difficult to quantify the effects of car sharing or bike sharing on eco-efficiency. In general, car sharing fleets have smaller cars than the average fleets in a country and the organisations themselves usually claim to use eco-efficient vehicles. Furthermore, car sharing is seen as a good concept for introducing alternative fuels and propulsion technologies into the market, since customers would be enabled to choose a specific car for a specific purpose. However, for these approaches it should not be overseen that they can also induce traffic or rebound effects.

Organisational innovations offer interesting potentials for the air sector. Regarding passenger air transport, an important issue is a better organisation of traffic flows at airports. Furthermore, a rather efficient way of reducing energy consumption and emissions is to use slower aircraft configurations. In the freight sector, organisational approaches offer interesting potentials for reducing CO_2-emissions. Again, many of these measures are strongly linked to ICT applications as a kind of enabling technology. Another promising approach is the delivery of goods at night with relatively quiet electric engines. A different example is using a tram for goods transport as it is done by the freight tramcar in Dresden, Germany.

These technological and organisational approaches are embedded into the scenarios described in section 3.

[18] See STOA 2012b

3. Scenarios

There definitely is a high degree of uncertainty with regard to the potential future development in complex socio-technical systems such as the transport system.[19] External factors such as oil prices or economic growth and also upcoming technical and organisational innovations can have far-reaching impacts on transport and transport related behaviour. Furthermore, societal preferences and attitudes also change over time. Recently, it can be observed that a growing group of younger adults in urban areas is losing interest in car transport.[20]

Scenarios are a meaningful and often used tool to cope with this high degree of uncertainty. In particular in the transport sector, scenarios are used to assess future developments and potential impacts of policy.[21] They help to analyse potential linkages between different factors in the system. Further, working with scenarios can help to obtain clarity on the plausibility and desirability of developments of different stakeholders' perspectives. In this project the scenarios illustrate the potential impacts of the technical and organisational innovations described in DEL 2 of the project in combination with different policy strategies. Furthermore, the scenarios and their elements were used to trigger the debate with stakeholders (see section 4).

The scenarios are described in this section. In doing so, in the section:

- The methodology for developing the scenarios will be explained
- General framework conditions will be explained
- Descriptions of the scenarios in form of storylines and quantifications with the ASTRA model will be provided
- Comparative discussions of the scenarios will be carried out

A brief description of the ASTRA model is provided in the text box on the next page.

[19] See Schippl & Fleischer (2012); Geels, Kemp, Dudley & Lyons (2011).

[20] See STOA (2012b).

[21] See e.g. Schade & Krail (2012); Skinner et al. (2010); Petersen et al. (2009); STOA (2008).

Brief description of the ASTRA model

ASTRA is the acronym for 'ASsessment of TRAnsport Strategies'. The model was developed in the context of the 4th Framework Programme of the European Commission. In the subsequent framework programmes it has continuously been further developed and improved. It is already in use in several European projects.[22]

The tool was designed with the objective to visualize the impact of long-term European transport policy strategies. It is able to take into account possible political, technical and socio-economic framework settings for the future and to draw conclusions on respective systemic effects (e.g. regarding transport, technology, economy, and environment) on a European scale. This allows for the elaboration of 'strategic policy assessments' with a long-term perspective for stakeholders[23].

The main advantage of ASTRA is the possibility to consider feedbacks in interacting systems (such as the economic and transport systems) on a wide scale (EU) and in a long-term horizon. In order to simulate 'real world' interactions, a system dynamics methodology was chosen.[24] The model offers a solution to make different scenario assumptions, which also follow different socio-economic approaches, leading to coherent model results. The transport module, in particular, provides the possibility to take into account a set of framework changes such as new breakthrough technologies or new regulations.

Possible technology or policy measures can be modelled by ASTRA in different ways: If measures "change directly some elements within the model domain"[25], they can be modelled directly; if measures "change something outside the model domain"[26], this is modelled indirectly by estimating effects on model parameters. For example, in the 'real world' the implementation of a technological innovation may require research and development (R&D) investments and may influence the costs of vehicles and lead to more efficient fuel consumption of these vehicles. In ASTRA, this would be modelled by changing fuel/energy consumption factors (and CO_2 emission factors) of vehicles, by changing vehicle costs, and by considering the R&D investment costs[27]; the diffusion of the innovation would then be calculated endogenously by the model.

Note: A more detailed description of the ASTRA model can be found in Deliverable 3 and at http://www.astra-model.eu/index.htm

3.1. Behind the scenarios: concepts, methods and the reference scenario

As mentioned above, over the last years, a broad range of scenarios on sustainable transport futures for Europe have been designed that provide an integrative perspective on potential developments in the transport sector. Other prospective activities (e.g. roadmaps, impact assessments) focus on segments or specific measures in the transport sector. They all illustrate that there are pathways for achieving targets such as a reduction in CO_2 emissions or a reduced consumption of fossil fuels. Also the Commission's 2011 White Paper sets clear targets and lists key activities on how to reach them. But these future-oriented activities also illustrate that there are different views on the feasibility and desirability of the various measures and pathways. An important reason for this variety of opinions surely is that transport is a complex system with many mutual interdependencies between internal and external factors. This leads to a high degree of uncertainty regarding the potentials and the exact

[22] See http://www.astra-model.eu/index.htm

[23] Fiorello et al., 2008, p.3f

[24] See Schade (2005).

[25] Fiorello & Krail, (2011), p. 5.

[26] Fiorello & Krail, (2011), p. 5.

[27] Fiorello & Krail, (2011), p. 7.

impacts of interventions in the system. Changes in the transport system are often triggered by technological progress, but there are different views on the potentials and impacts of certain technologies such as batteries, fuels cells, or the automation of car transport. Whether a measure or pathway is considered as being likely or desirable quite often depends on the assumptions used for the calculation of a scenario or an impact assessment. Thus, it is important to make these assumptions transparent and understandable.

In this project, a set of scenarios on eco-efficient transport futures are developed with the purpose to better understand reasons for and assumptions regarding the different assessments referring to the feasibility and desirability of different pathways or policy measures. These draft scenarios consist of qualitative storylines that are combined with quantitative calculations (with the transport model ASTRA).

Within the scenarios the following basic principles are applied:

- It is not possible and it was not intended to deal with the whole range of potential future developments in a project like this. Therefore, the scope of possible futures is limited by some general assumptions (see section 3.2). Further, the focus is on road, rail, and waterborne transport (aviation excluded).
- **Eco-efficient transport** is understood as getting access to a certain place related to an activity/purpose (working, shopping, recreation, etc.) with a smaller ecological footprint (see section 1).
- The three scenarios focus on **three different basic strategies** for achieving eco-efficiency:
    - Scenario I: **Making transport modes cleaner** (users/goods use the same modes)
    - Scenario II: **Changing the modal split** (users/goods use different modes)
    - Scenario III: **Reducing growth rates in transport demand** (users/goods have different origins/destinations)

Each of the three scenarios puts the main focus on one of these three strategies.

All three scenarios are embedded in the same set of general assumptions. These general assumptions are summarised in a so-called "Advanced framework scenario" (AFS).[28] This AFS is described in section 3.2.

Table 2 provides an overview on the main settings of the scenarios.

[28] In previous deliverables of the project it was called "optimistic reference scenario" – the term "optimistic" was omitted because it appeared to have a too strong normative connotation.

	Advanced Framework scenario (AFS)	Scenario I	Scenario II	Scenario III
Main focus on	Technology optimistic approach	Market penetration of cleaner technologies	Shift to more eco-efficient modes	Avoiding and reducing physical transport
Main policy orientation towards	Green new deal	R&D, regulations and incentives	Financing of infrastructures	Fostering virtual mobility and eco-efficient land-use planning
Main technological changes are related to	Various	Fuels & propulsion + vehicles / vessels	Infrastructures	ICT
Consequences for the users	Not many changes in travel patterns	The same modes being used by users and for goods - unchanged travel patterns	A shift to other modes regarding users and goods but origins and destinations basically remaining the same	Origins and/or destinations changing, and in the passenger sector a shift from trips to virtual mobility taking place

Table 2: Overview on the main settings of the scenarios.

For the quantitative modelling of the scenarios the transport model ASTRA[29] was used. As a reference case for the scenarios, it turned out to be meaningful to make use of the reference scenario (REF) developed for the project "GHG TransPoRD". In doing so, it is also possible to relate the STOA scenarios to an "external" reference scenario worked out on a much more resource intensive basis. This project, GHG TransPoRD, is focussed on the GHG-emissions of the transport sector. However, its main assumptions and results are also useful for the project on eco-efficient transport.

A reference scenario usually is a sort of business as usual case where no striking or surprising changes to recent trends are assumed. Generally, it takes into account progress that is envisioned nowadays but it does not assume that visible trends are broken and that challenges will decrease significantly. In the transport sector, this usually means that steady growth in transport volumes is expected, mainly in the freight sector and to a lesser extent also regarding passenger transport. Continuous but only slow technological progress is expected. Also for the modal split no drastic changes are assumed. Consequently, the negative impacts of transport growth are only slightly decoupled from transport growth. Technological progress is not strong enough to offset the negative consequences of transport growth. These general settings for the reference case can be found in various scenarios in similar

[29] See Box at the beginning of chapter 3, deliverable 3 or http://www.astra-model.eu/index.htm

magnitudes.[30] In line with this, the reference case adopted from Schade & Krail shows the following characteristics:[31]

- The assumed growth rate for GDP is 1.7%
- There is a growth in the passenger sector of 0.6% yearly. This means demand is increasing from 6,680 billion passenger kilometres travelled in 2010 to 8,625 passenger kilometres in 2050
- In the freight sector the assumed yearly growth is 1.8% which leads to an increase from 3,699 billion kilometres travelled in 2010 to 7,642 kilometres in 2050.
- Transport related energy consumption is growing from 268 million toe/km to 320 million toe/km (0.4% yearly).
- CO_2 emission (tank-to wheel) are growing from 848 million tonnes/year to 1,047 million tonnes a year (0.5% yearly)

More information on the reference case can be obtained from the GHG TransPoRD deliverable 4.1 that is available online (see http://www.ghg-transpord.eu/ghg-transpord/index.php).

Regarding CO_2, please note the drawback that CO_2 emissions are calculated on a so-called tank-to-wheel (TTW) basis – which is a common method for the calculation of CO_2 emissions. The targets in the Commission's White Paper on transport are also based on a TTW calculation. This methodology is more or less appropriate for conventionally fuelled cars since most of the CO_2 is emitted by combustion in the engine. Regarding BEVs and also hydrogen, the situation is completely different: Most of the CO_2 is emitted when producing the electricity or the hydrogen. Also biofuels can induce large amounts of GHG emissions upstream before the fuel reaches the tank. Accordingly, the positive results are only fully valid on a well-to-tank (WTT) basis if "clean" energy is used for the production of the fuels. However, it goes beyond the scope of this project to have in-depth analysis of the energy mix for different scenarios.[32] In ASTRA, TTW CO_2 emissions of biofuels, BEVs, and FC cars are assumed to be zero. In addition, the modelled figures do not cover the so called "embodied energy" CO_2 emissions from the manufacture of vehicles and from the construction of roads and other components of transport infrastructure.

3.2. Advanced framework scenario - AFS

The three scenarios described in the following sections are all based on a set of "general" assumptions. They are the framework in which the scenarios are embedded. In other words: The measures defined specifically for the scenario I, scenario II, and scenario III are implemented on top of the measures defined for the AFS.

Since the STOA panel deals with science and technology options assessment, it was decided to apply an approach that is rather optimistic about technology. Therefore, all scenarios, in principle, assume high – sometimes extremely high – rates of innovation and a very high pace of technological change and of diffusion of new technologies within society. It is assumed that by 2050 in all scenarios a strong progress in science and technology development will have been made.

[30] See Hill et al. (2012); Skinner et al. (2010); STOA (2008).

[31] See Schade & Krail (2012)

[32] See JRC (2011a) for further information on that.

A moderate growth in GDP is assumed as well as a clear decoupling of passenger growth rates from growth in GDP. For freight transport no visible decoupling is assumed. Consequent investments in R&D and in education lead to progress in various technological fields. "Green markets" become very important for the European economies. European economies are driven by a sort of "Green New Deal" which has become the overarching paradigm for economic activities. Clean technologies bear a key pillar for EU competitiveness ("lead markets" are developing in various fields, even if the concept might fail in some sectors where Europe's progress does not unfold fast enough). Based on this increasingly important linkage between sustainability and competitiveness, it is possible to achieve far reaching societal acceptance for stringent standards and strong incentives for technological progress. Overall income growth with ongoing diversifications is part of the scene. The international diversification of labour continues to grow. A range of further policies are implemented all over Europe aiming at supporting the progress of eco-efficient technologies. Subsidies for renewable energies and related technologies (power lines and storage facilities) are important.

Regarding demographics and lifestyles, higher shares of older people still active are assumed for the future. The number of small households continues to increase. Younger people in urban areas are more flexible in modal choices and open for intermodal transport chains.

With regard to transport policies, a uniform toll system on highways and national roads across Europe is introduced in 2025, presumably earlier. A CO_2 related extra toll for city access ("City Maut") is implemented in every agglomeration larger than 10,000 inhabitants. High oil prices (200 $/b), the road charging schemes, and investments in the rail sector are expected to be in favour of a certain modal shift leading to a lower employment of cars and trucks.

The European energy sector of 2050 is characterised by high oil prices (200 $/barrel) and by high shares in renewable energies. By 2050, a diversified network of fuelling stations has been established in all of the European countries. Conventional fuels as well as electric power, hydrogen and compressed natural gas (CNG) are available. Electric drives (fuelled by batteries and hydrogen) enter the passenger and the urban freight vehicle market. New types of vehicles have gained importance (higher shares in pedelecs, e-bikes, and two-seaters such as the Renault Twizy). Significant progress has been made regarding inexpensive light materials. These materials are highly competitive, widespread, and relevant for all of the modes (mainly for cars and bikes). Vehicles, trains, and vessels profit from that progress in the field of light weight materials.

In the infrastructure sector, significant progress has also been made. The Trans-European Transport Networks (TEN-T) are pushed forwards. Investments in rivers have increased the competitiveness of short see shipping. Borderlines are no longer significant hurdles for rail freight.

Important is particularly the progress and further spreading of ICT that is a crucial enabling technology for the increasing eco-efficiency in the transport sector. ICT has allowed approaches such as "Automated Platooning" on major highways. In urban areas, city logistics become increasingly widespread. In larger agglomerations, most goods are delivered at night with silent electric vehicles (EVs).

<u>Main results:</u>

The overall results expected from this scenario are a significant reduction of CO_2 emissions even if the modal split, the composition of the car fleet, and the mobility patterns will not be changed too much (cf. Table 3).

In the simulations, the car fleet is still dominated by gasoline (51%) and diesel fuelled vehicles (30%). But efficiency has strongly increased. In 2050 cars remain the most important mode in the passenger sector. Modal shares of cars increase with respect to the reference case despite of road charging and policies in favour of the rail. The reason for this is that conventional cars have become much more efficient and, therefore, also much cheaper. The savings on the fuel consumption override the higher fuel prices and the additional tolls. Also the "slight" support of rail does not show effects since bus transport also benefits from more efficient engines (trains also become less consuming – see energy transport intensity –, but the impact of energy cost on passenger train fares is minor).

Nevertheless, as expected, CO_2 emissions (TTW upstream emissions are not considered) are reduced significantly: by 50% in the year 2050 with respect to the reference case. Compared to the transport emissions in the year 1990, this means a 38% reduction (the White Paper of the European Commission sets a target of a 60% reduction, so, this scenario would obtain good results but not good enough ones).

Innovative cars enter the fleet in a limited fashion as expected in the scenario definition. It is noticeable that fuel duty revenues are more than halved due to lower consumptions, and toll revenues are incapable of offsetting this dramatic loss.

- Passenger transport demand: 9.153 billion pkm; +6% compared to REF
- Modal share passenger: car 69%; bus 7%; train 7%; air 12%; slow 4%
- Freight transport demand: 7.757 billion tonnes-km; +2% compared to REF
- Modal share freight: road freight 57%; rail freight 17%; maritime 27%
- Transport related energy consumption: 178 million toe/year; −45% compared to REF
- CO_2 transport emission tank to wheel: 520 million tonnes/year; −50% compared to REF; −38% compared to the 1990 index
- Car fleet: gasoline 51%; diesel 30%; CNG 2%; LPG 1%; hybrid 7%; electric 1%; biofuels 3%; FC 4%
- Car fuels consumption: 102 million toe/year; −41% compared to REF

Table 3: Key data for the AFS (2050).

3.3. Scenario I: Focus on making transport modes cleaner

The main focus of this scenario is on making the different modes much cleaner. The process is accompanied by further progress in the field of energy systems. Political strategies focus on heavy public funding of R&D activities as well as on regulations pushing forward the market penetration of new technologies. This does not lead to significant changes in transport behaviour. Users do not switch to other modes; eco-efficiency is improved because the modes they are using are cleaner and require less resources.

Policy measures take advantage of the broad societal and political acceptance for the implementation of stringent standards and strong incentives for technological progress. CO_2 taxes are implemented for all transport modes. The market penetration of most efficient technologies is pushed by subsidies.

There is a feebate scheme reducing the price of innovative vehicles and increasing the price of less efficient ones. Speed limits are established all over Europe, and only zero-emission vehicles (on a well-to-wheel (WTW) basis) are allowed in European cities of more than 100,000 inhabitants.

Extreme progress in mobile and stationary battery technology as well as in hydrogen applications builds the basis for the transformation of the energy system. Innovative cars and trucks gain considerable market shares. The car fleet runs on non-fossil fuels and propulsion systems; fossil fuels have been banned completely in the car sector after 2040.

Further, there is a far-reaching electrification of vehicles in public transport (trolleys, taxis, railways, hydrogen busses). The share of rail electrification is above 80% in all EU countries. CNG, bio-methane, "wind-gas", or hydrogen is used for heavy duty vehicles (HDVs). Vessels' efficiency is increased and they use considerable amounts of liquefied natural gas (LNG). Further, there have been magnificent breakthroughs regarding ultra-light, robust, cheap, and recyclable materials that can be used for the construction of vehicles/vessels/trains.

Small and light cars have become widespread in urban areas; they are the typical vehicles of retired people. The option of letting the car drive autonomously at lower speeds is widely used by this group and enables them to still drive at an older age.

Main Results

As part of this "cleaner modes" scenario a large amount of innovative cars in the fleet as well as cleaner trucks are expected. High fuel taxes should help to counterbalance the rebound effect on road transport demand.

The results show the effects of the extreme technology development in the model simulations (cf. Table 4). In the year 2050 non-fossil based fuels and propulsion systems dominate the car fleet. It can be seen that the accelerating upsurge of electric cars crowd out biofuel cars and that there are three waves of electric propulsion systems: first hybrid, then BEVs, and finally FCs. In 2050 the dominating energy carriers for car fleets are hydrogen and electricity; in terms of propulsion more than 95% of the vehicles are driven by electric engines.

Also, other modes become more efficient. The transport related energy consumption is 177 million toe/y compared to 320 mtoe/y in the REF. So, energy consumption is quite similar to the ASF. But because of the rather considerable market penetration of cleaner technologies the CO_2 emissions are clearly lower than in the ASF. Based on increases in efficiency and phase-out of fossil fuels the CO_2 emissions reduction is substantial: minus 75% with respect to the REF, minus 68% compared to the year 1990. The latter figure means that this scenario simulation would meet the White Paper target.

- Passenger transport demand: 9,272 billion pkm; +7% compared to REF
- Modal share passenger: car 64%; bus 5%; train 14%; air 12%; slow 4%
- Freight transport demand: 7,279 billion tonnes-km; −5% compared to REF
- Modal share freight: road freight 56%; rail freight 17%; maritime 28%
- Transport related energy consumption: 117 million toe/year; −45% compared to REF
- CO_2 transport emission tank to wheel: 265 million tonnes /year; −75% compared to REF;

−68% compared to the 1990 index

- Car fleet: gasoline 2%; diesel 1%; CNG 0%; LPG 0%; hybrid 11%; electric 25%; biofuels 0%; FC 61%
- Car fuels consumption: 112 million toe/year; −35% compared to REF

Table 4: Key data for scenario I (2050).

The demand in the passenger sector is 7% higher than in the REF and in the freight sector it is about 5% lower.

The rebound effect determined by the lower transport costs is attenuated, especially on the freight side and on the car demand side. Also, as expected, the loss on fuel tax revenues is lower than in the AFS (although it is still high: more than one third of the revenues of the reference case is lost).

So, it can be concluded that on the basis of these extreme technology optimistic scenarios there is a chance to reach the CO_2 targets. However, the achievements of CO_2 emission is mainly enabled by substituting fossil fuels with a relatively high CO_2 emission in the TTW part of the chain by energy carriers that do not cause too many emissions on a TTW basis. The emissions induced by the generation of these energy carriers (electricity, hydrogen or also biomass) are not part of the scenarios. Accordingly, a high degree in eco-efficiency can only be ensured if the generation of energy is getting much cleaner than it is now. In other words: the eco-efficiency of the transport sector becomes increasingly dependent on the eco-efficiency of the entire energy sector.

The likeliness of achieving these extreme technological changes can be questioned. Many comparatively simple targets have not been achieved yet. For example the market penetration of EVs is still very low in spite of many programmes in different countries. For decades CNG is being discussed as a still fossil based but cleaner alternative; not much progress was made in this case as well; in particular the assumed progress regarding energy intensity in the trucking sector will be very difficult to achieve. At least on a short term alternative fuels and propulsion technologies are more expensive than the established ones and there is a need to extend the corresponding infrastructure which also comes along with additional costs.

It is obvious that a fast and far reaching market penetration of new technologies needs political initiators. Push and pull measure are required. In particular, the pull measures often lack in public acceptance or stakeholder support.

3.4. Scenario II: Focus on Modal Shift

The main focus of this scenario is on achieving a modal shift towards more eco-efficient modes of transport. Public funding is concentrated on supporting the infrastructures needed for such a shift. The principle of “internalising external costs” is the basis for transport policies. Further, urban transport policies are strongly prioritising public transport, car-sharing schemes, cycling, and walking. Regulations to make the different modes cleaner are also used as a means to achieve eco-efficiency. Efficient fuels and propulsion technologies are also pushed in this scenario – but not as strong as in scenario I. Similar to scenario I, various rather stringent regulations are implemented. Efficiency and CO_2 taxes are phased in for all modes. Fossil fuels are banned after 2040. A feebate scheme reducing the price of innovative vehicles and increasing the price of less efficient ones is introduced. Speed limits are implemented all over Europe.

An interoperable road charging system on the trans-European road network is implemented in all EU member states, taking account of the external costs of air pollution, noise pollution, and congestions. There are very high tolls for highways and national roads across Europe. The most striking characteristics of this scenario are the extremely high subsidies for investments in infrastructures for the implementation of intermodality. Investments in infrastructures for rail and water transport are high, Personal Rapid Transport and CargoCaps (see deliverable 2) have become widespread in urban areas. Public Private Partnerships are an important tool for such investments.

Highly advanced and ubiquitous ICT makes public transport as well as intermodal freight much more attractive. Common technical, administrative, and legal standards are identical throughout the European rail network. This enables operators to seamlessly run trains across Europe. Many innovative approaches are implemented to improve public transport services and to overcome the "problem of the last mile". For example, passengers who have booked a public transport ticket are picked up by a semi-autonomous driving system from their door and are carried to the next public transport station, and vice versa. An interoperable electronic ticketing application for public transport is available all over Europe. This enables users to use the same means of payment for different modes and services (including conventional public transport and, e.g., bike-sharing and car-sharing). Car-sharing is widespread, highly attractive, and integrated in public transport tariff systems.

Main Results

In principle, in this scenario, the mode shift was intended to be "extreme". However, the results of the modelling do not show such extreme changes in the modal split as previously expected (cf. Table 5). It must be noted that this is, at least partly, enforced by the fixed settings of the model itself. Several parameters present in the model have been calibrated on a situation where road transport had been dominant for years.

Given these parameters, there are limits to the demand that can be shifted from road modes to other modes of transport (this applies especially to freight transport where on short distances roads are, basically, unrivaled). Therefore, the quantitative results of this scenario can reasonably be considered as a prudential estimation of the effects of the mode shift strategy.

But still, a significant modal shift can be observed. The mode share of cars is reduced from 70% in 2010 to 58% in 2050 and the share of trucks is reduced to 50% in the 2050s, whereas, in the ASF it is expected to be around 57% in 2050. So, according to the "modal shift" scenario, half of the tonnes-km are transported via roads, 20% via rail, and 30% of the transportation is maritime.

- Passenger transport demand: 9,130 billion pkm; +6% compared to REF
- Modal share passenger: car 58%; bus 10%; train 15%; air 12%; slow 4%
- Freight transport demand: 7,808 billion tonnes-km; +2% compared to REF
- Modal share freight: road freight 50%; rail freight 20%; maritime 30%
- Transport related energy consumption: 152 million tons/year; −53% compared to REF
- CO_2 transport emission tank to wheel: 320 million tonnes/year; −69% compared to REF; −62% compared to the 1990 index
- Car fleet: gasoline 4%; diesel 2%; CNG 0%; LPG 0%; hybrid 28%; electric 20%; biofuels 6%; FC

40%

- Car fuels consumption: 80 million tonnes/year; −54% compared to REF

Table 5: Key data for scenario II (2050).

The feebate scheme and the high fuel duties eventually prove to be effective to support the innovative vehicles even without the additional technological investments assumed in scenario I. However, it can be noted that the share of innovative vehicles in this scenario is very high in the year 2050 but grows slower than in scenario I. For example, in the year 2030 the share of innovative vehicles is 27% compared to 52% in scenario I. According to the calculations in 2050 28% are hybrids (compared to 11% in scenario I).

The contribution of technology to energy and emission savings comes quite late in this scenario but looking at the reduction path it can be seen that this scenario is at least as effective as the cleaner modes scenario thanks to the modal shift. Only in the year 2050 this scenario comes up with a lower result. It should be considered that the contribution of innovative cars, here, is lower because it is applied to less vehicle kilometres travelled by car. In other words, moving the demand from the road to other modes reduces the overall effectiveness of technological change in the car fleet. However, overall energy consumed by transport is clearly lower in this scenario compared to scenario I even though freight volumes are slightly higher.

This scenario would also meet the White Paper target as emissions are finally cut by 62% compared to the level in the year 1990.

The scenario also shows considerable technological progress. Several measures are similar to scenario I, however, the push and pull for new technologies is not as strong as in the former one. This has to be balanced by a modal shift that is not as strong as it was expected but still considerably stronger than in the other scenarios. The energy consumption is even lower than in scenario I, whereas transport volumes are similar for passengers and slightly higher for freight transport.

So, this scenario is not that greatly depending on technical progress as the first one. But still, modal shift alone would not have been able to reach such a high reduction in energy consumption and CO_2 emissions. Furthermore, the underlying assumptions about extending infrastructures require considerable investments – in addition to investments required for setting up an infrastructure for hydrogen and BEVs (in 2050, 40% of the cars are supposed to be FC cars).

So, in this scenario, too, the provision of "clean energy" also on a WTT basis is crucial for the targets being met. So again, eco-efficiency in the transport sector is highly dependent on developments and policies in the energy sector.

3.5. Scenario III: Reducing transport volumes

In line with the European Commission's statement in the 2011 White Paper that "curbing mobility is not an option", this scenario is not about "curbing" mobility but about reducing the need to travel physically for fulfilling certain purposes, and about reducing distances. Daily activity patterns in 2050 are not necessarily different in principle but a significant number of trips are substituted by virtual mobility and by the reduction of trip lengths for people and goods that have become a widely accepted paradigm for land-use planning. In this way, a strong increase of eco-efficiency in the transport system is achieved. So, the idea is that purposes can in principle still be fulfilled as in the reference case but the amount of resources needed for doing so is smaller because certain trips are avoided and for other purposes the trip length is reduced.

Policies try to give incentives for any virtual substitution of trips and they give a high priority to land-use planning aimed at reducing distances (City of short distances, decentralised concentration). Result of the latter is a shift from longer distance trips to shorter destinations. Also the share in long-distance holidays is much lower than it used to be decades ago.

A key driver for these developments are the extremely high energy prices (oil around $300/b). Induced by this development, regional clusters of production and consumption are fostered by policies on different levels and receive strong support from the attitudes and preferences of the citizens. This goes hand in hand with an accelerated urbanisation. So, smart urban logistics are crucial in this scenario. Goods delivery at night with silent EVs is a standard that helps to optimise logistic concepts. Further, so-called Cargo Tubes (see Deliverable 2 of the project) become an important element for logistics in larger agglomerations. In general, the load factors of HDVs and light duty vehicles (LDV) are improved significantly.

There is an extreme increase in "tele-x" (e.g. tele-working, tele-shopping, video conferencing, etc.) that significantly reduces transport demand (trip rates for all purposes). Tele-working has become standard, in particular for families with smaller children.

Overall, there is a change in attitudes and lifestyles which can be described as being slower and more reflexive.[33] This trend also manifests itself in passenger transport demands. Travelling safely and conveniently is important, using travel time is crucial. Cycling has become trendy all over Europe, and energy efficient technologies are popular. For example, small cars and e-bikes are widespread. Access instead of ownership is an overriding paradigm and, consequently, car-sharing is highly attractive and integrated in public transport tariff systems (similar to scenario II). Further, in this scenario, energy efficient technologies are popular. In particular, elderly people ask for small cars and e-bikes.

Main results

It should be noted that in deliverable 3 of this project, this scenario was actually split into two different ones: one scenario reducing volumes only in the passenger sector and one scenario reducing volumes only in the freight sector. For reasons of simplification only the combined version was used at later stages in the project.

It is interesting to investigate the strong impact of a high oil price (300$/b) combined with overall social and economic re-arrangement towards more local habits, work, production, etc., accompanied by improvements in logistics. Without any additional policy measures, this mixture of oil-price, land-use planning, improved logistics and virtualisation leads to a cut in passenger demand by 45% and to a cut in freight demand by nearly 60% compared to the REF- which indeed can be called "extreme" (cf. Table 6).

In this scenario neither the modal split nor the fleet composition is drastically changed compared to the AFS although the market penetration of innovative vehicles is somewhat higher because of the high oil price which makes non-oil-based fuels more competitive. But still, diesel and gasoline are clearly dominating the car-fleet. So, according to the calculations made for this scenario, an oil price of 300$/b is not enough to reach shares in alternative fuels and propulsion technologies of 30% or even more. With regard to the modal split, it is noticeable that in the freight sector road is becoming much

[33] See STOA (2008).

more competitive mainly at the expense of short sea shipping and inland shipping. In other words: the cut in freight volumes mostly affects the maritime sector. In the passenger sector aviation is losing shares clearly above average.

- Passenger transport demand: 4,712 billion pkm; −45% compared to REF
- Modal share passenger: car 67%; bus 8%; train 12%; air 8%; slow 5%
- Freight transport demand: 3,118 billion tonnes-km; −59% compared to REF
- Modal share freight: road freight 69%; rail freight 18%; maritime 14%
- Transport related energy consumption: 93 million toe/year; −71% compared to REF
- CO_2 transport emission tank to wheel: 286 million tonnes/year; −73% compared to REF; −66% compared to the 1990 index
- Car fleet: gasoline 45%; diesel 28%; CNG 2%; LPG 1%; hybrid 8%; electric 4%; biofuels 4%; FC 7%
- Car fuels consumption: 42 million toe/year; −75% compared to REF

Table 6: Key data for scenario III (2050).

In this scenario, the total emissions reduction is 73% with respect to the reference case and 66% compared to the year 1990. In principle, the role of technological improvement is attenuated because of the lower demand both for passengers and for freight.

Scenario III differs considerably from the other ones. Some elements seem to be hardly realistic such as to substitute huge amount of transport by virtualisation. The resulting travel demand in freight corresponds to levels of the late 80s, early 90s – it surely can be questioned whether this would be an attractive option for the European economies. However, the scenario illustrates that the measures implemented here can well have a significant impact in terms of eco-efficiency. And it should be kept in mind that about 40 years ago, in the 1970s, it was hardly envisioned that 40 years later people will grow up surrounded by virtual social networks and that most people will have small telephones with internet connections wherever they are.

3.6. Combination of scenarios I, II, and III: “Full scenario”

This scenario is a combination of the scenarios I, II, and III. It is called “Full scenario” since all measures dealt with in the other scenarios are implemented.

<u>Main results</u>

As expected, this is the most effective scenario when it comes to the reduction of CO_2 emissions. The simulation results in almost 80% less emission than in the REF case and nearly three quarters of CO_2 tonnes are saved compared to the year 1990 (cf. Table 7).

Also as expected, even this remarkable result is considerably poorer than the sum of the single scenarios because some of the measures cancel out. In particular, like in the reduced mobility scenarios, the efficiency gains are applied to a lower traffic volume.

- Passenger transport demand: 4,621 billion pkm; −46% compared to REF
- Modal share passenger: car 60%; bus 11%; train 14%; air 9%; slow 5%
- Freight transport demand: 2,901 billion tonnes-km; −62% compared to REF
- Modal share freight: road freight 64%; rail freight 21%; maritime 15%
- Transport related energy consumption: 104 million toe/year; −67% compared to REF
- CO_2 transport emission tank to wheel: 219 million tonnes/year; −79% compared to REF; −74% compared to the 1990 index
- Car fleet: gasoline 2%; diesel 1%; CNG 0%; LPG 0%; hybrid 13%; electric 23%; biofuels 1%; FC 59%
- Car fuels consumption: 52 million toe/year; −70% compared to REF

Table 7: Key data for the "Full scenario" (2050).

In this scenario, also a further attenuating effect is present: when conventional ICE cars are highly improved but innovative cars are pushed in the fleet, most of the efficiency gains are lost because the two solutions cannot be fully realised at the same time: A person either drives a much more efficient conventional car or an electric car. Both solutions are effective in theory but just one provides its effect in practice.

Still, this scenario reaches very good values and a high degree of eco-efficiency in the European transport sector.

3.7. Comparative discussion of the scenarios

To start with GHG emissions it can be stated that all three scenarios are able to reach the White Paper targets on CO_2 emissions but this is achieved in very different ways. Scenario I strongly relies on technologies; in scenario II cleaner technologies are also playing a significant role but not as much as in scenario I; instead modal shift is pushed strongly. So, in contrast to scenario I changes that directly affect travel patterns are induced, to a certain extent goods and passenger have to use other modes of transport compared to the REF. This scenario appears to be more flexible and "robust" compared to the first one since there is higher variability in the choice of assumptions and measures. However, in both scenarios the reduction in CO_2 emissions depends heavily on development in the energy sector. The provision of "clean" energy is crucial for the overall eco-efficiency.

Of very different character is scenario III where many parameters are similar to the REF but demand is cut heavily. There is not too much focus on technological progress apart of the general optimistic assumptions on technological developments in the ASF. The reduction in CO_2 emission is to a large extent achieved by the extreme reduction in transport related energy consumption (93 mtoe/y compared to 178 mtoe/y in the ASF and 320 mtoe/y in the REF). So, the achievement of CO_2 reduction comes closer to a WTW calculation. The "success" of this scenario is not that much dependent on developments in the energy sector. This reduction of transport volumes goes along with other benefits in terms of eco-efficiency: fewer raw materials are used, other emissions than CO_2 are reduced as well and less waste is produced. However, just reducing volumes would be of a much too simplistic approach and not in line with the concept of eco-efficiency as it was applied for this project. Eco-efficient approaches are understood as getting access to a certain activity/purpose (working, shopping, recreation etc.) with a smaller ecological footprint. The general quality of life and the economic wealth should explicitly not be reduced. So, the desirability and acceptability of the scenario can be questioned.

The crucial question that is revealed by this scenario is to what extent transport can be avoided without endangering other societal goals (e.g. quality of life, wealth, competitiveness). Some of the measures in this scenario illustrate how this might become feasible. Aspects of virtualisation still are comparatively new to society and it is open what future development in this area will bring. Fast changes and progress has proved to be not unlikely in this field. At the other side, there are broad experiences with the negative impacts of urban sprawl and there is far-reaching consensus on the need for more integrated transport and land-use planning to reduce distances travelled (which usually is going along with saving time and, thus, an increase in the quality of life). But in contrast to the high dynamics in the strongly market driven field of ICT and virtualisation, changing land-use structures needs time, strong and persistent political will and corresponding policy goals. Still, eco-efficient land-use and transport planning brings significant benefits as regards different aspects and therefore should be treated with higher priority on the agendas on all political levels.

The three scenarios illustrate that the different approaches can have strong impacts on the eco-efficiency of the transport system. It is interesting to see, that also in the "Full scenario", which combines all the measures from scenario I, scenario II and scenario III, the further reduction in energy consumption and emissions is not that extreme as it might have been expected. However, in terms of CO_2 emissions this scenario clearly is the most successful one.

The following charts (Figure 1 – Figure 5) provide an overview on the main results of the scenarios.

Figure 2 shows the modal share for the passenger sector. In all scenarios cars are the dominating mode. Also in scenario II which is focussed on modal shift, cars are close to a 60% share. But the figures of the other scenarios are larger.

As it has already been mentioned in the description of scenario I, the configuration of the model follows the Status Quo and, thus, it is rather difficult to reduce its competitiveness in the road sector. However, that matches the real world experiences which show that, for several reasons, larger scale shifts are difficult to be reached. The same line of arguments accounts for the figures on freight that are shown in Figure 3.

Figure 4 shows that the AFS does not reach the 60% CO_2 emission reduction target. The other scenarios meet the target in 2050. In the simulations, the "Full scenario" meets the targets already before the year 2040.

Figure 5 shows the development of new fuels and propulsion technologies. The way the model is configured, very high figures are reached for hydrogen FC vehicles in scenario I, scenario II and in the "Full scenario". In all these scenarios alternative fuels and propulsion technologies are strongly pushed.

Table 8 provides an overview on the main parameters of the different scenarios.

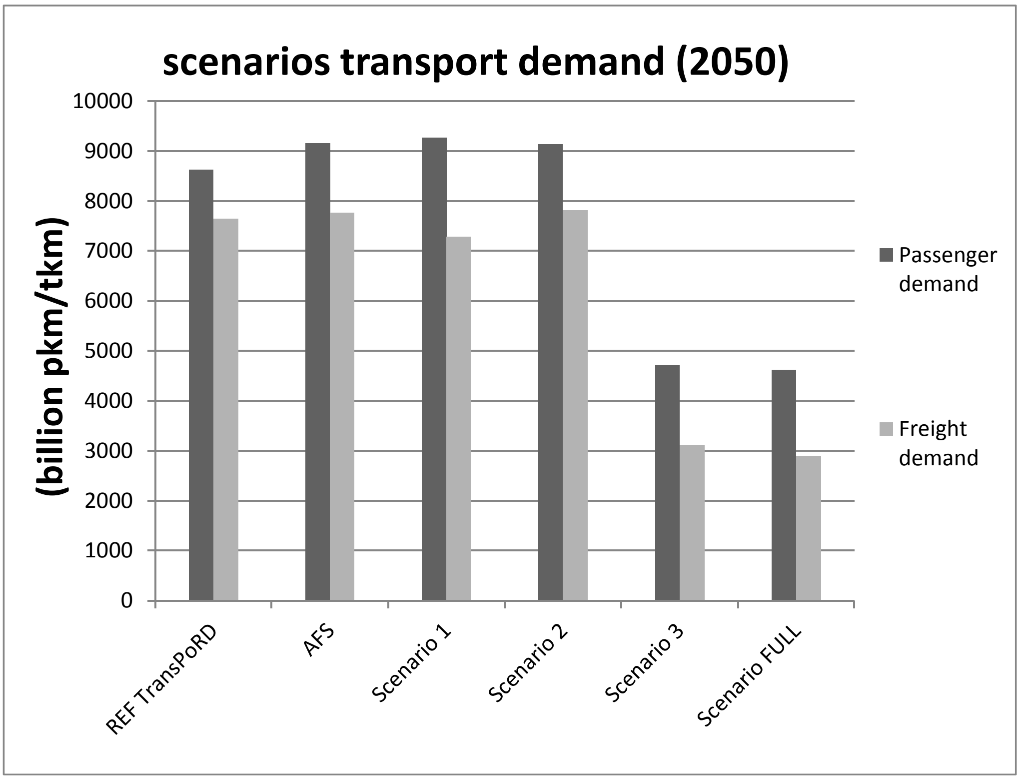

Figure 1: The transport demand for the different scenarios is slightly higher than in the Reference in the AFS, scenario I and scenario II. Only in the scenario III a significant reduction in passenger volumes is achieved.

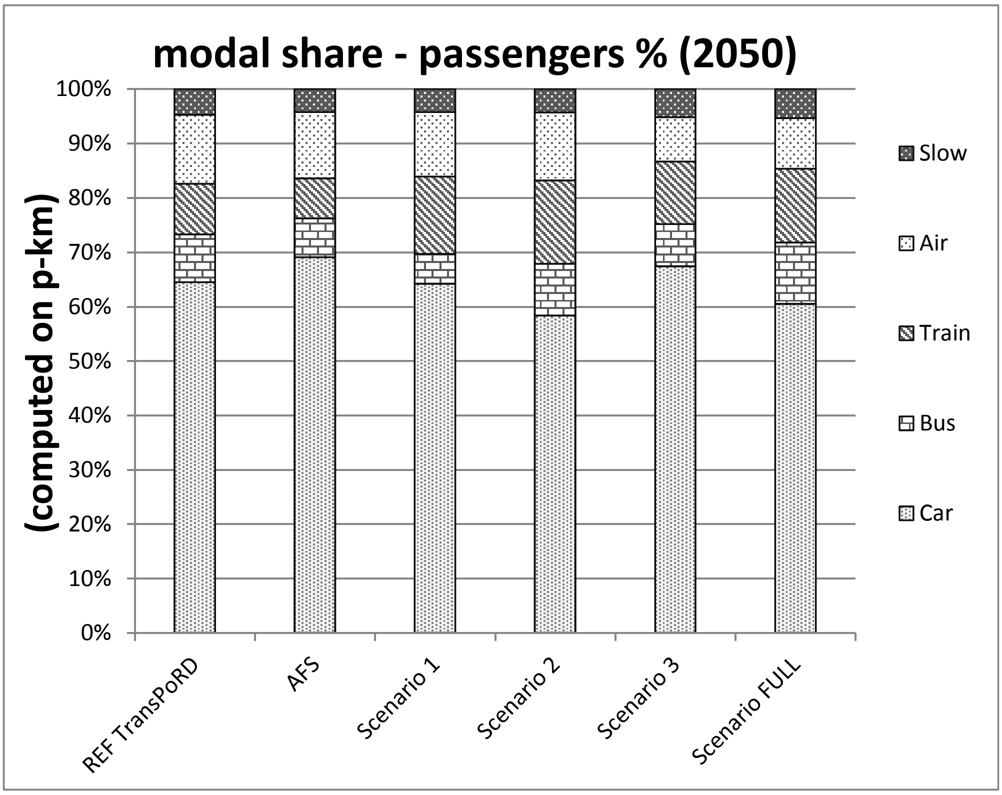

Figure 2: Modal share for the passenger sector (the category "slow" is used in ASTRA to summarize not motorized modes such as bicycles and pedestrians).

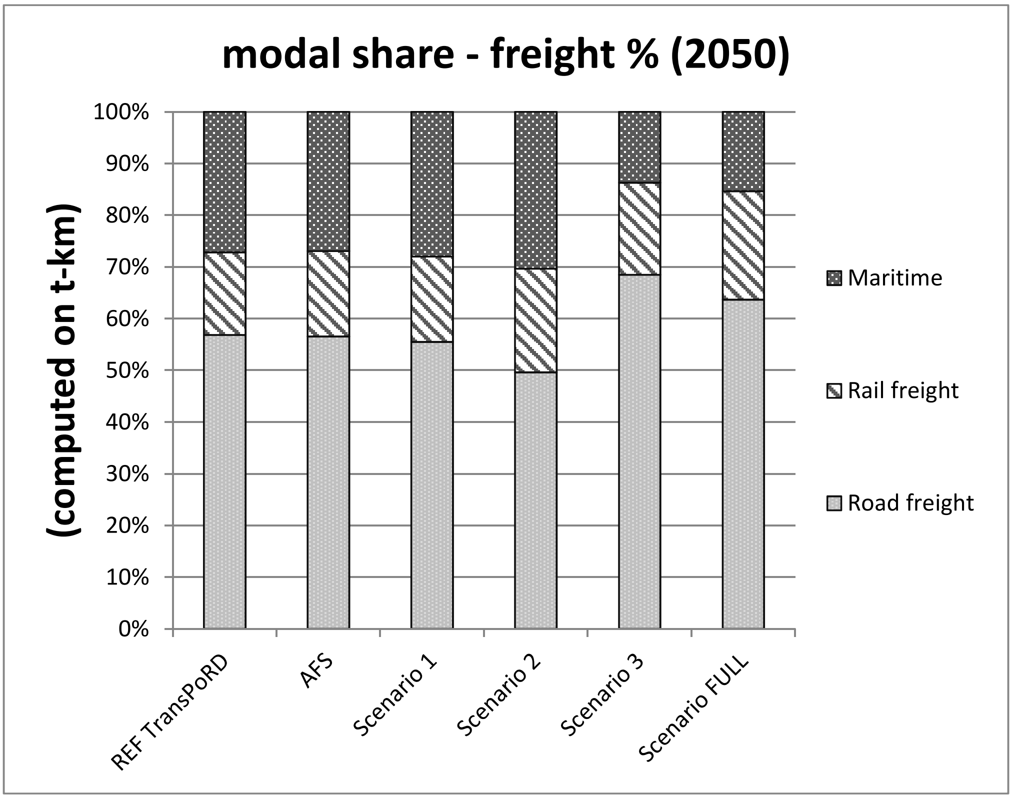

Figure 3: Modal share in freight transport.

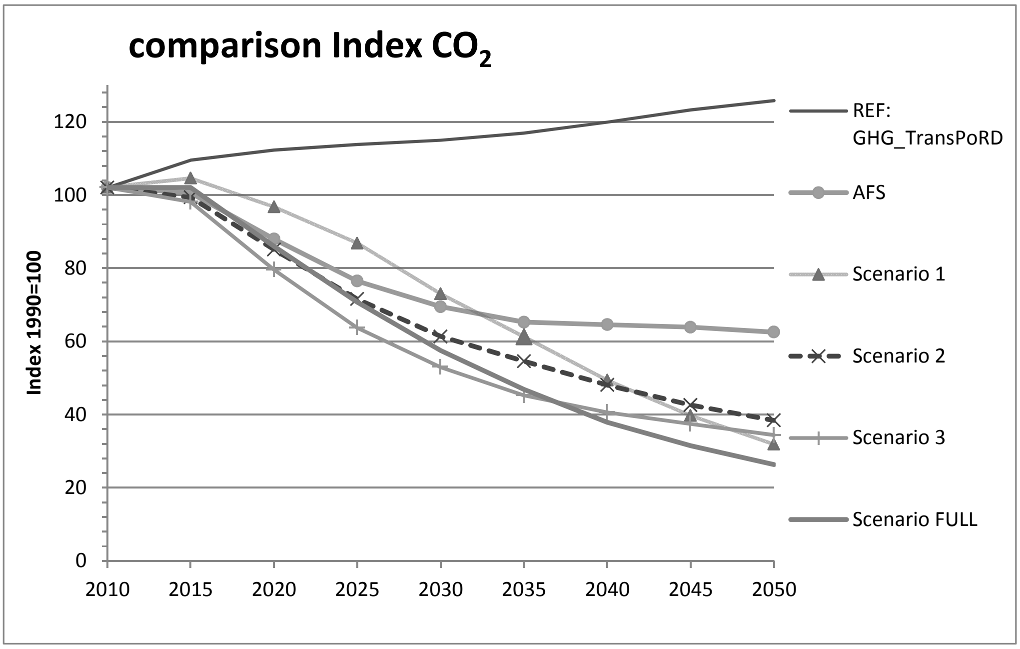

Figure 4: Transport related CO_2 emissions.

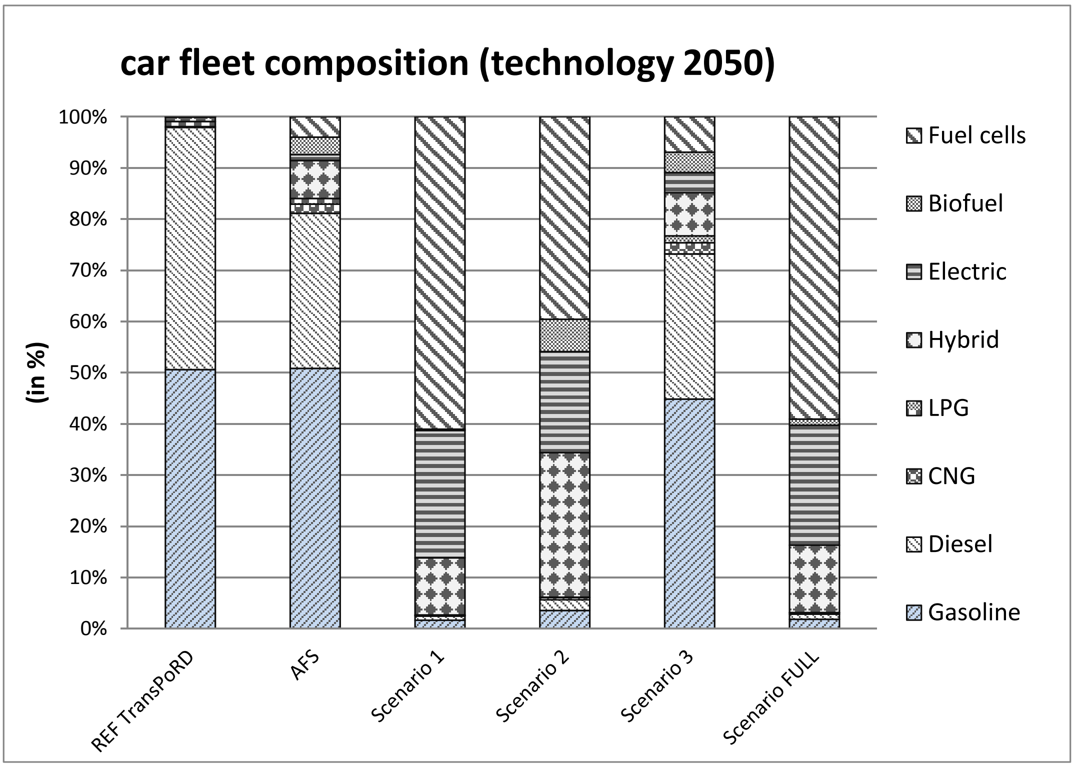

Figure 5: Development of new fuels and propulsion technologies.

Modelled main figures in 2050		REF TransPoRD	AFS	Scenario I	Scenario II	Scenario III	Scenario FULL
	Passenger demand	8625	9153	9272	9130	4712	4621
	Passenger	0%	+6%	+7%	+6%	-45%	-46%
	Freight demand	7642	7757	7279	7808	3118	2901
	Freight	0%	+2%	-5%	+2%	-59%	-62%
modal share -passangers	Car	64%	69%	64%	58%	67%	60%
	Bus	9%	7%	5%	10%	8%	11%
	Train	9%	7%	14%	15%	12%	14%
	Air	13%	12%	12%	12%	8%	9%
	Slow	5%	4%	4%	4%	5%	5%
modal share freight in %	Road freight	57%	57%	56%	50%	69%	64%
	Rail freight	16%	17%	17%	20%	18%	21%
	Maritime	27%	27%	28%	30%	14%	15%
	Transport related energy consumption (Million toe/year)	320	178	177	152	93	104
Energy consamption in comparsion to REF SCEANRIO	Comparsion to REF SCENARIO (% difference)	0%	-45%	-45%	-53%	-71%	-67%
	CO_2 transport emission (Million tonnes/year Tank to wheel)	1047	520	265	320	286	219
CO_2 emission in comparsion to REF SCEANRIO	Comparsion to REF SCENARIO (% difference)	0%	-50%	-75%	-69%	-73%	-79%
Car fleet composition %	Gasoline	51%	51%	2%	4%	45%	2%
	Diesel	47%	30%	1%	2%	28%	1%
	CNG	0%	2%	0%	0%	2%	0%
	LPG	1%	1%	0%	0%	1%	0%
	Hybrid	1%	7%	11%	28%	8%	13%
	Electric	0%	1%	25%	20%	4%	23%
	Biofuel	0%	3%	0%	6%	4%	1%
	FC	0%	4%	61%	40%	7%	59%
Car fuels consumption (Million toe/year)	Gasoline	84	47	6	9	16	4
	Diesel	80	34	6	8	14	3
	CNG	0	3	0	1	2	0
	LPG	2	1	0	0	1	0
	Biofuels	7	11	2	6	5	1
	Hydrogen	0	6	85	49	5	38
	Electricity	0	0	12	7	1	5
Modelled main figures in 2050		REF TransPoRD	AFS	Scenario I	Scenario II	Scenario III	Scenario FULL

Table 8: Overview of the main parameters of the different scenarios.

4. Stakeholder assessment of scenarios and their elements

In this section, the stakeholder consultation conducted in the project is described.[34] The scenarios and their elements served as a basis for the consultation. The main task of this phase was to discuss the feasibility (drivers, barriers, financial presuppositions) and the desirability (expected impacts, pros and cons) of potential eco-efficient developments in the European transport sector. In doing so, the scenarios and their elements were used to trigger and structure the debate, to try to point at crucial issues, to approach questions and to discuss pathways in order to overcome barriers, and to identify differences in assessment and uncertainties as well as widely accepted solutions.

This section entails:

- A description of the methodology applied (section 4.1)
- A summary of the results of the written consultation (survey) (section 4.2)
- A summary of the discussion in the workshop (section 4.3)
- Conclusions drawn from the stakeholder consultation (section 4.4)

4.1. Methodology

The stakeholder consultation was carried out in two steps:

- A survey was conducted to collect opinions related to the feasibility and desirability.
- A workshop was carried out. The results of the survey were used to focus and trigger the debate in the workshop.

As mentioned in section 1, when it comes to the discussion of scenarios, it is not only necessary to look at the figures resulting from the scenarios; for understanding and assessing the scenarios it is even more crucial to look at the assumptions that go into the scenarios.[35] Therefore, before the workshop, elements of the scenarios where assessed in a specifically designed online survey.

Designing a survey always means to deal with a trade-off between the time that is needed to fill out the survey and the amount of details that can be gathered. If the survey is too long and detailed, interviewees might not be willing to fill it out. If it is too short and general, not so many insights can be gained from it. Against this background, the project team made a selection of 14 theses that were considered as being most relevant for the stakeholder consultation (see annex 4). These theses were selected on the basis of previous work carried out in deliverable 2 and deliverable 3 of the project. The selection was carried out by the project team supported by several external experts. As a point of orientation the following criteria were used for selection:

- The thesis needed to be allocated to one of the scenarios
- The thesis were discussed in several studies/documents because of having a potential to significantly improve the eco-efficiency of the transport system

[34] This section is strongly based on deliverable 4 of the project which was written by Gy Larsen, Marie Louise Jørgensen and Katrine Lindegaard Juul from The Danish Board of Technology.

[35] See Schippl (2013).

- The thesis had to relate to emerging technologies / approaches or targets which have not been established yet
- A certain level of uncertainty regarding the feasibility (might be for technical, financial, political, or other reasons) of the thesis had to be observable
- Some controversy regarding the desirability (expected impacts might be perceived differently; side-effects or unintended impacts might be discussed controversially) of the thesis had to be observable.

On the basis of these criteria, a long-list was developed and cut down to 14 theses in order to keep the questionnaire as short as possible (cf. the list of theses in Table 9). The 14 theses can be allocated to the three scenarios. Each thesis entailed questions related to the feasibility ("In which period would you expect this development to become true?"; "Which of the following factors could impede this development?") and the desirability ("is this development desirable"; "reaching this development would have the following impacts") (cf. the questionnaire in Figure 6). Several weeks before the workshop, the theses were sent to the participants of the workshop in form of an online survey. The main results of the survey are summarised in section 4.2.

	Theses	mainly relevant for scenario ...
1.	Half of the road based freight transport (tkm) in the EU will be carried out by alternative propulsion technology (e.g. by hydrogen, gas, or biofuels).	I
2.	More than half of the passenger cars sold per year will be battery electric vehicles with driving ranges of 400–500 km.	I
3.	Only local zero emission (tank-to-wheel) passenger vehicles will be allowed in European cities of more than 100.000 inhabitants.	I
4.	In Europe, half of the passenger kilometres travelled by car will be made using full autonomous driving systems. This allows driving without human assistance as the car keeps the road and navigates on its own.	I
5.	An interoperable electronic ticketing application for public transport will be available all over Europe. This will enable users to use the same means of payment for different modes and services (including conventional public transport and e.g. bike-sharing, car-sharing).	II
6.	In Europe, public transport, cycling (including e-bikes) and walking will have a modal share of 75 % in urban areas of more than 100.000 inhabitants.	II (III)
7.	An interoperable road charging system on the trans-European road network will be implemented in all EU states, taking account of the external costs of air pollution, noise pollution and congestion.	II
8.	A sophisticated EU regulatory framework (e.g. loan guarantee schemes, risk facility funds, creation of additional revenue streams) will make infrastructure investments more attractive to the private sector. That way, private capital will bear half the EU infrastructure development costs.	II
9.	Common technical, administrative and legal standards will be identical in the European rail network. This will enable operators to seamlessly run trains across Europe.	II
10.	The freight transport volume (tkm) on inland waterways will increase by 50 % (compared to 2012).	II
11.	In waterborne transport, operational improvements (e.g. speed reduction, autopilot upgrade) and new technologies (e.g. alternative propulsion systems, propeller design, auxiliary use of wind power) will lead to a reduction of greenhouse gas emissions by 50 % (compared to 2012).	I
12.	Widespread application of tele-x (tele-working, tele-shopping, video-conferencing, etc.) will lead to a reduction of transport-related greenhouse gas emissions by 25 % (compared to 2012).	III
13.	A trend of regionalisation (driven by e.g. transport costs, societal values and related policies) will lead to a stronger spatial concentration of production and consumption of goods and services.	III
14.	Underground transport systems (urban freight tubes) will be implemented and used for more than half of the urban goods distribution in larger European agglomerations (> 500.000 inhabitants).	II

Table 9: Overview on the theses used in the stakeholder consultation.

Thesis XY:

(Text of the thesis)

a) How would you assess your own expertise concerning this thesis?

- ○ I do research and publish in this field
- ○ I have only focal or generalized knowledge in this field
- ○ I am working in this field / following the professional discourse
- ○ I have no knowledge in this field

b) In which period would you expect this development to become true?

- ○ 2012-2015
- ○ 2021-2030
- ○ Later than 2050
- ○ I don't know
- ○ 2016-2020
- ○ 2031-2050
- ○ Not realistic at all

c) Which of the following factors could impede this development? *(multiple answers possible)*

- ○ Financial barriers
- ○ Lack of societal acceptance
- ○ Capacity limit of infrastructures
- ○ Uncoordinated institutional actions/responsibilities
- ○ Ongoing technical problems that need to be solved
- ○ Differing interests of involved stakeholders (e.g. politicians, industry, NGOs)
- ○ Lack of government-funded research and development
- ○ Lack of entrepreneurial vision
- ○ European and/or national legislation/regulation
- ○ Lack of political vision
- ○ I don't know

d) Is this development desirable?

- ○ Very undesirable
- ○ Undesirable
- ○ Desirable
- ○ Very desirable
- ○ I don't know

e) Reaching this development would have the following impacts: *(each row requires an answer)*

	negative impact	positive impact	both positive and negative impact	no impact	I don't know.
Growth of European economies	○	○	○	○	○
Labour and employment	○	○	○	○	○
Accessibility of the transport system	○	○	○	○	○
Reduction of congestion levels	○	○	○	○	○
Modal shift towards more resource-efficient transport modes	○	○	○	○	○
Reduction of transport volumes	○	○	○	○	○
Improvement of human health	○	○	○	○	○

Biodiversity	○	○	○	○	○
Reduced use of fossil fuels (oil/gas)	○	○	○	○	○
Reduced use of other non-renewable resources	○	○	○	○	○
Reduction of greenhouse gas emissions	○	○	○	○	○
other/comments:					

Figure 6: Questionnaire.

As indicated above, the aims of the workshop were to receive feedback from the stakeholders on the theses and assumptions that are discussed in the context of eco-efficient transport, to gain a better understanding of the feasibility and desirability of measures/pathways towards eco-efficient transport, to discuss on pros and cons of different approaches and to scan main controversies. The starting point of the workshop debate was to consider the scenarios and its three different basic strategies of advancing an eco-efficient development: technological improvements to make existing transport means cleaner, pushing modal shift, and reducing transport.

The invited stakeholders were mainly organisations based in Brussels in the transport area and the workshop was held in Brussels. ITAS and DBT invited the relevant European stakeholders to participate in this workshop and to contribute to phase 4 of the project. A week before the workshop, the participants received a programme, a list of participants, and three short summaries of the scenarios that they were asked to read as part of their preparation for the workshop.

Beforehand, the 21 stakeholders were divided into groups of five. The formation of groups was done on the basis of the stakeholders' professional affiliations to ensure a good mix and combination of different positions on transport issues. Beside stakeholders, a staff member from ITAS or DBT was present at each table with the purpose of taking detailed notes of the group discussion. The staff members were not allowed to join the conversation.

All participants had a computer at their disposal and were supplied with an individual log-in, so they could write comments in a shared blog. The web supporters at DBT developed a simple template that people with very limited computer skills could easily use. The purpose of the blog was to support the group discussions and to ensure that as many of the participants' positions and reflections as possible were captured and documented. E.g. if a participant did not get the chance to develop a thought further, he/she could do that on the blog. The blog was interactive; it was internet-based and, therefore, the participants had the possibility to read comments at the very moment that other participants posted. This meant that the blog could also facilitate a discussion online. In this way, it was possible for the participants to express differences of opinion by posting a comment. The participants could post anonymously on the blog but their identity was known to DBT. It was not only during group discussions that the blog could be used. The participants would have the opportunity to post on the blog throughout the day and after the workshop as well; DBT kept the blog open for a week. The blog was not open to the public. The debate was documented anonymously. The workshop debates were summarised in section 4.3.

4.2. Results from the survey

In this section, the results from the stakeholder survey are briefly summarised. More detailed information can be obtained from deliverable 4 of the project.

Thesis 1: Half of the road based freight transport (tkm) in the EU will be carried out by alternative propulsion technology (e.g. by hydrogen, gas, or biofuels). (n=15)

40% of the stakeholders believe that this development will come true between 2021 and 2030. Main factors impeding this are financial barriers, ongoing technical problems, uncoordinated institutional action, and differing interests of involved stakeholders (all 46.7%). Another response to this question is that the industry alone is not able to sustain alternative fuel vehicles and infrastructure but that it needs larger scale programmes financed by the EU and through local and national budgets. 80% of the respondents find this development desirable (46.7%) or very desirable (33.3%). In line with this relatively high level of desirability, most of the stakeholders estimate impacts rather positively. 86.7% believe that this development reduces the use of fossil fuels. Other positive impacts are seen in the improvement of human health and in the reduction of GHG emissions (both 73.3%), in the growth of European economies and in the development regarding labour and employment (both 60%), in biodiversity, in reduced use of non-renewable resources (both 53.3%), and in a modal shift towards more resource-efficient transport modes (46.7%). The majority does not see any impact on congestion levels. But an additional comment points out that impacts depend on the frame conditions, especially when it comes to the production of hydrogen gas or biofuels. Another respondent comments that Europe is a market leader in hydrogen and FC technology and that an acceleration of battery transport applications in European cities could make this technology even more competitive in global markets.

Thesis 2: More than half of the passenger cars sold per year will be battery electric vehicles with driving ranges of 400–500 km. (n=15)

60% of the respondents believe that this development will become true before 2050 (with 33.3% thinking that the time span 2031 – 2050 is most realistic). 13.3% estimate that it is not realistic at all. The mostly mentioned factor to impede this development is ongoing technical problems that need to be solved. But also financial barriers (53.3%) and capacity limits of infrastructures (47.7%) are mentioned relatively often. 73.3% find this development desirable (40%) or very desirable (33.3%). Only one respondent finds it undesirable. However, one respondent comments on this saying that passenger e-cars are only desirable if they are used differently compared to conventional cars and if power comes from renewable resources. Concerns about the way power is generated is subject of three further comments. This development is assessed rather positively by the stakeholders as well. 73.3% state that it will have a positive impact on the reduction of fossil fuels. 66.7% believe in a positive outcome regarding the improvement of human health. 53.3% certify that this development will reduce GHG emissions. More than half of the respondents (66.7%) state that it will have no impact on congestion levels.

Thesis 3: Only local zero emission (tank-to-wheel) passenger vehicles will be allowed in European cities of more than 100.000 inhabitants. (n=14)

More than half of the stakeholders believe that this development will become true before 2050. Only 21.4% think that this will come true later than 2050 and none of the stakeholders think that this is not realistic at all. By half of the respondents ongoing technical problems, a lack of political vision, and societal acceptance are seen as factors to impede this development. Desirability levels are relatively high, 50% find the development desirable (35.7%) or very desirable (14.3%). Around 20% find it very undesirable or undesirable. Positive effects are rated very high in almost all areas asked, mainly regarding the improvement of human health, the reduction of congestion levels, and the potentials for modal shift. Only impacts on the accessibility of the transport system are rated controversially: 28.6% believe that this development will have negative consequences while 21.4% think that impacts will be positive and another 28.6% believe that it will have both negative and positive consequences at the same time.

Thesis 4: In Europe, half of the passenger kilometres travelled by car will be made using full autonomous driving systems. This allows driving without human assistance as the car keeps the road and navigates on its own. (n=14)

One third of the stakeholders (28.6%) believe that this development will come true between 2031 and 2050, another third (28.6%) believe this to happen after 2050. Ongoing technical problems and a lack of societal acceptance are seen most probably as impeding (by 57.1% each). Lack of government-funded R&D (35.7%) and capacity limits of infrastructures (28.6%) are also seen as hindering. 35.7% assess this development as desirable, 21.4% as undesirable, and 35.7% do not know. For the different impact categories, many respondents do not know an answer (between 42.9% and 57.1%). Those who express an opinion most apparently see a positive impact on congestion levels (50%) and on the improvement of human health (35.7%), a positive or ambivalent impact on the accessibility of the transport system (21.4% each), and a negative impact on the modal shift towards resource-efficient modes (21.4%).

Thesis 5: An interoperable electronic ticketing application for public transport will be available all over Europe. This will enable users to use the same means of payment for different modes and services (including conventional public transport and e.g. bike-sharing, car-sharing). (n=14)

Most of the stakeholders (64.3%) believe that this development will come true before 2030, another 14.3% expect it to come true before 2050. Only one respondent does not find it realistic at all. By the majority (64.3%), uncoordinated institutional action is seen as a factor to impede a roll-out. But also a lack of political and entrepreneurial visions or ongoing technical problems is mentioned as a barrier for the development. There is a very high level of desirability, 78.6% find it very desirable (42.9%) or desirable (35.7%). No negative impacts are seen in the development of integrated ticketing, but many positive impacts. Among the mostly mentioned positive outcomes is the accessibility of the transport system (71.4%), the reduction of congestion levels (64.3%), and a modal shift towards more resource-efficient transport modes (57.1%).

Thesis 6: In Europe, public transport, cycling (including e-bikes) and walking will have a modal share of 75 % in urban areas of more than 100.000 inhabitants. (n=13)

Around one third (30.8%) believe that this development will come true before 2030 but another quarter (23.1%) thinks that this is not realistic at all. One comment on this is that cycling and walking is only applicable for short distances and for healthy people and that it thus cannot replace private motorised transport. Another stakeholder comments that massive investments in public transport would be required to make this come true. Especially a lack of political vision and societal acceptance are seen by the majority of the stakeholders (both 61.5%) as factors that could impede the development. Desirability is seen controversially; more than half of the participants find this development desirable (30.8%) or very desirable (23.1%), but nearly 40% say it is undesirable or very undesirable. This development is also estimated to have preponderantly positive impacts. Among the mostly mentioned positive outcomes are: the reduction of congestion levels and a modal shift (both 84.6%), the reduced use of fossil fuels and reduced GHG emissions (both 76.9%), and improvements for human health (69.2%). Only impacts on labour and employment are assessed controversially; one third (30.8%) believes that the development will have a negative impact, another third thinks it will have a positive impact, and further 15.4% believe that it will have both positive and negative impacts on labour and employment.

Thesis 7: An interoperable road charging system on the trans-European road network will be implemented in all EU states, taking account of the external costs of air pollution, noise pollution and congestion. (n=13)

Most participants (69.3%) believe that this development will come true before 2050. By the majority, factors that could impede the development are seen in differing interests of involved stakeholders (69.2%) and in a lack of political vision (61.5%). Almost half of the respondents (46.2%) find this development desirable. None states to find it very desirable. Most respondents answer not to know whether certain impacts are positive or negative. 38.5% state that it would have a positive impact on modal shift, on the improvement of human health, and on the reduction of fossil fuels and other non-renewable resources. However, one respondent states that the thesis is not complete because it is not clear what there will be included in the charging system.

Thesis 8: A sophisticated EU regulatory framework (e.g. loan guarantee schemes, risk facility funds, creation of additional revenue streams) will make infrastructure investments more attractive to the private sector. That way, private capital will bear half the EU infrastructure development costs. (n=13)

Nearly one third of the participants believe that this development will be realised until 2030, another 15% say it will come true between 2031 and 2050. However, nearly 40% use the category "I don't know" which documents the high level of uncertainty in this field. Financial barriers were seen as the impeding factor by 61%; also a lack of political vision (46%) and uncoordinated institutional actions/responsibilities are mentioned frequently. It is striking that 53.8% do not know whether this development is desirable; only one person assesses it as being undesirable. Positive impacts are expected for the accessibility of the transport system (38.5%), for labour and employment (38.5%), and for the growth of the European economies (30.8%). However, in most cases the category "I don't know" is used most frequently which again underpins the high level of uncertainty related to this thesis.

Thesis 9: Common technical, administrative and legal standards will be identical in the European rail network. This will enable operators to seamlessly run trains across Europe. (n=12)

About one third expect this development to come true between 2021 and 2030 and 25% say it will be realised only after 2050; about one third says "I don't know". Lack of political visions, uncoordinated institutional actions/responsibilities and different interests of involved stakeholders are most frequently marked as impeding factors. About 75% consider the development as desirable or very desirable. A broad range of positive impacts are expected; most frequently, positive impacts on the growth of European economies, on labour and employment, on the accessibility of the transport system, and on a modal shift towards more resource efficient transport is marked.

Thesis 10: The freight transport volume (tkm) on inland waterways will increase by 50 % (compared to 2012). (n=12)

There was not much expertise in the group related to this thesis. 50% say that they do not know when this development will come true; one third consider this development as not being realistic at all. So, the feasibility of this thesis is assessed rather low. With regard to impeding factors, most frequently marked is the capacity limit of infrastructure. About 40% consider the development as desirable whereas, also in this case, 50% say "I don't know". Positive impacts are mainly related to a reduced use of fossil fuels (41.7%) and a reduction of GHG emissions (41.7%). 16.2% see negative impacts on biodiversity. For all potential impacts, 50% or more use the category “I don’t know”.

Thesis 11: In waterborne transport, operational improvements (e.g. speed reduction, autopilot upgrade) and new technologies (e.g. alternative propulsion systems, propeller design, auxiliary use of wind power) will lead to a reduction of greenhouse gas emissions by 50 % (compared to 2012). (n=12)

Also for this thesis, there is a low level of expertise in the group. 58.3% of the participants mark “I don’t know” regarding the feasibility of the approach, 16.7% say it will be realised only after 2050. As far as impeding factors are concerned, financial barriers, ongoing technical problems, and European and/or national legislation/regulation, each is marked by one third of the participants. 41.7% assess the development as being very desirable, the same count says “I don’t know”. Positive impacts are mainly related to a reduced use of fossil fuels (41.7%) and a reduction of GHG emissions (33.3%). For all potential impacts 50% or more use the category “I don’t know”.

Thesis 12: Widespread application of tele-x (tele-working, tele-shopping, video-conferencing, etc.) will lead to a reduction of transport-related greenhouse gas emissions by 25 % (compared to 2012). (n=12)

25% expect this development to come true between 2016 and 2020 and another 25% say it will be realised before 2030. 66.7% mark a lack in societal acceptance as an impeding factor, 33.3% opt for different interests of involved stakeholders. 75% assess this thesis as desirable or very desirable, 16.7% mark “I don’t know”. A broad range of positive impacts are expected from this development. 75% see positive impacts on the reduction of congestion levels, on the accessibility of the transport system, on the improvement in human health, on the use of fossil fuels, and on GHG emissions. 58% expect positive impacts, 16.7% see negative impacts on labour and employment.

Thesis 13: A trend of regionalisation (driven by e.g. transport costs, societal values and related policies) will lead to a stronger spatial concentration of production and consumption of goods and services. (n=12)

Most of the stakeholders (41.7%) state to not know whether this development will come true at all, 25% say it is not realistic at all. Half of the respondents say that uncoordinated institutional actions could impede the development of regionalisation. Also a lack of societal acceptance, differing interests of involved stakeholders, and European and/or national legislation are seen as impeding factors by a quarter of the respondents (41.7% each). One comment states that this development would restrict the benefits of the single market. To the question of desirability most participants (41.7%) answer to not know whether it is desirable or not. Another 41.7% find it desirable (16.7%) or very desirable (25%). This development is also assessed as rather positive, ‘negative impacts’ has no significant amount of marked answers. Positive outcomes are expected for the reduction of congestion levels and for a reduced use of fossil fuels as well as regarding GHG emissions (58.3% each). About one third (41.7%) also anticipate positive impacts for the growth of European economies, for labour and employment, for the accessibility of the transport system, and for the reduction of other non-renewable resources.

Thesis 14: Underground transport systems (urban freight tubes) will be implemented and used for more than half of the urban goods distribution in larger European agglomerations (> 500.000 inhabitants). (n=12)

Half of the respondents state that this development is not realistic at all; another five stakeholders do not know whether this will come true or not. Especially capacity limits of the infrastructure are seen as a factor to impede underground transport systems. Asked for the desirability, half of the respondents state not to know, a quarter says it would be desirable. Similar are the replies to the questions on impacts; most respondents answer to not know whether certain impacts would be positive or negative. Only the reduction of congestion levels is seen as a positive impact by 41.7% of the stakeholders.

4.3. Results from the stakeholder workshop

Note: This section is mainly taken from deliverable 4 of the project which was written by Gy Larsen, Marie Louise Jørgensen and Katrine Lindegaard Juul from DBT.

4.3.1. Scenario I: Making transport modes cleaner

Scenario I focuses on making the different transport modes cleaner. This development would be pushed by public funding of R&D activities, regulations and taxes. The main technological changes are related to fuels, propulsion, and vehicles/vessels. The stakeholders did not expect technological elements to prompt eco-efficient transport in itself; they stressed the importance of the right infrastructure and of a modal shift to be fully implemented.

In the questionnaire, the desirability of the development of alternative fuels and propulsion technologies was generally perceived as being high. But there were significant differences in the assessments of feasibility. This was the case for example when it came to whether half of the road based freight transport in the EU would be carried out using alternative propulsion technology. More than 50% believed it would be true/happen before 2030, while only a quarter of the stakeholders found the same to be true with passenger cars as EVs with driving ranges of 400 to 500km. Furthermore, only a little more than a fifth believed that in 2030 we would see regulations leading towards only local zero-emission passenger vehicles being allowed in cities with more than 100,000 inhabitants.

The stakeholders questioned the feasibility of achieving a smaller ecological footprint based on this scenario alone. They addressed that cleaner technologies could not stand alone. In some cases, the technologies were already mature but the question of implementation and about economy could be a serious hindrance. E.g., the proportion of electrification of rail networks differed substantially in the different member states, e.g. in some countries, close to 90 to 100% of the rail networks were already electrified while in other countries less than 20% were electrified. A need of large European investments in infrastructures in order to be able to use the more eco-efficient technology were identified – rail wise, but also road wise. Some also addressed that there were too many “islands” in the European rail system, and that stronger national providers rather than privatisation were needed to push the progress. Others underlined that there was too little competition to drive the development towards more attractive and efficient services.

Some stakeholders argued that, e.g., alternative propulsion technologies such as hybrids only existed because of legislation; they were very costly and still needed technological improvements. Others addressed that as long as so many different technologies were still in a development phase, investors could hesitate and hold back deciding on big investments.

The stakeholders’ assessment of scenario I underlined that it was necessary to improve the attractiveness of alternative propulsion technologies in order to achieve a faster (or larger) introduction into the market. This could be done by promoting the advantages and by providing incentives. Overall, this demanded a greater understanding of the market and of the consumers. An example from the workshop on the necessity to look beyond the technological scope were the discussions on how to reach half of the road based freight transport carried out using alternative propulsion technology. Many of the participants in the workshop pointed to the fact that most alternative technologies were already rather developed or available and that it was the non-technical barriers that had to be observed. In the questionnaire, three factors beside the technological elements were stressed as factors that could impede the development. These were financial barriers, uncoordinated institutional actions/responsibilities, and differing interests of involved stakeholders (e.g. politicians, industry, non-governmental organisations (NGOs)). Each of these three factors had been pointed out by almost half of the respondents who underlined that the technical issues were only part of the obstacles for achieving half of the road based freight transport to be based on alternative propulsion. As one of the respondents replied, "Industry alone is not able to sustain alternative fuel vehicles and infrastructure roll out". Leveraging of EU, national, and local budgets, and the development of financial schemes for larger scale programs were urgently needed. This viewpoint was largely supported at the workshop where several participants/stakeholders addressed the need for more focus on the non-technical barriers such as planning, implementation, and citizen and stakeholder demands. Furthermore, the high costs of alternative propulsion technologies were also mentioned.

The following technological issues were part of the workshop debate: biofuels were not only an issue related to technology; the key issues were different effects, e.g. the problem of indirect land use change. FCs were enablers of electric propulsion but production still had to be improved (FC engineering was fairly fluent). At the moment, it was not a matter of technology but of market breakthrough. Main drivers could be either the availability of energy resources or the environment: hydrogen, seen as a fuel, ads no CO_2 (if nothing was emitted during production). Long-term eco-efficient solutions were considered to be related to electricity, but problems were related to the not yet existing perfect battery technology.

It was stressed that, right at the time, hydrogen and gas were costly alternatives to gasoline and diesel – and that biofuels were linked to land use problems. Comments on the perspective of the thesis that in 2050, 50% of the road based freight transport in the EU should be carried out involving alternative propulsion technology were considered as unrealistic. But it could be interesting to work with specific potentials in combined solutions related to hydrocarbon fuels, gas, and biogas.

4.3.2. Scenario II: Changing the modal split

When it came to the question of having a modal share of public transport of 75% in urban areas of more than 100,000 inhabitants, several stakeholders/participants pointed out that this development would depend on public transport being more attractive, including more flexible and comfortable solutions that were not only able to transport people but also the things/what people carried with them e.g. bicycles, children, groceries, and baggage. There were some discussions on the potential of bicycles, as there was a large potential to be seen here if easier and safer options were offered.

This scenario development required that the individual citizens changed their transport behaviour. The stakeholders/respondents stressed that a massive investment in public transport was needed in order to achieve this development. Some also addressed that private transport still would be necessary in the future as this provided a better mobility service than public transport. The general message was that incentives were needed in order to change people's transport behaviour.

Several also addressed a lack of political visions regarding more cycling/biking in urban areas. In the questionnaire some factors were recognised as barriers for this development: More than 60% pointed to "lack of political vision" and "lack of societal acceptance" as factors that could impede the development Additionally, more than 50% noted "uncoordinated institutional actions/responsibilities" as a factor, and almost 50% also pointed to "differing interests of involved stakeholders (e.g. politicians, industry, NGOs)" and "capacity limit of infrastructures".

Some stakeholders pointed out that it was not just a question of technical solutions but also one of land-use and city planning – what kind of city do we want – and again, this was also a political issue – which development/infrastructure was desired in the specific city or region.

In general, the participants/stakeholders saw scenario II as the most realistic and relevant one to achieve more eco-efficient transport. Scenario II focuses on achieving a modal shift towards more eco-efficient modes of transport. This has to be pushed by public funding and by high subsidies for investments in infrastructures, for a highly advanced, convenient, and attractive public transport system, and for common technical, administrative, and legal standards for the European rail network. At the given time, it was possible to identify some change in the transport modes used, but the travel patterns were basically the same.

Several stakeholders mentioned that there was a need for better infrastructures in order to achieve the modal shift in transport modes and that this could be achieved by providing public investment in infrastructures. They also stressed the requirement of European investment in infrastructures. Others pointed out that there was a need to explain more clearly what benefits could be achieved by investing in infrastructures such as in better cross-border transportation as especially cross-border rail systems needed improvements. One of the problems was a massive resistance and a lack of will.

Some stakeholders addressed the fact that investing priorities regarding infrastructure differed very much in the different member states which could make it difficult to roll out connected infrastructures and common standards, e.g. some countries did not have an extensive motorway network yet, they prioritised the building of roads and motorways in preference to building rail networks/infrastructures to accommodate common European standards. The member states had different strategies when it came to transport in spite of existent EU strategies. The implementation took place at the national level, and here, national transport strategies would be prioritised over EU strategies. The EU needed to have more focus on the implementation of the EU strategies and on how to encourage implementation on the member state level. At the workshop, it was thematised that there was a gap between policy and reality – how would the EU put the strategy/plan/white paper into effect? As one of the stakeholders/participants put it, "after the political messages – actions should reflect the target mentioned in the political documents."

Some stakeholders questioned whether the modes described in the scenario were capable of handling the increasing number of people and goods to be transported. Would there be a margin to increase the capacity? Some stakeholders addressed the need to look at the mobility chain in its entirety.

Several stakeholders also pointed at the costs occasioned by the different transport modes which influenced the usage substantially. In many cases it was more expensive to go by train than by car or by airplane. This had prompted less usage of train/rail transport even though, in many cases, it would have been more eco-efficient and comfortable/convenient. There were examples of rising costs for a transport mode if a modal shift had been promoted, e.g. the congestion charge in London. Rising oil prices might also have an effect but it was difficult to influence the prices directly. It was easier to directly influence taxation, which could have the same effect. Some addressed the need for internalisation of external costs, not just for motor vehicles but for all transport modes.

Some stakeholders/participants objected the notion of "less clear transport modes", arguing that transport was not an end product in itself but that this was more about moving people or goods in the most eco-efficient way.

Some stakeholders/participants were concerned that the scenario might have a negative impact on the overall economy.

A debate was held regarding the fact that some capacity requirements were needed. Delivery of goods at night to avoid peak hours was not seen as a general option as this had many consequences and effects on working conditions (e.g., shopkeepers would have to work at night), and on noise in residential areas at night (none silent loading equipment could challenge this option); the whole supply chain could be affected. Furthermore, some areas had night driving bans which prevented delivery at night.

By many, ICT based mobility management was seen as a possibility to achieve more eco-efficient transport; this makes it easy to connect different transport modes so that they can be used most effectively.

In the questionnaire, many pointed out that “uncoordinated institutional actions/responsibilities” were a factor that could impede the realisation of more eco-efficient transport, e.g. regarding the thesis “interoperable electronic ticketing for public transport”, "common technical, administrative, and legal standards in the European rail networks”, “large shares of public transport, cycling, and walking in larger cities”, and “regionalisation and concentration of production and consumption” more than 50% of the respondents identified uncoordinated institutional actions/responsibilities as impeding factors for an eco-efficient development in transport. The stakeholders at the workshop saw two levels for this – an EU level and a member state level. It was not only at the European level that uncoordinated institutional actions/responsibilities hindered a more eco-efficient transport, also at member state level, lack of coordination between different operators of public transport lead to a public transport system that was not easy to use, not flexible, not convenient or assessable, and that resulted in not giving people the incentives to use public transport opposed to private transport. Others addressed the fact that there were too many authorities in charge of the different transport modes and for different geographical areas, also at the local level. This needed to be integrated better, too. Several stakeholders emphasised that the EU could play an important role by, e.g., providing a more systemic view or by stimulating overall systematic changes, e.g., for the purpose of securing an integrated railway system. The EU should, for example, provide common standards for European rail so that interoperability was achieved. From the systemic point of view, it should also be taken into consideration that transport could be a multimodal activity and that, therefore, interoperable ticketing was needed, especially in urban areas. Furthermore, the stakeholders demanded a stronger focus on the implementation. There were already some guidelines at a European level but they needed to be put into practice.

There was an agreement stating that there was a lack of coordinated/comparable data on transport on a European level which hampered comparison, common debates, and initiatives.

There were quite large discrepancies in the feasibility assessment of the different modes, e.g. in thesis 6 (in Europe, public transport, cycling (including e-bikes) and walking would have a modal share of 75% in urban areas of more than 100,000 inhabitants); 30.8% believed it would come true before 2030 and 23.1% believed that it was not realistic at all. Within the same thesis, there was also a disagreement about whether the development was desirable; 53.9% believed that the development was desirable or very desirable but 38.5% believed that the development was undesirable or very undesirable. One stakeholder commented in the questionnaire “a massive investment in public transport would be required in order to make this possible”.

The idea of an interoperable electronic ticketing application for public transport available all over Europe was considered desirable by the stakeholders. In the questionnaire, a total of 78.6% found this desirable or very desirable. The main factor to impede the development was "uncoordinated institutional actions/responsibilities" which 64.3% of the stakeholders identified as an impeding factor, 35.7% also pointed at "on-going technical problems that need to be solved" and at "lack of entrepreneurial vision".

In the questionnaire, 75% of the stakeholders found it desirable to have common identical technical, administrative, and legal standards in the European rail network. But the assessment of feasibility was not as clear. 33.3% believed it to become true before 2030, 33.3% believed it to become true later than 2050 or not at all, and 33.3% did not know. The main obstacles for achieving this development was a lack of political visions, uncoordinated institutional actions/responsibilities, and differing interests of involved stakeholders (e.g. politicians, industry, NGOs); all three factors were pointed out by 58.3% of the respondents.

4.3.3. Scenario III: Reducing transport demand

Scenario III focuses on reducing the need to transport goods or people physically and to reduce the distances. This is achieved by having policies that give incentives for the virtual substitution of trips and by having policies that give high priority to land-use planning and to extremely high oil prices. The main technological changes are related to ICT. Travel patterns change and passenger trips are shifted towards virtual mobility.

The stakeholders showed a lot of concern regarding the social aspects of this scenario, especially concerning the aspect of tele-working. Some questioned if this lead to less interaction among people, fearing that some people might be cut off from society. If society did not interact or people did not meet each other in everyday life the cohesion of the society or the society as a whole might be at risk/would stop existing. There would still be a need for face-to-face contact. In some cases it might be a cultural matter to learn not to meet face-to-face, in some countries, for example, it was more widespread to be able to work from home part of the time or having video conferences. Also webinars could substitute the need to be present at the same physical location in order to have meetings. This approach could have huge potential. However, not all psychical contact could be substituted.

Trends were identified that worked against the outset of this scenario, trends due to globalisation, such as diversity of working models, more international cooperation, online shopping (buying goods/commodities from other countries), and long distance holidays. It has become easier to have contact and meetings and to do business with people far away because you could use online tools for this, but, at the same time, this has also expanded the global network of people which might increase the general need for long distances travels. Furthermore, the idea behind the European single market emphasised the free movement of goods, capital, services, and people across borders within the EU. This worked against the trend of more regionalisation in producing the goods closer to the consumer. If transport expenses rose, it would become more expensive for goods and people to travel long distances, which would favour the trend of regionalisation. But this required that products from other parts of the world were more expensive than locally produced products. It was about the costs but it was also about changing the mindset of people, e.g., having local holidays instead of long-distance holidays. But travel plans also depended on the prices; sometimes it was cheaper to travel long distance than short. The stakeholders addressed a need for a better understanding of people's travel demands and user behaviours, not just as consumers but as citizens. We could profit from better understanding of the transport needs and behaviour in order to foster changes. New transportation modes should be "closer to the costumers" – and we should aim at being more mobile in a more effective way – planning with technology in mind. Technologies are parts of a more green way – mobility management should be the main framework.

When answering the questionnaire, there was no agreement among the stakeholders to whether the trend of regionalisation leading to stronger spatial concentration of production and consumption was a good thing (Thesis 13). 41.7% believed it was desirable or very desirable but another 41.7 % replied "don't know" to the question of whether the development was desirable.

Some stakeholders mentioned that the expected growth rates for personal and freight transport required that we focused on capacities to improve the attractiveness of other transport modes as well as of co-modality. At the moment, only few are able to shift from road based transport to other modes. Some suggested that we should also start to focus on how to use existing infrastructure efficiently. Maybe focus on delivering goods during off-peak hours, e.g. at night. Also in public transport, outbalancing the need for transport was a huge challenge so that the public transport was used more during off-peak hours. One stakeholder suggested that we started thinking about access instead of ownership. This might be relevant to get people using different transport modes and might also lead to more efficient transport. With car sharing, it was more relevant to plan personal transport needs, what might lead to lowered personal transport kilometres. But also to get people to using car sharing options they would need to be more accustomed to using different transport modes. Another stakeholder also addressed the option of sharing in the freight sector so that the same truck could be used for different cargos. Some suggested a "neutral" freight forwarder, but this might be a problem for competitive businesses.

Some stakeholders were concerned that this scenario would reduce business and have a negative impact on the economy, but it might also lead to new business models at the same time.

A combination of all scenarios was needed, so that all alternatives / all transport modes were made more attractive and efficient.

Should a modal shift be forced in order to make it happen? Some stakeholders thought that there had already been too much "stick", and we needed to focus more on "carrots" to stimulate an eco-efficient development.

The concern for the social aspects of the scenarios was also seen in the questionnaire in thesis 12 "Widespread application of tele-x (teleworking, tele-shopping, video-conferencing, etc.) will lead to a reduction of transport-related greenhouse gas emission by 25% (compared to 2012)". Here, 66.7% of the respondents pointed to "lack of societal acceptance" as a factor that could impede the development. The factor that came as second was "differing interests of involved stakeholders" which 33.3% pointed at. However, still 75% found the development desirable or very desirable.

4.4. Summary and conclusions of stakeholder assessment

One of the interesting findings from the stakeholder consultation was the emphasis on looking beyond the technological scope in order to move towards a more eco-efficient transport system in Europe. At the workshop, the stakeholders were asked which scenarios they found most attractive and realistic. There was an overall agreement on focusing on core elements in scenario II as the most robust scenario – in combination with mobility elements of scenario III. In the discussion, it was more or less taken for granted that the technical developments sketched in scenario I would be realised on the mid to long term; these technical approaches were framed as something that was needed anyway to cope with future challenges and that most of the stakeholder organisations had already been tackling. According to the stakeholders, elements and approaches described in scenario II were also needed. In addition, many stakeholders emphasized the need for mobility management that was actively trying to take influence onto the number, length, and distribution of trips. In other words:

technologies were understood as a necessary but not as a sufficient requirement for a transition to an eco-efficient transport system.

Though, stakeholders found that scenario I could be an enabler for scenarios II and III – especially in times with a high need for growths impulses and for employment. Some of the stakeholders argued that in general there was too much focus on fuels and technologies when working towards more sustainable solutions in transport. Expecting too many changes from technological issues had its limits and was often costly; it was important to put efforts in improving systems, usability, management, and alternative mobility options rather than trust too much on developments in technologies itself to provide eco-efficient transport. Stakeholders pointed to the importance of addressing infrastructure challenges; they saw technology only as one part of eco-efficient transport; it was also about service, attractiveness, information, planning, cooperation, etc.

According to many of the participants, better infrastructure is needed to achieve a modal shift in transport. This has to be pushed by public funding and subsidies for investments in infrastructures, for a highly advanced, convenient, and for attractive public transport and common technical, administrative, and legal standards for, e.g., the European rail network.

ICT based mobility management was seen by many as a possibility to achieve more eco-efficient transport while it was able to help integrating different transport modes and make use of these modes more effectively.

An eco-efficient development in transport also required that individual citizens changed their transport behaviour. The stakeholders stressed that a massive investment in public transport was needed in order to achieve this development. The general message was that incentives were necessary to change people's transport behaviour. "We could profit from better understanding of transport needs and behaviour in order to foster changes" was one of the comments. New transportation modes should be "closer to the costumers" – and "we should aim at being more mobile in a more effective way – planning with technology in mind". Technologies are part of a more green way – mobility management should be the main framework.

The EU needs to have a stronger focus on the implementation of EU strategies on eco-efficient transport and on how to encourage implementation on the member state level. At the workshop, it was commented that there was a gap between policy and reality. It is not only at the European level that uncoordinated institutional actions and responsibilities hindered a more eco-efficient transport system; also at a member state level, lack of coordination between different operators of public transport lead to a public transport system that was not easy to use, not flexible, and not convenient or assessable. This is supported by the results of the survey: uncoordinated action and a lack of political visions were mentioned quite often as hampering factors.

Further, there was an agreement on the lack of coordinated/comparable data regarding transport on a European level, which hindered comparison, common debates, and initiatives. This also affects the knowledge on consumer behaviour and preferences. It can be concluded that corresponding research is needed for the successful design of policy measures supporting eco-efficient transport.[36]

Looking at the results of the survey, some striking observation should be mentioned related to the more general statements above. Indeed, the feasibility and desirability of alternative fuels for the freight sector and the progress in battery technologies was assessed rather positively. However, it was clearly emphasised that the development and the commercialisation of technologies needed to be accompanied by corresponding infrastructures. In general, it was the non-technical issues that were

[36] See STOA (2012b) as an example for such an approach.

seen as hampering factors, first of all the high costs of cleaner technologies and the high investments needed to implement the supporting infrastructures. Further, a better understanding of the consumers and the market was needed, according to the stakeholders. R&D strategies for alternative fuels and propulsion technologies would need to be embedded into a broader context. Among others, these fields of high desirability and feasibility will be looked at in more detail in section 5 (key areas). Another thesis that was rated with both high feasibility and desirability was integrated ticketing (thesis 5) which was also selected as a key area. A further key area is related to thesis 9 on harmonised standards for rail which was assessed as rather uncertain but highly desirable.

To a lesser extent, a comparatively high desirability and feasibility can also be stated for thesis 12 (tele-working, tele-shopping, etc). The main controversies emerged on measures restricting car transport in urban areas. This was mainly triggered by thesis 3 on zero-emission zones as well as by thesis 6 that assumes a modal share of 75% for non car-based modes in urban areas by 2050. A majority welcomed these approaches but there were clear critical voices as well pointing at negative consequences on the economy. Controversial opinions related to desirability and to impacts were also characteristic for thesis 7 regarding the road charging system.

For some of the theses, a high level of uncertainty can be observed with regard to feasibility and desirability. First of all, thesis 4 on autonomous driving needs to be mentioned here since it really brings a new element into the transport system but the impacts and its relevance for eco-efficiency seems to be far from being clear. This thesis is also further developed in a corresponding key area. For the thesis related to waterborne transport there was not much expertise in the group. There were some positive assessments but many made use of the category "I don't know". The thesis of shift to water was selected as a key area since it plays an important role in scenario II. Uncertainty was also high for thesis 8 on infrastructure investments. Also for the thesis 12 on regionalisation a lot of uncertainty was visible regarding feasibility and desirability. But there were several positive assessments for both categories as well. The only thesis that by a clear majority was assessed as being rather unrealistic and uncertain in terms of desirability was the one on underground freight tubes in urban areas.

4.5. Assessment of scientists

The original intention of the survey was not to use it as a stand-alone tool, but for preparing the workshop. The idea was to find out the most striking issues and controversies in advance in order to structure the workshop in most efficient way.

However, as an add-on to STOA project, which is focussed on stakeholder consultation, the questionnaire was also circulated among scientists[37] in order to get an impression of their perspectives on the theses. 40 scientists answered the questionnaire, whereas not all of them filled out all questions.

Results need to be treated carefully, since – in contrast to the stakeholder consultation – the scientists' answers have not been discussed at the workshop. Transport is a highly complex system and the survey is simplifying highly complex cause-effect relations in the system. However, it still is interesting to see in which fields there is a high degree of consensus and where the most significant controversies are.

The most important findings will be briefly mentioned in the following.

[37] 146 scientists with expertise in all relevant fields of transport science were carefully selected and received a paper-based version of the questionnaire.

Thesis 1: Most scientists considered this thesis as being feasible, but only after 2020. Only 5% consider it as being not realistic at all. There was a broad range of impeding factors identified, more than 40% marked "financial barriers", "lack of political vision", "differing interests of involved stakeholders (e.g. politicians, industry, NGOs)". About 80% assessed this development as being desirable or very desirable.

The general response pattern is similar to the stakeholders' pattern.

Thesis 2: Almost 60% believe that this development will become true until 2050, 15% say after 2050 only and 20% consider it as not being realistic at all. Most impeding factor are "ongoing technical problems" (62.5%) and "financial barriers" (50%). More than 80% assess this development as being desirable or very desirable; 12.5% say it is undesirable or even very undesirable. So, controversies can be observed in relation to both desirability and feasibility.

The general response pattern is similar to the stakeholders' pattern, but scientists are more sceptical than stakeholders with regard to feasibility.

Thesis 3: Feasibility of this thesis is assessed rather sceptical. Only 15% say that this development will be realised before 2031; 27,5% say later than 2050 and 12.5% say "not realistic at all". Most important impeding factors are a "lack of societal acceptance" (65%), "a lack of political vision" (60%) and "financial barriers" (50%). 75% assess the development as desirable or very desirable, 15% say is is not desirable. Positive impacts were seen in relation to reduction of GHG-emissions (90%), "improvements in human health" (87.5%), "reduced use of fossile fuels (87.5%) and "modal shift towards more resource-efficient modes of transport" (77.5%). Most important negative impacts were related to the "accessibility of the transport system" (22.5%)

The general response pattern is similar to the stakeholders' pattern, but scientists are more sceptical than stakeholders with regard to feasibility.

Thesis 4: 40% believe that this development will become true between 2021 and 2030, 22.5% say after 2030. 15% consider the thesis as being not realistic at all. Most important impeding factors are "ongoing technical problem that need to be solved" (55%) and a "lack of societal acceptance" (50%). 22.5% say that they do not know whether this development is desirable or not, 17.5% say it is undesirable and 47.5% say it is desirable or very desirable.

There is a relatively high uncertainty among scientists concerning desirability.

Thesis 5: Half of the respondents say the development will be realized before 2030; 25% say between 2030 and 2050, 17.5% say after 2050 or not realistic at all. 80% see uncoordinated political action as the main impeding factor. No expert says it is not desirable, 85% say it is desirable (7.5% each marked I don't know or did not answer the question). It was the thesis with the highest degree in desirability. 87.5% see positive impacts on the accessibility of the transport system

Scientists are more sceptical about feasibility than stakeholders, but they assess the desirability higher than stakeholders.

Thesis 6: The results for feasibility point at a controversy in this field. 50% say it will become true between 2021 and 2050. At the other hand, 30% assess the development as not being realistic at all. As main impeding factors a "lack of political vision" (75%) and a "lack of societal acceptance" (67.5%) are marked. 80% consider the development as desirable or very desirable. 92.5% each see positive impacts on reduction on congestion levels and reduction of GHG-emissions. 87.5% marked "reduced use of fossil fuels" as positive impact.

The general response pattern is similar to the stakeholders' pattern, but scientists assess the thesis as more desirable and see more positive impacts.

Thesis 7: 37.5% see this development to be realized between 2021 and 2030, 30% say between 2031 and 2050. 82.5% consider the thesis as desirable. As most impeding factors "Lack of political vision" (67.5%), "uncoordinated institutional actions" (67.5%), "differing interests of involved stakeholders" (62.5%) and "European and/or national legislation/regulation" (65%) are mentioned.

Scientists assess this thesis as far more desirable than stakeholders, and they expect much more positive impact.

Thesis 8: There is a relative low degree of expertise in the group and the category "I don't know" was used quite often. 25% see the development as being realised between 2021 and 2030. 17.5% marked "not realistic at all". One third (32.5%) assess it as being undesirable or very undesirable, 27.5% say it is desirable or very desirable.

The general response pattern is similar to the stakeholders' pattern, but scientists assess the thesis as being less desirable.

Thesis 9: 17.5% say it will be realized until 2020. No one says it is not realistic at all. 77.5% assess it as being desirable or very desirable. "Uncoordinated institutional actions" (77.5%), "differing interests of involved stakeholders" (70%) and "European and/or national legislation/regulation" (57.5%) are mentioned as the most important impeding factors. 72.5% see a positive impact on the modal shift towards more resource-efficient transport modes.

Scientists are more optimistic about the feasibility of this thesis than stakeholders, and they see more positive impacts.

Thesis 10: 35% do not know the feasibility of this thesis. The remaining believe it to be realized between 2012 and 2050 (37.5%) or to be not realistic at all (15%). "Capacity limits of infrastructures" (45%) and "differing interests of involved stakeholders" (42.5%) are seen as the most impeding factors. Still, 52.5% believe this development to be desirable or very desirable, but 30% do not know. Corresponding to the lack of knowledge about shipping issues, experts are as well uncertain about potential impacts ("I don't know" between 27.5% and 42.5%).

Scientists are more optimistic about the feasibility of this thesis than stakeholders.

Thesis 11: The realization of this thesis is seen between 2031 and 2050 by 35% and later than 2050 by 15%. Again, 30% do not know and exhibit the lack of knowledge about shipping. However, 60% assess the thesis as either desirable or very desirable and positive impacts on "reduced use of fossil fuels" (57.5%), "reduction of GHG emissions" (55%) and "improvement of human health" (42.5%) are expected.

Scientists are slightly more optimistic about the feasibility of this thesis than stakeholders.

Thesis 12: While 22.5% believe this thesis to be realized between 2016 and 2050, but 52.5% do not consider it realistic at all. "Lack of societal acceptance" (57.5%) is seen as the most impeding factor. Still, 67.5% consider the thesis as either desirable or very desirable, and positive impacts on "reduction of congestion levels" (65%), "reduction of transport volumes" (50%), "reduced use of fossil fuels" (50%) and "reduction of GHG emissions" (50%) are expected.

The general response pattern is similar to the stakeholders' pattern, but more than half of the scientists assess this thesis as not being realistic at all.

Thesis 13: 22.5% consider this thesis as not being realistic at all, 30% do not know. “Differing interests of involved stakeholders” (47.5%), “lack of political vision” (45%) and “lack of societal acceptance” (45%) are seen as the most important impeding factors. However, 52.5% see this thesis as being desirable or very desirable, and only 12.5% consider it undesirable or very desirable. Positive impacts on “reduction of transport volumes” (57.5%), “reduction of congestion levels” (52.5%), “reduced use of fossil fuels” (50%), “reduction of GHG emissions” (50%), “reduced use of other non-renewable resources” (47.5%) and “labor and employment” (45%) are expected.

The general response pattern is similar to the stakeholders’ pattern.

Thesis 14: This thesis is considered the most unrealistic one. 10% expect it to be realized until 2050, while 57.5% do not consider the thesis to be realistic at all. “Financial barriers” (67.5%) are seen as the most important impeding factor. 32.5% do not know if this development is desirable, 37.5% consider it desirable or very desirable, and 22.5% consider it undesirable or very undesirable. A positive impact on the “reduction of congestion levels” (55%) is expected.

Scientists are less optimistic about the feasibility of this thesis than stakeholders.

5. Key areas

Based on the previous results, twelve key areas were identified that seem to be of major relevance for eco-efficient transport. They are crucial for the realization of scenario II, which has been considered as the most promising sample of technologies and policy measures for reaching eco-efficiency in the transport sector. Thus, the selected key areas aim at significant contributions towards the achievement of the scenario II goals and characteristics. They either seem to have a huge potential for further innovations or they were being identified as extremely relevant during the workshop discussions.

Table 10 lists the key areas that will be presented in section 5.

Table 10: Key areas.

5.1. Energy system

> *"The Energy Roadmap 2050 shows that decarbonisation is feasible. Whichever scenario is chosen, a number of "no regret" options emerge which can bring down emissions effectively and in an economically viable way."*[38]

In all three scenarios and, as a consequence, also in the stakeholder consultation, non-fossil based fuels and propulsion technologies play a key role for increasing the eco-efficiency of the transport system. It is often emphasised that BEVs as well as vehicles powered by hydrogen offer local zero emissions. In a similar vein, it is argued that biofuels are a carbon-neutral approach since they only emit as much carbon as needed for their formation. However, with the envisioned substitution of fossil fuels by other energy carriers, issues of eco-efficiency are transferred from the TTW to the WTT part of an energy carrier's life cycle: The generation of the energy carrier becomes the crucial step in terms of eco-efficiency. So, with a market penetration of hydrogen and FCs, BEVs, and biofuels as it is envisioned in particular in the scenarios II and III, the crucial technologies for eco-efficiency are available for the generation and processing of energy carriers. In the workshop, several stakeholders pointed at the need of taking into account the developments in the energy system. From this perspective, energy policy will become increasingly important for transport policy – and vice versa.

[38] CEC (2011e), p. 18.

On the one hand, this means LCA is needed to capture the full ecological footprint of the different energy carriers. On the other hand, also the relevance of the technological pathways for the functioning of the overall system can be a highly crucial factor for the overall eco-efficiency of the energy and transport system. A technology that allows the integration of fluctuating renewable energy sources (for example by transforming electric power into a storable energy carrier) offers benefits that go beyond what can be covered by an LCA approach. The flexibility of a pathway might well be a value on its own that can be highly relevant but difficult to measure in purely quantitative terms.

The European Commission's energy roadmap 2050[39] explores the challenges imposed by delivering the EU's decarbonisation objective. It underlines the high degree of uncertainty related to future developments in the energy system. Even in technology-optimistic approaches there usually is no "silver bullet"; all technology pathways have different pros and cons, in general depending on how other factors in the energy and transport system and beyond are developing. It is far from being clear which role batteries, hydrogen, or biofuels will play for which transport mode in the future. As it was illustrated in the different scenarios and also discussed in the stakeholder workshop, it is not unlikely that there will be a mix of all three respective strategies – at least for a certain period of time. The Commission's alternative fuels strategy[40] as well assumes a mixture of different fuels and propulsion systems over the next decades – a situation that is completely different from today where the transport sector is still mainly running on oil. However, the scenarios developed in this project – as well as other scenarios (see the key area on cleaner cars, section 5.2) - also show that the fuel mix can vary considerably depending on the underlying set of assumptions. This accounts in particular for the car sector. Rather different futures are possible. Therefore, it is important to have robust solutions in the portfolio that can principally make sense under different framework conditions. One of the main reasons for the stakeholders' preference for scenario II was explicitly the robustness of this scenario. In contrast to scenario one it is more flexible in terms of available strategies. It needs to be further discussed to what extent such issues of flexibility can be better included into the evaluation of an approach's eco-efficiency.

A good example for the clean and flexible production of energy carriers for transport is the pathway offered by 'windgas'. This approach is strongly linked to the integration of fluctuating renewable energy sources into the energy system. Many European countries aim at a higher share of renewable energy, for example Germany aims at increasing the share of renewable power generation from some 20% today to 80% in 2050. Already today, this higher share leads to excess power when at the same time the wind is strongly blowing and the sun is shining. In such a situation, much more energy than actually needed is produced. This excess power is difficult to store. The idea of windgas is then to make use of this excess power by converting it into hydrogen or synthetic gas. Both products can be stored in the existing natural gas grid.[41]

Technically, the concept uses wind power to produce hydrogen via electrolyse whereby an efficiency of more than 70% is reachable. Up to a certain amount the hydrogen can easily be stored in the natural gas network. It is also possible to use hydrogen for the production of natural gas. Besides hydrogen, the so-called process of methanisation needs additional CO_2 that could be gained from fossil fuel burning power plants (carbon capture and usage (CCU)). The transformation process of wind power

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[39] See CEC (2011e).

[40] See CEC (2013d).

[41] See http://www.research-in-germany.de/46100/2010-05-06-storing-green-electricity-as-naturalgas,sourcePageId=8240.html

to natural gas is possible with an efficiency of above 60%.[42] So, this process provides either hydrogen or renewable gas (methane) for a variety of applications. Both products can be employed in the transport sector. Of course, the electric power could also be used directly to charge BEVs. These kinds of approaches need to be fostered since they are highly relevant for the transformation of the energy system; furthermore they are highly flexible as far as the product delivered for the transport system is concerned: this can be electricity, hydrogen, or natural gas. It is this flexibility which makes such an approach as windgas attractive – also in the light of the fact that it is not clear yet which fuel-propulsion technologies will be dominant in the future.

5.2. Cleaner cars

"[E]lectric cars are not the "silver bullet" solution that some people might be waiting for. That said, we are now at a point where electric propulsion is finally becoming a viable alternative: As oil gets more expensive, the alternatives become more attractive. And customer awareness for 'green' vehicles has never been higher than today."[43]

Car transport is responsible for a high degree of energy consumption and GHG emissions. As the scenarios illustrates well, it is not unlikely that also in 2050 a considerable amount of passenger transport will still be done by cars. Even in the modal shift scenario still more than half of the person kilometres are driven by car. In the cleaner modes scenario I, more than 60% of the total energy used in transport in 2050 is consumed by cars. Therefore, it is important to address this segment for the purpose of increasing eco-efficiency. It is essential to bring cleaner cars on the market. There are still potentials to further improve the efficiency of the ICE. The fleet composition itself can be shifted to more efficient cars – but would still be based on fossil feedstock. In scenario I, several measures are implemented to push the market penetration of non-fossil fuels. For example, there is a feebate scheme reducing the price for innovative vehicles and increasing it for less efficient ones. It is assumed that fossil fuels have been banned completely in the car sector after 2040.

It is noticeable that the different assumptions applied in the three scenarios lead to rather different fuel mixes for 2050. In the scenarios with less strict regulations and incentives, gasoline and diesel are still dominating the fleet. In scenario I gasoline and diesel are no longer relevant in 2050, but also in this scenario the car fleet in 2050 is characterised by a mix of different fuel and propulsion systems. Figure 7 illustrates that other studies also show a mix of alternative fuels.

[42] See http://www.greenpeace-energy.de/engagement/unsere-gasqualitaet/die-technik.html

[43] Zetsche (2010), p. 7.

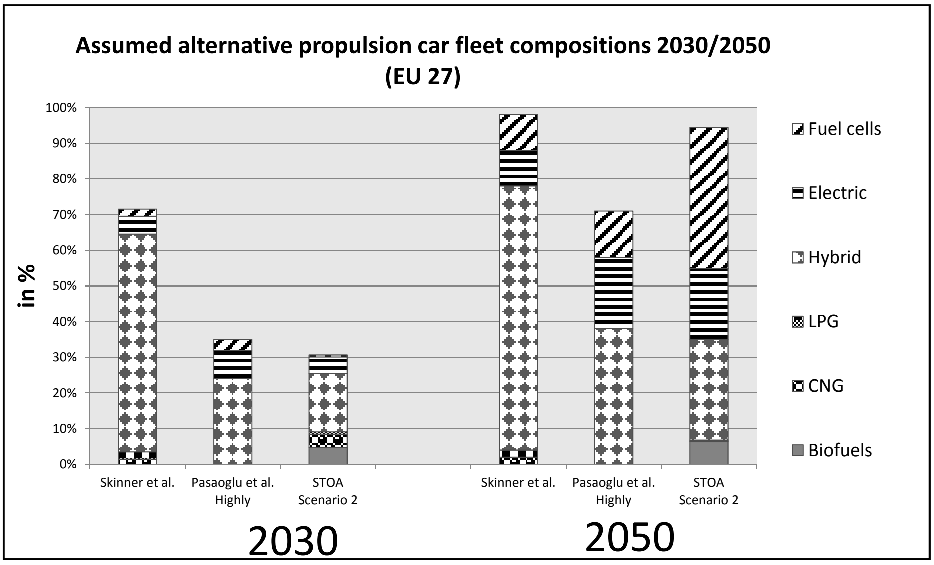

Figure 7: Car fleet consumption for 2050 in scenarios of different authors. Note: The diagram excludes gasoline and diesel cars. Sources: own chart, figures adapted from Skinner et al. (2010) and Pasaoglu et al. (2012).

So, it is obvious that there is no "silver bullet" when it comes to a substitution of fossil fuels in the car sector. Several options are possible and all these options have their specific pros and cons. [44]

Biofuels, batteries as well as hydrogen have all experienced their ups and downs in political, public, and scientific debates, which underpins the high degree of uncertainty regarding the fuel and energy mix of the mid- to long-term future. A good example is hydrogen. About ten years ago, in his book on the "hydrogen economy", Jeremy Rifkins framed hydrogen as the "next great economic revolution".[45] One key element of his vision is that hydrogen will replace oil as the primary energy carrier. Even if one does not follow his far-reaching vision, the book clearly illustrates that the integration of hydrogen production into the energy system could become a crucial factor for its use in transport. Thus, the further development of hydrogen driven vehicles surely depends not only on technical progress (also in batteries) and the development of the automotive sector but also on the future design of the European energy system.

Recently, the often apparent dichotomy between hydrogen and BEVs was replaced by the notion of coexistence in the rhetoric of many experts and stakeholders. A good example is offered by a recent announcement of the European Regions and Municipalities Partnership for Hydrogen and Fuel Cells (HyRaMP) that refers to "fuel cell electric vehicles".[46] Other experts share this (cf. Figure 8).[47]

[44] See also JRC (2011a&b); CEC (2013d)

[45] See Rifkins (2002)

[46] http://www.hy-ramp.eu/news/events-calendar/european-electric-vehicle-congress-26th-28th-october-2011

[47] See Eberle & von Helmolt (2010).

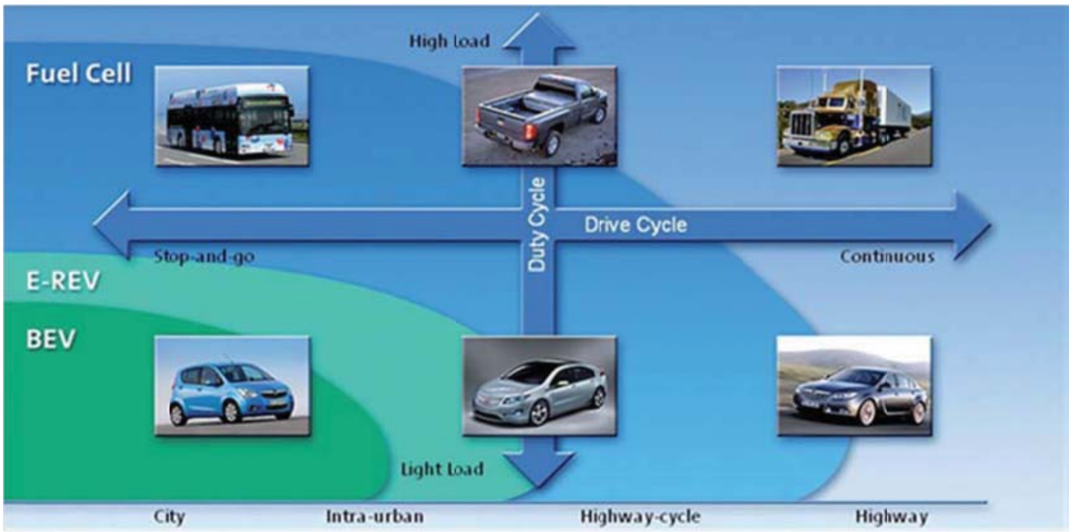

Figure 8: Application map for various EV technologies. Source: Eberle and von Helmolt (2010).

There are two methodological reasons that contribute to the uncertainty in assessing what is the appropriate fuel of the future: A systemic perspective as well as LCA are actually needed but are not easily applicable. The need for a systemic perspective was already underlined in the previous section. In this chapter an example for the relevance of LCA approaches is given for BEVs: The production, use, and recycling of metal products used for batteries and other components that could have a potentially harmful impact on the environment. Unfortunately, environmental impact assessments or LCA for EVs are at an early stage. One study from the Swiss Federal Laboratories for Materials Science and Technology (Empa) has ventured an attempt and compares a conventional gasoline car (Euro 5 standard, 5.2 l/100 km) with an EV (VW Golf size, 200 km range, battery capacity 0.114 kWh/kg) using four different impact assessment methods.[48] As the aim of this study was to determine the potential contribution of Li-ion batteries to the overall burden of mobility, the modelling in the pre-life and end-of-life stages was done in such a way that it resulted in the highest possible environmental burden for the battery (e.g. all burdens were allocated to the first-life use of the vehicle, no recycling or other uses were considered).

Empa's assessment shows that the environmental impact of both BEVs and ICEs is dominated by the operation phase (see Figure 9). The environmental burden of the ICE is higher in all four assessments, and the share of the Li-ion battery on the overall environmental impact of the BEV is only between 7% (CED) and 15% (EI99 H/A).

It can be concluded that there is an urgent need to further develop and apply LCA approaches for fuels and propulsion technologies. However, in addition to LCA an even broader approach is needed to allow a systemic perspective on the pros and cons of different fuel-propulsion combinations. The latter should at least be done in a qualitative way, if no reliable quantifications are possible.

[48] See Notter et al. (2010).

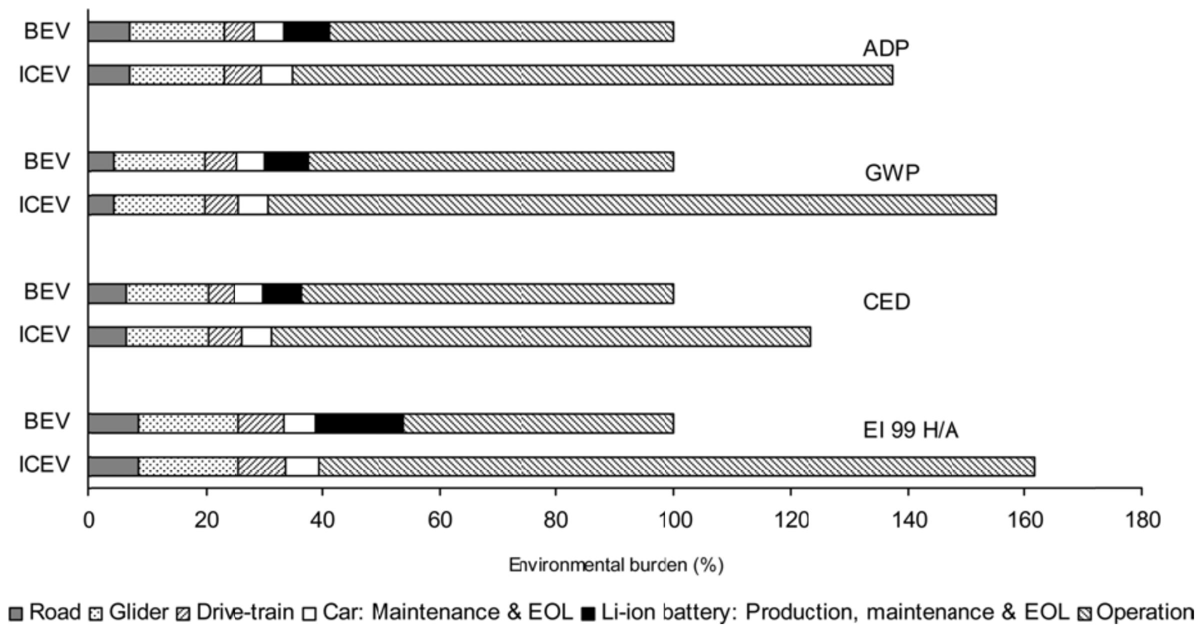

Figure 9: Comparison of shares of total environmental impact of an ICE car and a BEV. The impact assessment methods used were: abiotic depletion potential (ADP), non-renewable cumulated energy demand (CED), global warming potential (GWP) and Ecoindicator 99 H/A (EI99 H/A). The share "Road" includes construction, maintenance and end-of-life treatment (EOL); "Glider" includes chassis, car body parts, wheels, interiors, safety devices, acclimatisation devices). Source: Notter et al. (2010).

In the transport and energy system, there is a high degree of complexity present and, thus, a high degree of uncertainty regarding future developments. Taking this into account, it must be emphasised that yet different fuels and propulsion technologies should be supported. These findings support the Commission's recently published alternative fuels strategy that claims: "There is no single solution for the future of mobility and all main alternative fuel options must be pursued, with focus on the needs of each transport mode"[49].

5.3. Cleaner trucks

LNG is particularly suited for long-distance road freight transport for which alternatives to diesel are extremely limited."[50]

Figures from the statistical pocketbook 2012 illustrate that road freight transport is responsible for 45.8% (1756 billion tkm) of the total freight performance within the EU-27; rail, on the contrary, accounts for 10.2% (390 billion tkm) of the total freight transport performance.[51] In the REF road freight accounts for roughly 30% of total transport related CO_2 emissions; in the REF this share is projected to increase up to about 36% in 2050 (see Deliverbale 3 of the project). In the optimistic scenario I with regard to technology, trucks (road freight) are, by far, the most important emitter of CO_2. These figures indicate that, beside cars, road freight transportation will be the main source of emissions and energy consumption in 2030 and 2050 although some expected improvements in the

[49] CEC (2013d), p. 4.

[50] CEC (2013d), p.5.

[51] CEC (2012), p.36.

REF scenario for 2050 have been considered. The energy intensity may be reduced by approximately one third but, at the same time, it is likely that the demand in freight transport will heavily increase. As a conclusion, eco-efficiency of the transport sector strongly depends on increasing energy efficiency, use of cleaner fuels, and on reductions in the energy intensity of trucks as well as on a modal shift to cleaner modes. Since, it is likely that also in 2050 a significant share of freight will be carried on trucks, this key area on cleaner trucks will focus on technology measures to reduce energy and GHG emissions.

To illustrate the thematic field, 'trucks' (e.g. HDVs) will be generalised due to slight deviations within the literature, i.e., all vehicles (> 7.5 t) whose purpose it is to carry or move large quantities of freight or passengers. Two approaches will be discussed: to make vehicles more efficient and/or to use cleaner fuel and propulsion technologies.

The broad range of truck-related technology measures indicated that there is a serious potential for improvements. Discussed measures encompass: improvement of engine efficiency, aerodynamics, hybridisation of vehicles, tyres, and wheels (in order to reduce rolling resistance), lightweighting, transmission, as well as driveline and driving management. The CO_2 reduction potentials are estimated from 28% for lightweight constructions up to 39% for improved diesel engines.[52] Figure 10 illustrates the discussed truck-related technology pathways and their GHG reduction potentials in different truck segments.

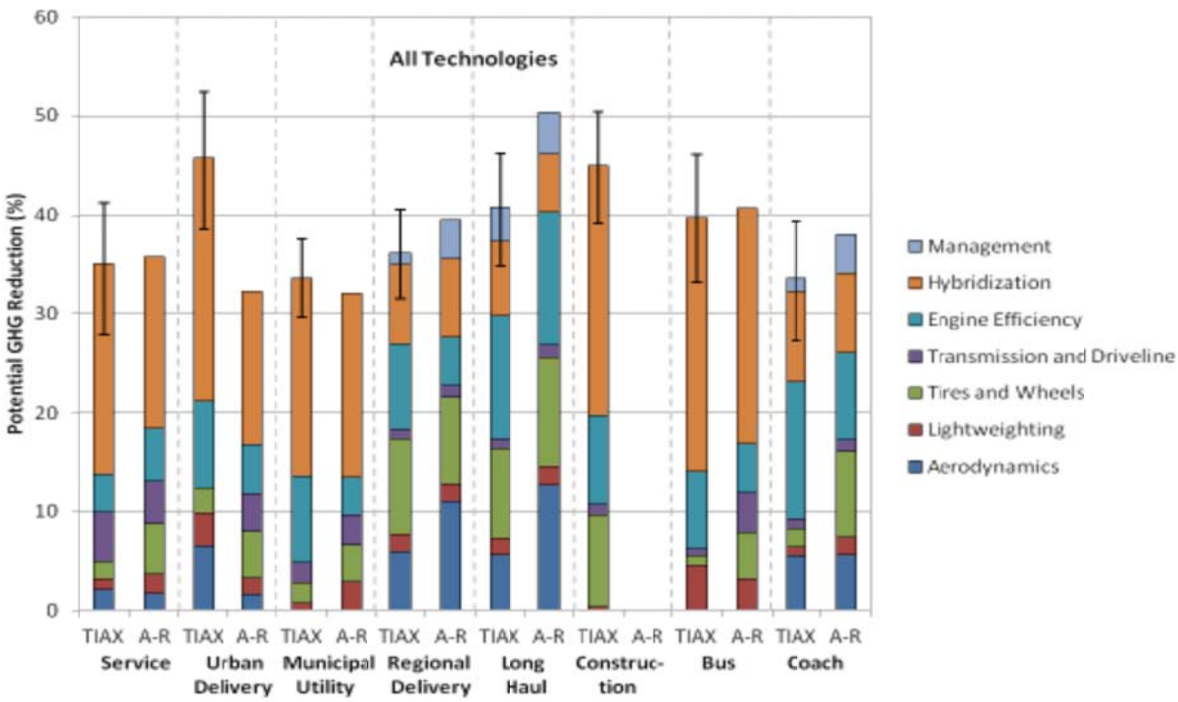

Figure 10: Potential new EU vehicle GHG reductions regarding all technologies. Source: Law, Jackson & Chan (2011), p. 5.

The field of aerodynamics is an interesting approach due to its estimated short-term reduction potentials. An aerodynamic design of trucks (e.g. adaptations of cabin forms and trailers) reduces the aerodynamic drag and may offer CO_2 saving potentials from 2% up to approximately 10%, depending

[52] See Akkermans et al. (2010); Schroten et al. (2012); Law, Jackson & Chan (2011).

on the truck category and measurements.[53] A recently lanced proposal of the Commission will adapt the older Directive 96/53 and will allow for different measures on trucks – such as on their weight and dimensions – in order to make them safer and more fuel-efficient by using aerodynamic devices.[54] According to Transport & Environment, this proposal will be slightly in line with aerodynamic measures in the study of the fka Aachen, on the one hand[55]; but on the other hand, it may be a first step towards establishing the controversially discussed cross-border mega trucks between European countries – with the argument of removing cross-border barriers in the freight transport sector in this way.[56]

The controversial discussions about mega-trucks indicate that there are some uncertainties about benefits and impacts of these up to 25.25 metres long vehicles. While proponents expect to save fuel consumption by increasing transport volumes (increasing load factors) per truck unit, opponents argue that the external costs are not well understood.[57] Negative implications caused by necessary adaptation and quicker wear of infrastructure as well as by a possible shift from rail and water transport to road transport, especially in the container and combined freight transport segment, are considered possible.

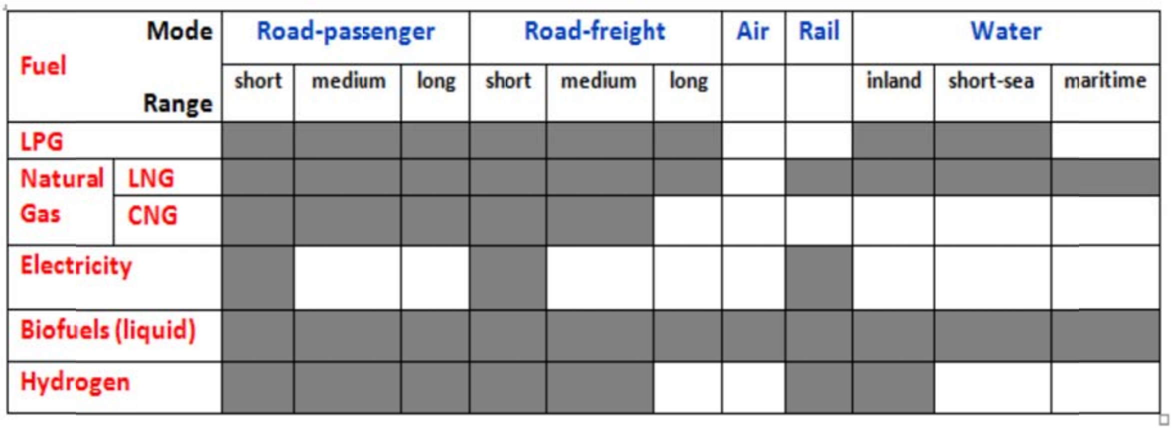

Figure 11: Illustration of the coverage of transport modes as well as of their range by alternative fuels. Source: CEC (2013), p. 4.

An important discussion is related to the usage of alternative fuels and propulsion technologies in the freight sector. EVs and also hydrogen driven vehicles are not expected to become an option for the long distance sector (see Figure 11). Higher energy densities are needed to carry heavy loads over long distances. Hydrogen might be an option for medium distances. For longer distances, LNG and biofuels might be a more eco-efficient alternative. However, for all these options the WTW balance is of utmost importance. As far as biofuels are regarded, it is important where and how the feedstock is produced and processed. Further, it is important to consider if the biomass might also be needed

[53] See Law, Jackson & Chan (2011); T&E (2013).

[54] See CEC (2013e).

[55] See fka (2011).

[56] See T&E (2013)

[57] See Kienzler & Doll (2011).

elsewhere, for example, in aviation or for stationary application to produce flexible and/or base load compatible electric power (e.g. via biogas) and heat. Again, a systemic perspective is required.

The lack of adequate infrastructure requirements is one of the common arguments of why alternative propulsion systems will not be accepted until these bottlenecks will have been resolved. This accounts for LNG and also for hydrogen. The commission alternative fuel strategy is addressing this issue (proposal COM (2013) 17[58]).

As previously discussed in the STOA report (Del. 2, p. 23f.), hydrogen offers a wide range of opportunities in transport applications (e.g. directly ICE-burned or for FC vehicles and EVs) as well as regarding storage opportunities for energy. It depends on a variety of criteria such as on the WTW fuel analysis, on the truck-end user perspective, the assumed service life time and, last but not least, on total pricing and business cases under which circumstances considerable losses of energy within the electrolysis route of hydrogen seem tolerable. This applies to all other alternative propulsion systems; similar methodological considerations are important for the assessment of the potentials of biofuels, LNG/CNG, batteries, and different hybrids, as well as of combinations of these.[59]

More out-of-the-box and with a visionary character, but following the pathway of electrification of the transport system is the recently (again) discussed idea about an electrification of road freight by using the trolley-truck approach.[60] Considerable disadvantages from the logistics entrepreneurship perspective such as losing some load factors due to technology requirements, or even advantages such as being quiet and clean, as well as incentives and positive labelling may play a significant role in overcoming barriers (e.g. higher investment costs). With regard to some recommendations, a variety of options are on the table. They range from load factor standardisation (e.g. fuel consumption per unit payload) to setting a basis in order to compare different HDV types, to operational measures and the usage of ICT[61], up to technological pushes by supporting a behavioural change (e.g. for logistics entrepreneurs to think and act multi-modally) and by considering consistent policy measures (e.g. taxation and incentives).[62]

5.4. Smart logistics

"More cargo bikes delivering goods means less trucks in city centres and safer, liveable streets for people"

Rob King, Outspoken Delivery[63]

It was already indicated in the key-area before, that the scenarios conducted in this project clearly point at a need to improve the eco-efficiency also in the freight sector. The importance of approaches related to the design and to the propulsion systems of trucks were mentioned there. This chapter focusses on logistics as a complementary approach. Smart logistics is a concept that promises

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[58] See CEC (2013b,c&d).

[59] See Akkermans et al. (2010); Schroten et al.(2012); Law, Jackson & Chan (2011); Schade & Krail (2012); Smokers et al. (2012); Hill et al. (2011).

[60] See SRU (2012).

[61] See Hill et al. (2011).

[62] See Schade & Krail (2012).

[63] Cited in Neslen (2012).

significant improvements in the eco-efficiency of freight transport. It includes specific technical innovations as well as organisational innovations and new business models. Von der Gracht and Darkow found (among others) the requirement for social responsibility, ecological awareness, globalisation, demand for convenience and flexibility, and the "digitisation of business" as major factors that will influence the logistics sector in the future.[64] Smart logistics could play an important role in dealing with these challenges.

The contribution to eco-efficiency in the transport sector through smart logistics can be made through the facilitation of optimal mode choices (favouring intermodal transport and modal shift, cf. scenario II 'modal shift') and through the reduction of the actual need for physical transport (by optimising routes etc., cf. scenario 3 'reduced volume growth')

Smart logistics is about intelligent use of ICT solutions and about using the most efficient technical means for freight transport in the most efficient way. In Berlin, DHL as one of the global players in the logistics market, tested the 'smart truck'.[65] This "intelligent transporter" uses radiofrequency identification (RFID) sensors onboard the vehicle and optimises its own route by satellite-based positioning data and additional real-time data on traffic flow etc. This enables the respective driver to deliver in the most effective way; the potential CO_2 emission savings are estimated to be around 10–15 %.[66] As another example, the 'bring buddy' goes even a step further: In this approach, private 'buddies' partly take the role of logistics service providers.[67] Linked via social media, persons can just take deliveries with them whenever the addressee is on their way or only a short detour away. People can earn small amounts of money for offering this service and at the same time enter into a new type of physical social networking. Approaches like this point to the so-called 'internet of things', where physical products find their own efficient way – like today's bits and bytes on the internet.[68] Schilk and Seemann similarly call this the 'internet for the cargo' and describe the manifold possible usages of ITS in this field (see Figure 12).[69] All these innovations contribute to reducing the need for physical transport by optimising routes and by always choosing the optimal means of transport.

The facilitation of optimal choices through smart technology can also allow for the use of locally emission-free EVs where they are most useful, e.g. electrically driven small delivery trucks in cities. Even cargo bicycles are considered to have a significant potential in most densely populated areas and are therefore promoted by the European Cycle Logistics Federation.[70] Respective applications of EVs in fleets offer the additional advantage of limited operational areas, as limited vehicle ranges are less relevant than in private usage. EVs could contribute once more to improved eco-efficiency of freight transport.

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[64] Von der Gracht and Darkow (2010), p. 57.

[65] See Deutsche Post AG (2011).

[66] Deutsche Post AG (2010: 91).

[67] See Weber (2011).

[68] Deutsche Post AG (2009: 56).

[69] See Schilk & Seemann (2012), p. 629.

[70] See European Cyclists' Federation (2012).

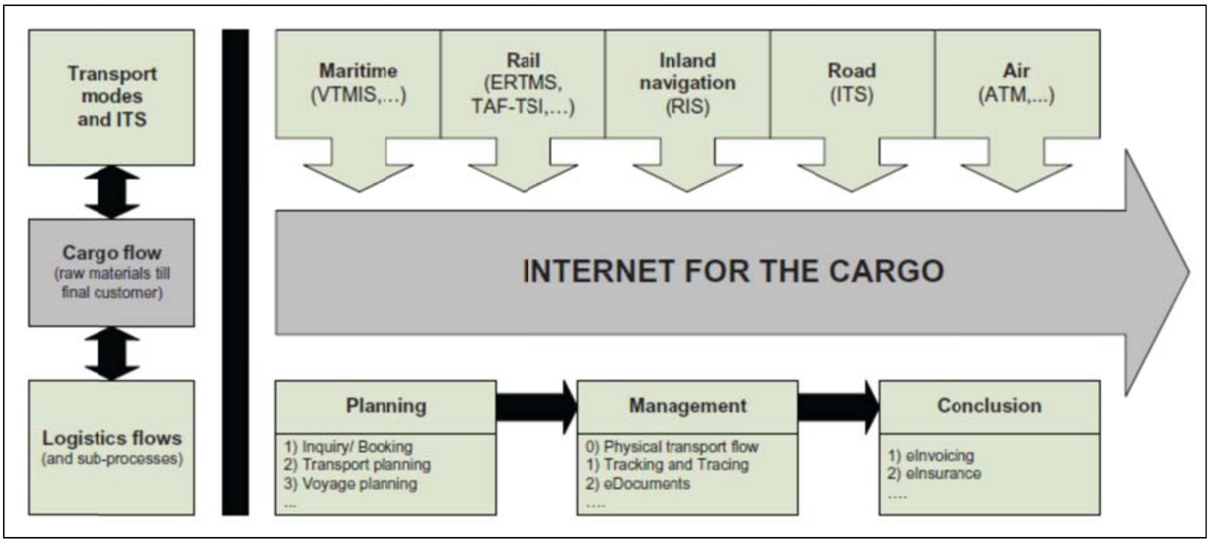

Figure 12: Internet for the cargo using ITS for optimizing transport logistics flows. Source: Schilk and Seemann (2012), p. 629.

However, the issue of night delivery[71] shows the need for an integrated perspective: Night delivery turns out to only be a viable option when combined with quiet (e.g. electrically driven) delivery vehicles and there were concerns voiced during the stakeholder workshop in phase 4 regarding the social consequences of the respectively changing working conditions. Online shopping is another complex case, where Wiese et al. have shown that online shopping can have positive environmental impacts – by reducing transport efforts – in many cases, but in case of short travel distances and high shares of public transport, bicycles and walking may as well be counterproductive.[72]

As a starting point for policy actions, the Alliance for European Logistics gives specific recommendations on how to "leverage the available technology and to deploy innovative technology solutions"[73] by policy measures, also referring to the vision of the 'internet of things'. A CEC study on urban freight transport underpins as well the necessity of "developing and disseminating good practice"[74], also urging for efficient deliveries, low emission vehicles, ITS, night deliveries and intermodal transfer facilities, and other infrastructure. That could all help to implement smart logistics.

5.5. Automation

"I took my hands off the steering wheel, lifted my foot off the gas pedal, and waited to see what would happen."
Will Knight[75]

[71] See Deutsche Post AG (2010), p. 108.

[72] See Wiese et al. (2012).

[73] See Alliance for European Logistics (2010), p. 9.

[74] See MDS & CTL (2012).

[75] Knight (2013).

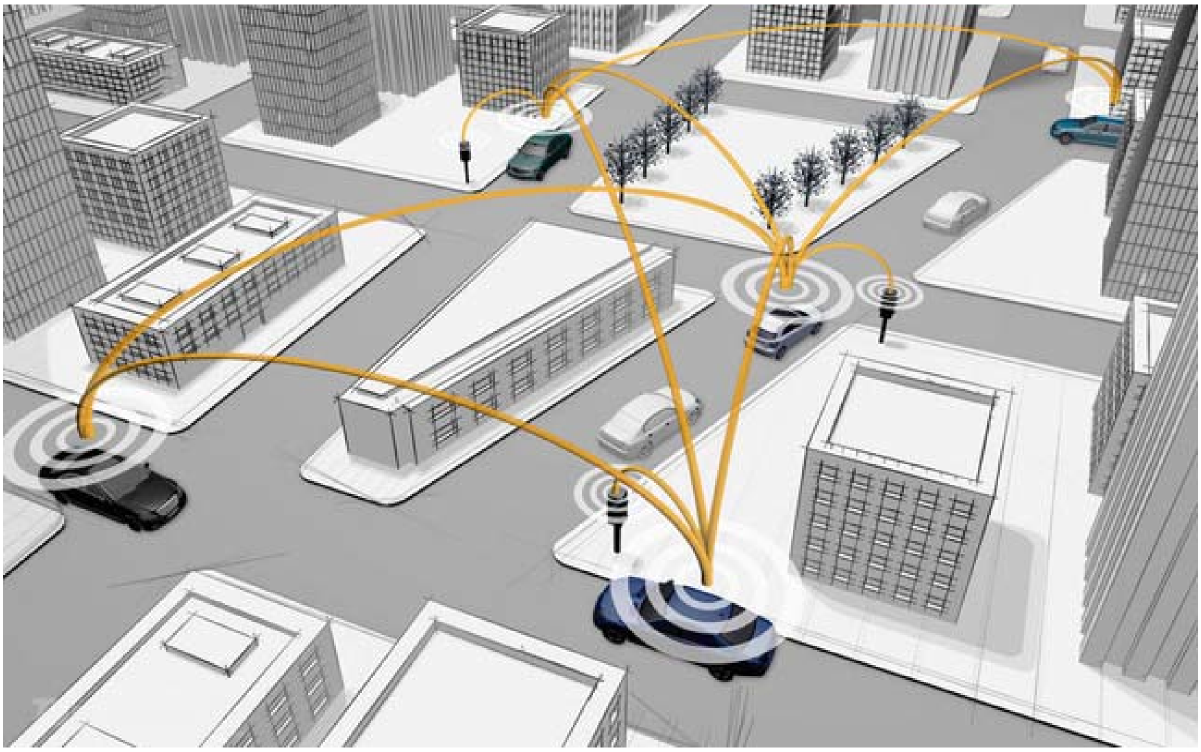

Figure 13: Illustration of autonomous driving technologies. Source: Elmer (2012).

Automation is a trend that is visible in many different areas. Industrial robots are well established. Approaches such as ambient assisted living aim at integrating ICT based automation and even robots in our homes; in aviation automation has become part of the daily routines and unmanned air vehicles become widespread. Therefore, it is not astonishing that also in the car sector automation is getting commercialised in form of driver assistance systems. However, full autonomous driving is still not playing a significant role in scenarios and visions on the future of European transport, although full autonomous cars would surely change the transport system and its eco-efficiency. It is argued here that these issues should be rated as of higher priority on research agendas, including the relationship between automation and eco-efficiency. The survey carried out in this project revealed that among stakeholders a high degree of uncertainty can be found when it comes to an assessment of the feasibility and desirability of autonomous driving systems. Ongoing technical problems as well as a lack of societal acceptance are seen as most probably impeding the implementation of such systems.

Automation in road transport is an approach that ranges from incremental introduction of specific and singular driver assistance systems to fully autonomous driverless cars. Potentials, challenges, and risks vary between these different kinds of applications and among the different levels of transport systems that range from single vehicles to whole transport networks.

At the vehicle level, automation (as yet the 'old' technology of automatic transmission) can contribute to more fuel-efficient driving by having the car choose its optimum operation mode based on its own optimised rationale. More important, the introduction of systems that actively influence the driving behaviour (e.g. proximity radars linked to the braking system) can contribute to reducing the still significant numbers of fatalities in road traffic.[76] When it comes to full autonomous driving, the integration of multi-sensor information is an important issue as the information from the necessary

[76] See Campbell et al. (2010),p. 4667.

multitude of different types of sensors may be inconsistent.[77] The autonomous vehicle has to integrate this information to build the base for its own operational decisions.

At the platooning level (e.g. small to medium numbers of vehicles / vehicle convoys involved in an actual traffic setting), the coordination of vehicles is crucial. Approaches range from centralised decision-making (e.g. by a platoon-leading vehicle) to cooperative exchange of information between the various vehicles in a platoon, and even fully independent behaviour of the single vehicles is also an option.[78] Additionally, the distribution of information across vehicles can ensure safety: vehicles that spread warnings are expected to improve the collective reaction to dangerous situations. Thus, neither the centralistic approach (implicating complex requirements for the leading vehicle) nor the fully independent vehicle (by giving away advantages of cooperative communication) seem to be optimal solutions.[79] It is then about the actual implementation of vehicle to vehicle communication, coming down to technical questions of e.g. where on a vehicle to place necessary antennas.[80] Autonomous platooning has been included in the AFS scenario as a promising approach for more efficient road freight transport.

At the transport system level, autonomously cooperating vehicles and driver assistance systems that rely on communication across vehicles (and on communication with infrastructure, e.g. traffic signs and traffic lights, and with data sources providing additional information, e.g. on weather conditions) can lead to a more efficient usage of infrastructures (cf. Figure 13). In densely populated areas, this can eventually help to reduce congestion. For achieving this, systems that control traffic flows on whole road networks or segments of these networks are developed. In the case of Baskar, Schutter and Hellendoorn, the system introduces – in contrast to the above mentioned platooning strategies – again some centralistic, "hierarchical traffic control architecture"[81]. These traffic control systems are "particularly challenging"[82] because of the heterogeneity of data sources. Apart from technical issues (cf. antenna example above), challenges in automation also refer to human mannerism and habits. Saffarian, Happee and Winter simulated driving in fog where drivers felt more risky when loosing visibility of the car in front while the distance was still being controlled automatically.[83] Automated driver assistance systems should therefore include such 'irrational' aspects to balance actual and subjective safety.

More important, authors refer to an unpublished study of the American Federal Aviation Administration that showed that "overreliance on automation"[84] and loss of routine can contribute to accidents caused by a failure of the automatic system. As long as automation only assists, this means that a careful balance with drivers' capabilities is necessary.

Security against misuse and manipulation of communication channels and autonomous vehicles is another issue of major relevance.[85] It even comes to complex ethical and normative considerations

[77] See Li & Leung (2004).

[78] See Michaud et al.(2006).

[79] See Michaud et al (2006), p. 444.

[80] See Bergenhem, Hedin & Skarin (2012).

[81] Baskar, Schutter & Hellendoorn (2012), p. 838.

[82] Campell et al. (2010),p. 4669.

[83] See Saffarian, Happee & Winter (2012).

[84] Knight (2013).

[85] Cf. similar considerations for ad-hoc wireless communication networks in: Ben Othman & Mokdad (2010).

when it is e.g. reflected whom an autonomous car should hit and kill in the case of an inevitable fatal accident. It is in question, if and how the respective 'rules' of moral decision-making can be implemented in autonomous technical systems.[86] In case of an actual accident, the issue further affects considerations about responsibility and accountability (the 'driver', the vehicle manufacturer, the vehicle as a new form of legal entity itself?).

Finally, it is in question if and how increasing automation could lead to rebound effects and modal shifts that could again influence the transport system: Driving in autonomous cars that allow for working or leisure activities during the ride could make the road individual car mode again more attractive compared to the more eco-efficient modes of public transport, cycling and walking. This issue could be especially relevant as elderly and retired people are expected to be more active in the future.[87] Supported by the future availability of autonomous cars or driver assistance systems that prolong the ability to drive, efforts towards the modal shift to generally more eco-efficient modes might be directly counteracted.

The ambivalence of automation technologies apparently shows the need for an integrated perspective on potentials and risks regarding applications in the transport sector. Technology assessment can provide this integrated perspective. Technology assessment studies on the implications of automation in the transport sector would be seamlessly in line with the requirements of Horizon 2020 that shall ensure responsible research and innovation.[88]

5.6. Integrated ticketing

„Promoting a more wide-spread and universal use of integrated payment systems could also contribute to an improved travel experience for the passengers and therefore increasing public transport usage."

Informal Meetings of Ministers, Nicosia 16.–17.07.2012[89]

Having an intermodal mobility card usable in all urban areas in the EU was part of scenario II that entails a number of measures to lead to a modal shift of passenger transport towards public transport. One of the key barriers to use public transport for people that are unfamiliar with public transport usage is "a lack of information and motivation, and incorrect perceptions of the alternatives to the car".[90] The overall idea of integrated ticketing is to combine several modes of transport (e.g. tram, bus, car-, and bike-sharing) on a single ticket and thus facilitate access to public transport and offer tailor-made services to their users. Ticketing practitioners agree that it offers a variety of benefits to end-users that paper based tickets cannot offer. It is perceived to "be a lot more reliable, convenient, faster and easier to use"[91], and that it delivers a much better overall product with greater flexibility within tariff structures.[92] Though, it is not only a means of payment but a source of huge amounts of information on transport usage including mode choice, travel, and waiting times. This opens up new

[86] See Bendel (2013).

[87] See deliverable 2 of the project: STOA (2011a).

[88] See CEC (2011c)

[89] Retrieved from: http://www.cy2012.eu/index.php/en/file/b2KSi_qGBxf2nxXo9+AUZw

[90] Brög, Erl, Ker, Ryle, & Wall (2009), p. 281.

[91] AECOM (2011), p. 10.

[92] See AECOM (2011).

opportunities in service provision and for a better exploitation of the network's capacity. On the other hand, it includes potential risks for privacy and data protection.

For many years, public transport operators have been trying to replace paper-based tickets by electronic media and many countries have already or are about to introduce integrated ticketing schemes.[93] But schemes have not yet been implemented on a wider scale in Europe. So far existing schemes have remained relatively small and mutual acceptance is currently not possible.[94] However, there seems to be a considerable potential for integrated ticketing within Europe. According to the Flash Eurobarometer on the future of transport, one in two EU citizens said they would definitely use public transport more frequently if a single ticket for their complete journey covering all possible modes of transport was available (cf. Figure 14). Especially 15-24 year olds, students, metropolitan residents, and non-working respondents were more likely to give this answer. Interestingly, about 43% of car drivers said they would definitely use public transport more frequently if a single ticket for all means existed.[95] The survey conducted during this project points into a similar direction. Almost 80% of the stakeholders found the idea of an interoperable ticketing system desirable or very desirable. The main factor to impede the development was seen in "uncoordinated institutional action" that almost 65% identified as a barrier for the introduction. Nevertheless, 65% believe that an integrated ticketing system for Europe will come true before 2030.

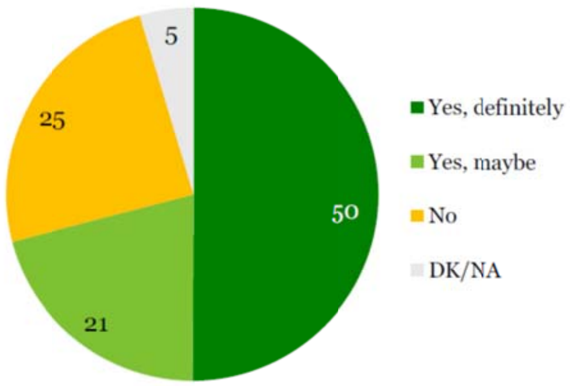

Figure 14: Would respondents consider using public transport more frequently if it would be possible to buy a single ticket covering all possible transport modes? Source: CEC (2011d).

There are different generations of ticketing: paper tickets, magnetic stripe cards, contactless ticketing (using RFID or near-field communication (NFC)), or mobile ticketing (using short message service (SMS), mobile barcodes, or NFC) – in some cities or regions they even co-exist.[96] Today, most ticketing applications use smart cards with RFID technology from a variety of suppliers. Modern multi-application smart cards are able to incorporate different fields of application (e.g. library, leisure, financial schemes) by storing different data in separated secure elements. The most successful schemes in Asia, such as the Octopus Card in Hong Kong or EZ Link in Singapore are characterised by such special features. Additionally, the front-end and back-office systems in use are different; each scheme

[93] See Stroh, Schneiderbauer, Amling, & Kreft (2007).

[94] See International Association of Public Transport (2007).

[95] See CEC (2011d).

[96] See Mezghani (2008).

has its own specific set-up.[97] However, according to a consultation with an international panel of practitioners, the technology of the future will be driven by NFC-capable mobile phones.[98] But also the other way round, ticketing is expected to be one of the main drivers to bring NFC technology forward, with public transport being a likely platform to do so. Since most contactless operating systems in public transport use RFID technology, the existing infrastructure is compatible with NFC standards in most cases (sometimes an upgrade for interoperability with NFC is needed). Other features, such as tickets to amusement parks, museums, events, theatres, etc., are also potential applications for multi application smartcards and NFC and could be embedded into the schemes.[99]

The key benefit of interoperable ticketing for customers is that a number of operators work together and combine their products on a single card, ideally throughout different operating regions. In order to make a system interoperable, standardisation is an important term. A difficult undertaking, since the public transport market is "characterised by decentralised decision-making divided between public authorities and operators and the parcelling-up of a market that must cater for the needs of everyone, including people who do not have a bank account."[100] Furthermore, the market is characterised by a complex financing structure of various sources in which "the benefits of cooperation counterbalance the constraints of competition."[101] One of the main barriers for a large-scale implementation is the difficulty in agreeing on standards that all stakeholders involved are satisfied with. Especially operators or countries that have already introduced an integrated ticketing scheme do not want to give up initial investments they have already undertaken. Additionally, it seems to be difficult for government bodies and transport operators to agree on how and what to fund.[102]

The EU could help in providing the necessary strategic guidance. One of the most important actions is to encourage partnership between those involved in the implementation process. Besides public transport operators and authorities also financial service providers, mobile phone providers, standardisation bodies, and public transport users play a role in the implementation process. It seems that there is a need for organisational-, management-related, and governance-related changes to make integrated ticketing systems come true. Encouraging knowledge exchange and research into new technologies and, thus, the support of technological convergence could be managed by national or even European government bodies.

5.7. Access instead of ownership

"It is not a threat for the industry because the people who will be sharing cars tomorrow are not using them today,"

Ayoul Grouvel, head of Peugeot EV projects, to EurActiv[103]

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[97] See AECOM (2011).

[98] See AECOM (2011); Stroh et al. (2007).

[99] See VTT (2009).

[100] de Chanterac (2009), p. 24.

[101] de Chanterac (2009), p. 29.

[102] See austriatech et al. (2011).

[103] Retrieved from: http://www.euractiv.com/specialreport-electric-vehicles/driving-2030-news-514929 (23.04.2013)

Shareconomy was this year's keynote theme at the world's largest business event for digital IT and telecommunications solutions, the CeBIT in Hannover, Germany. Sharing economy, or collaborative consumption is used to describe that a growing population seems to value access (e.g. to cars, software, or information) over ownership. The discussion about access instead of ownership is not new[104] but modern information and telecommunication technologies brought it to a next level as they bring together demand and supply in an efficient way.[105] The transport market is also affected. Car sharing and bike sharing have been established in an increasing number European agglomerations and regions. In May 2011, around 100 cities in 18 European countries have implemented bike-sharing schemes with almost 100.000 bikes and more than 7.200 stations. The largest schemes have been implemented in France, Spain, and Italy – countries that are not explicitly known as cycling friendly.[106] Car-sharing growth has occurred in nearly all car-sharing countries, with the biggest growth rates in North America. North America has now replaced Europe in being the epicenter of car-sharing activity (cf. Figure 15).[107] Even though, car-sharing does not have particularly high shares yet there seems to be a huge potential in the market.[108] Enormous dynamics are involved and related approaches are going on that accelerate the growth of the market.

Traditional car rental companies like Sixt, Hertz, or Avis have entered the car-sharing market and likewise most of the biggest car manufacturers have taken up the topic and are trying out new mobility services. BMW, Daimler, VW, General Motors, Honda, Mitsubishi, Suzuki, Toyota, and Peugeot have all entered strategic partnerships or have set up car-sharing programs.[109] Daimler was the first to set up a professional car-sharing scheme. The so called Car2Go is currently serving 18 cities in Europe and North America, being the fastest growing car-sharing company in the world.[110] Daimler's Car2Go, BMW's DriveNow, Hertz on Demand, CommunAuto and Autolìb, they all operate so called free floating (or point-to-point) car-sharing schemes, meaning that users can start and end at any point within a specified area, allowing one-way journeys. In October 2012 free floating car-sharing schemes are operated in seven countries worldwide.[111]

[104] See e.g. de Meza & Gould (1985); Truesdell (1992).

[105] See STOA (2011c).

[106] See Shaheen & Guzman (2011).

[107] See Shaheen & Cohen (2013).

[108] See Frost & Sullivan (2009) and Shaheen & Cohen (2013) for car-sharing trends and Shaheen & Guzman (2011) for bike sharing trends.

[109] See Shaheen (2011).

[110] See Daimler (2013).

[111] See Shaheen & Cohen (2012).

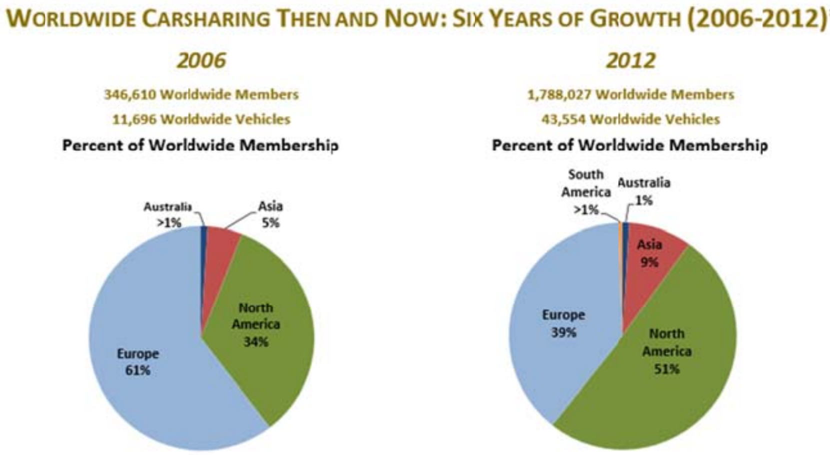


Figure 15: Worldwide Carsharing Then and Now. Source: Shaheen & Cohen (2012).

Since 2007, another promising approach broadens the car-sharing market worldwide. So called personal vehicle sharing (or peer-to-peer sharing) is an extremely new form of car-sharing where privately owned cars are offered to others for short-term access. In May 2012, 33 personal vehicle sharing operators existed worldwide, with 20 of them being located in Europe.[112] Operators do not offer the vehicles but make transactions among car owners and renters possible by providing the organisational resources needed (e.g. online platform, customer support, insurance, and technology).[113] A great hindrance to this form of car-sharing is the need of the renter to somehow receive the key to the car. Carzapp, a young German start-up company, addresses this issue by providing a technology that enables users to locate subscribed cars and open them with their Smartphone. The key is then located in the glove box.[114] This "unattended access mechanism" can also be provided by lockboxes, key fobs, or smart cards. While traditional car-sharing is usually located in high-density urban areas, personal vehicle sharing has the potential to expand to the suburbs. However, the worldwide potential for personal vehicle sharing is yet unclear.[115]

But not only cars and bikes can be shared, parking spaces seem to be suitable sharing objects as well. Shared parking is a type of parking management that enables users of parking facilities to offer their space to others when currently not needed. Since parking facilities often follow predictable daily, weekly, and annual cycles, shared parking allows for more efficient utilisation. Living in one location and working somewhere else often makes parking space available that can then be offered to others. The idea of young start-ups in France, UK, and Switzerland is that offering privately owned or blocked parking spaces that are publically available (such as carports or driveways) can help to create a parking network all around a city. The Parku AG in Switzerland for example offers its service in Zurich to individuals or companies that can register online. Available parking spaces can either be found via a Smartphone App or on the company's homepage. In one month, the App was downloaded 1.500 times; around 10% of the users are already using the service regularly.[116]

[112] See Shaheen, Mallery, & Kingsley (2012).

[113] See Shaheen et al. (2012).

[114] See Knoblach (2013).

[115] See Shaheen et al. (2012).

[116] See Weber (2013).

The rise of the sharing economy is highly relevant because it combines several advantages. Sharing instead of ownership increases efficiency in the car-sharing market because it has the potential to reduce land consumption through a substantial reduction of the numbers of vehicles in the city.[117] Car-sharing could also be an interesting niche-market for alternative fuels and propulsion technologies since the idea is to choose the vehicle according to the given circumstances. EVs could thus be used for inner-urban trips and vehicles with a range extender for longer trips. With bike-sharing the key advantage is the availability of bikes; cycling becomes a visible transport opportunity and is especially interesting for the "last mile". Using shared vehicles supports a more flexible handling of the transport system and thus meets the requirements of the new generation.[118]

Public authorities can support this broad range of private activities without high investments by supporting or implementing (depending on the political level) regulations and incentives that facilitate the usage of such approaches, e.g. of special parking spaces designated to car-sharing or bike-sharing vehicles and/or by the permission of using bus lanes, by information campaigns addressing the easy handling of sharing vehicles and the easy access to them.

5.8. Shift to rail

"To achieve a well-functioning European rail sector Member States must commit to investing in rail infrastructure, in line with the commitments made in the negotiations on the Trans-European Networks and Connecting Europe Facilities."

Matthieu Grosch, Member of the European Parliament[119]

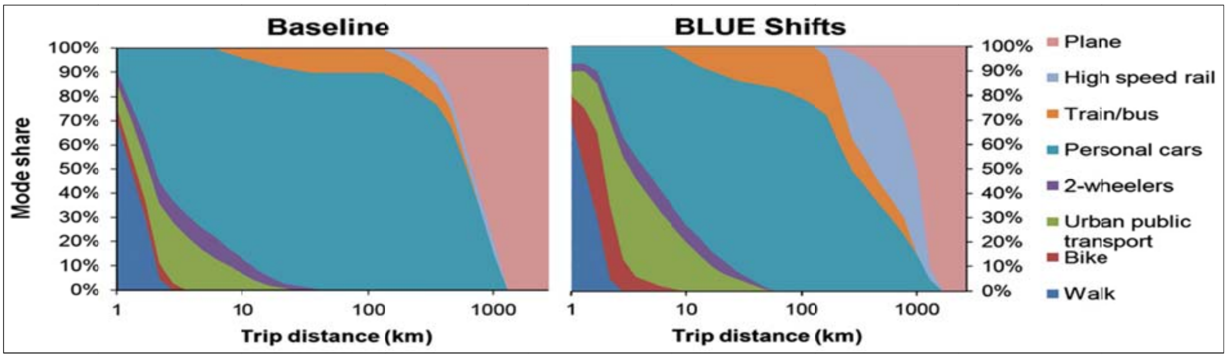


Figure 16: 2050 modal shares in passenger transport in the scenarios analysed by Cuenot/Fulton/Staub (2012, p. 104).

Shifting physical transport towards more resource-efficient modes of transport is, of course, at the core of scenario 2 'modal shift'. While modal shift at the local and regional level is mostly about a shift to local public transport (that can also include railways) and to slow modes (bicycle and walking), modal

[117] See Firnkorn & Müller (2011).

[118] See STOA (2011c).

[119] Cited in Spence (2013).

shift for medium and long-distance travel and transport aims at increasing the share of railway transport (and inland water transport (IWT) and short-sea shipping as well).

Den Boer et al. assess the general potential of modal shift to rail but argue for the necessity of giving better estimates of the achievable scale of such a modal shift.[120] While they refer to maximum achievable rail shares in freight transport of about 31–36%, the numbers for the passenger transport sector are not so clear. However, they report potential reductions in transport CO_2 emissions of up to 7% and up to 9% for freight and passenger transport, respectively.[121]

Cuenot et al. as well see significant potentials for modal shift. For the passenger transport sector, Figure 16 highlights the specific importance of high speed rail, competing against road and air transport in a specific corridor of trip lengths (up to ca. 1000km, today dominated by air transport).[122] While such gains of the rail mode are generally favourable, it must be taken into account that gains through increased speed (corresponding to higher competitiveness) could outweigh the positive effects on absolute resource consumption through rebound effects.[123] Generally, an improvement of infrastructures for long-distance travel could further an increasing interconnectivity of countries and regions, followed by increased demand.[124]

A level-playing field between transport modes is crucial to achieve the modal shift towards the most eco-efficient modes. As today actual external costs are often not represented reasonably in road and air transport costs (e.g. road infrastructure costs), the rail sector suffers from competitive disadvantages for having already internalised most of these costs.[125] Mobility pricing is one approach to overcome this imbalance through incorporating all relevant costs which then allows for optimal choices not only from a singular business economics perspective but, finally, from the social and environmental perspective as well – both for freight and passenger transport.

For the freight sector, the European Rail Research Advisory Council (ERRAC) – beyond purely technical measures – stresses e.g. the importance of flexible local distribution, interoperable and reliable information systems for operators and clients, and faster and seamless train operation.[126] Similarly, ERRAC addresses the need for seamless, comfortable, and convenient passenger travel, making use of an extended high speed rail network, integrated ticketing (cf. section 5.6) and incorporation of rail transport issues in spatial planning.[127]

Operators will have to further improve railway operation in the rail sector beyond the given state of eco-efficiency e.g. by targeting the "halving [of] the specific final energy consumption from train operations by 2050 compared to the base year 1990"[128]. Within the SHIFT2RAIL Joint Technology Initiative[129] the European rail sector is working on the necessary technological contributions to further

[120] See Den Boer et al. (2011), p. 5.

[121] See Den Boer et al. (2011), p. 5-6.

[122] See Cuenot et al. (2012).

[123] See den Boer et al. (2011), p. 6.

[124] See Cuenot et al. (2012), p. 105.

[125] Other external costs (e.g. noise, air pollution) still lack internalisation in all transport modes.

[126] Olsson & Irwin (2012a), p. 3–4.

[127] Olsson & Irwin (2012b), p. 41-42.

[128] ERRAC (2011), p. 27.

[129] See http://www.unife.org/page.asp?pid=194

improve the railway systems. Some countries have already electrified their rail network completely while others still rely on diesel engines in significant parts of their networks. The electrification of these networks offers the potential to use 'green' electricity sources and is therefore an important goal. More important, all of the desired modal shift will not be possible without the general upgrade and extension of railway infrastructures: ERRAC targets a "50% increase of capacity from existing infrastructure"[130]. As this is publicly owned infrastructure in many cases, this requires political commitment and comprehensive and consistent public engagement regarding strategic and financial terms. On the EU level, this issue is addressed by the 'Fourth Railway Package' announcing a number of legislative measures and urging for a "strategic integrated approach".[131]

In phase 4 of the project, most stakeholders in the workshop considered a shift to rail as a very desirable measure with a wide range of positive impacts on the transport system and beyond. But the feasibility was assessed clearly less positive and it was partly discussed controversially. The stakeholders stressed the need for coordinated action: Depending on the status quo of transport infrastructures, in some countries with not so dense highway networks, policy still sets high priority on upgrading their road networks even if there were large financial contributions from the EU available for the upgrade of railway infrastructure. This shows that there is still a long way to go to actually shift the transport to rail.

5.9. Shift to short sea and inland shipping

Thesis 10: The freight transport volume (tkm) on inland waterways will increase by 50% (compared to 2012)

Thesis 11: In waterborne transport, operational improvements (e.g. speed reduction, autopilot upgrade) and new technologies (e.g. alternative propulsion systems, propeller design, auxiliary use of wind power) will lead to a reduction of greenhouse gas emissions by 50 % (compared to 2012).

Figures from the statistical pocketbook 2012 help to get an impression of the performance of EU-27's waterborne transport in 2010.[132] For IWT, 147 billion tkm are assumed, for the maritime mode with 1415 billion tkm. This relates to a modal split of approximately 3.8% for IWT[133] and 36.9% for the maritime transport mode[134] (related to the European freight sector). The total waterborne CO_2 emissions (% of total transport CO_2 emissions, including international bunkers) in the EU-27 are assumed to be at 14.6% by 2009, out of which domestic navigation accounts for 10.7%.[135]

One of the key challenges regarding the White Paper goals for 2050 is to shift long-distance freight transport to cleaner modes: "30% of road freight over 300 km should shift to other modes such as rail or waterborne transport by 2030, and more than 50% by 2050, facilitated by efficient and green freight corridors."[136] Also the STOA scenarios presented in this report underpin the important role of maritime shipping for the future eco-efficiency of European freight transport. Usually, it needs to be distinguished between maritime shipping and IWT, which is not done in the scenarios for reasons of

130 ERRAC (2011), p. 33.

131 CEC (2013a), p. 10.

132 See CEC (2012), p. 36.

133 The split for IWT in freight inland transport modes is estimated at 6.1%.

134 These figures only apply to domestic and intra-EU-27 transport.

135 See CEC (2012), p. 130f.; CEC (2011b).

136 CEC 2011a.

simplification. However, there are some similarities between the challenges and the discussed solutions for both sectors (maritime and IWT) so this will be jointly discussed in the following. Nevertheless, some specifications for IWT will be mentioned as well.

The results from the stakeholder consultation indicated that, on the one hand, the modal shift scenario II was assessed as the most realistic one and as the most relevant one for reaching an eco-efficient transport system. On the other hand, the survey and the discussions at the stakeholder workshop demonstrated well that there are gaps between the perceived desirability and the perceived feasibility of the measures in the scenarios. The stakeholder assessment of theses 10 and 11 (both related to waterborne transport) shows limited knowledge regarding waterborne transport. Still, 50% of the respondents believe that the capacity limits of the infrastructure could impede growth of freight volumes on inland waterways (thesis 10). However, these responses were not detailed enough, to determine whether this results in environmentally difficult projects (i.e. such as new canals in order to prevent congestion thus increasing capacities on waterways in general) or in an improved utilisation of existing waterway capacities. Due to the existing capacity for the river Rhine in the medium-term perspective, the latter was mentioned as one of the key arguments to support IWT. Without the intended IWT waterway improvements (e.g. modernization/adaptation of bridges, locks, fairway depths and new links), however, the IWT modal share is assumed to stagnate or decrease in the long term as compared to other modes.[137]

One of the most promising pathways towards a modal shift is the establishment of interchanges between cleaner modes (ship/rail). A further development of the multi-modal infrastructure capacity would be to improve the hinterland connectivity from sea ports to inland ports and onwards to the respective destinations in order to provide logistics chains that are attractive to the customer as well as to increase freight capacities in general.[138] Figure 17 illustrates the locations of the sea ports and corridors in the assumed core regions.

[137] See Platina & Naiades (2010), p. 53; 58; 66.

[138] See CE Delft et al. (2012).

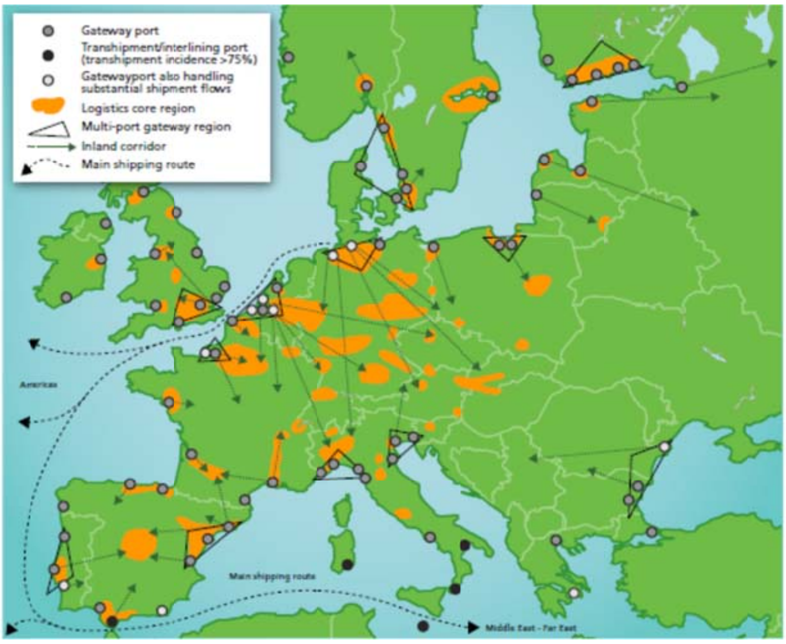


Figure 17: Illustration of waterborne freight transport gateways, which depend on IWT waterways. Source: Platina, Naiades (eds.) (2010), p. 18.

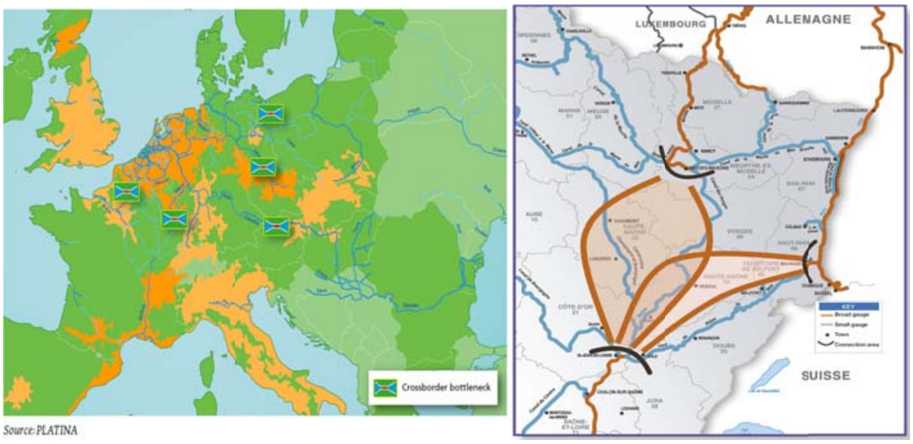
In spite of the high heterogeneity and complexity of regarding the different goods that are delivered by waterborne transportation (e.g. bulk vs. container, piece goods transport), some generalisations are possible to illustrate the potentials in and the barriers of identifying "key fields of action" that are focussing on the modal shift.[139] In the short and medium term, ICT applications are a promising option for closing the aforementioned gap between desirability and feasibility. In combination with standardisation, such as efficiency standards[140], it could help monitor ongoing progress and developments in the efforts to enhance GHG savings in combination with additional maritime observations. Multi-modal ICT solutions that are 'neutral and safe' in terms of data and business security as well as in terms of certainty of operation, offer in the short and medium term an opportunity to increase freight capacities within existing infrastructure systems. As an example for inland shipping, the River Information Services (RIS) may foster "the interoperability between the different modes of transport and their corresponding information systems and services"[141]. The RIS is embedded in the 'Internet for the cargo` concept which aims at covering the whole logistics chain in order to increase the general cargo flow (cf. key area smart logistics) of door-to-door services. Some European projects (like e-maritime and e-freight) continue work on these issues in order to develop possible solutions.[142]

139 See CE Delft et al. (2012); DST (2013) and Maddox Consulting (2012).

140 The SEEMP (Ship Energy Efficiency Management Plan), the EEDI (Energy Efficiency Design Index) as well as the EEOI (Energy Efficiency Operational Indicator) could all be useful instruments for the International Maritime Organisation's Marine Environment Protection Committee (MEPC).

141 Schilk & Seemann (2012), p. 630.

142 Available at: http://www.emaritime.eu/default.aspx?articleid=1095&projid=31; http://www.efreightproject.eu/default.aspx?articleID=1126 (access: 20/04/2013).



Source: PLATINA

Figure 18: (left): Illustration of identified cross-border bottlenecks that will impede a future IWT network connectivity. Source: Platina, Naiades (eds.) (2010), p. 37. (right): Illustration of the Saône-Rhine project (source: Mialocq (2012), presentation of the project, held at the UNECE working Party on the Standardization of Technical and Safety Requirements in Inland Navigation (41st session), 20 - 22 June 2012 in Geneva).

In the medium and long term, it is not clear if these measures are sufficient to cope with the future transport demand. A further option, in the long term, is to remove existing infrastructure bottlenecks.[143] Figure 18 presents an overview of identified cross-border bottlenecks that may impede a future IWT network connectivity.

The Saône-Moselle/Saône-Rhine project (a missing link) is mentioned as an example for other infrastructure projects. This project should help to balance all modes in a tri-modal way (i.e. good synergies of all modes).[144,145] The project of constructing a canal between Saône-Mosel and Saône-Rhine (cf. Figure 18), will create a waterway between the deepwater ports (ZARA) in the north and the Mediterranean Sea. It will strengthen the most-used and well-established European waterway Rhine,[146] especially in view of the parallel establishment of the north-south transversal railway line (TEN-T Priority Project 24). Synergies between different EU projects and tri-modality seem feasible.[147]

But infrastructure projects often come along with negative environmental impacts (ecological footprint). This is often accompanied by a lack of social acceptance. A recently much-discussed example for the multi-complexity of infrastructure extension is the Elbe dredging project in the Port of

143 'Bottlenecks' in IWT are composed of three elements. A basic bottleneck is where the current infrastructure does not sufficiently fulfil minimum standards for navigability (e.g. vessel dimensions of 80 m x 9.5 m). A strategic bottleneck fulfils the basic requirements, but ought to be modernized in order to raise waterway network quality and freight capacity. Missing links (the third element) do not exist at present, but play an important role for the future IWT network.

144 Cf. presentation of the project, held at the Working Party on the Standardization of Technical and Safety Requirements in Inland Navigation (41st session), 20 - 22 June 2012 in Geneva. Available at: http://www.unece.org/fileadmin/DAM/trans/doc/2012/sc3wp3/ECE-TRANS-SC3-WP3-2012-Pres02-e.pdf (access: 20/04/2013).

145 See Mialocq & Chaban-Delmas (2012).

146 See CE Delft et al. (2012).

147 See TEN-T, Priority Project 24. Available at: http://tentea.ec.europa.eu/en/ten-t_projects/30_priority_projects/priority_project_24/priority_project_24.htm, and CODE 24: http://www.code-24.eu/(access: 26/04/2013).

Hamburg.[148] The project is confronted with the challenge to mediate between different interest groups (i.e. ecological, economical, and social ones). Proponents argue that an extension of the Elbe is needed, not only for economical but also for ecological reasons since otherwise goods would be carried in a less eco-efficient manner on the road. Opponents argue that the consequences for the local eco-systems were very negative. The importance of these issues as "key fields of action" was also reflected in the survey responses as *"[…] lack of political visions, uncoordinated institutional actions/responsibilities, and differing interests of involved stakeholders (e.g. politicians, industry, NGOs) […]"* (see Del. 4).

„Take 'greening the fleet' […]. Much of today's road haulage uses cleaner and more modern engines than inland waterway transport. A lot of the fleet is also now quite old. In fact, it is no longer that green."[149] In a nutshell, Kallas points out what is assumed in several studies for maritime and inland shipping. In principle, waterborne transportation is a comparatively environmentally friendly way of freight transport, at least in terms of direct CO_2 emissions and energy transport intensity. Nevertheless, the biggest challenge is the average age of the vessel fleet. Especially the relatively high contribution to nitrogen oxide (NO_x), particulate matter (PM), and sulphur oxide (SO_x) emissions is still a challenge.[150] As discussed in the STOA interim report Del. 2b, a wide range of technology options is available to reduce emissions and to improve eco-efficient shipping. Ships (e.g. main engines) have a generally long lifetime that is assumed to be around 30 years.[151] The high investments in combination with their long lifetime, i.e. their economical amortisation time, may be a factor that leads to investment barriers in new eco-efficient technologies (e.g. engines with new emission standards or other fuels, such as LNG) because this poses a business risks. But how can a 'greening' of the existing vessel structure in IWT be reached? At the same event where Kallas presented his keynote, Hans van der Werf also made a presentation[152] proposing a modernising strategy that takes into account the size of the ship as well as the economic, ecological, and technological possibility of retrofitting. This approach may consider the more diversified entrepreneurial structure of IWT (e.g. the demographic structure of shippers and the lack of qualified staff). Retrofitting vessels is a technical approach to reduce NO_x, PM, and SO_x emissions, as proposed by den Boer. For example, Selective Catalytic Reduction (SCR) and Diesel Particle Filters (DPFs) may offer possible pathways, as discussed in the STOA interim report Del. 2b. In order to introduce an after-treatment technology as well as new innovation technologies into the existing vessel structures, den Boer suggests a variety of measures such as regulations (e.g. tighter EU emission standards, also for older vessels in IWT), economic instruments (e.g. incentives, taxation/funds), as well as initiatives and/or voluntary agreements.[153]

LNG is also mentioned in the previous STOA report as a possible alternative propulsion system. The recently launched clean fuel strategy may be a further step to establish an innovation-friendly environment in order to offer the possibility to introduce alternative fuels and propulsion systems for IWT.[154] In this context, the high uncertainties about price developments of all kinds of alternative fuels have to be mentioned, especially with regard to low sulphur fuels (LSFs) or liquefied petroleum gas

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[148] See Spiegel international. Available at: http://www.spiegel.de/international/europe/dutch-study-dredging-damaging-elbe-river-ecosystem-a-895853.html (access: 26/04/2013).

[149] See Kallas (2013).

[150] See EEA (2013); CE Delft et al. (2012) and den Boer (2011).

[151] See CE Delft et al. (2012); Maddox Consulting (2012).

[152] See Van der Werf (2013). Hans van der Werf is Secretary General of the Central Commission for the Navigation of the Rhine (CCNR).

[153] See den Boer (2011).

[154] See CEC (2013c); CEC (2013f), p. 4.

(LPG) and their possible impacts on operational costs (e.g. to pass the break-even point). Existing studies illustrate the high complexity in the modelling of these issues. As regards the competition between waterborne and road transportation, much attention should be paid to identifying possible negative modal shifts (rebound effects) and to prevent distortions of competition.[155,156] Particularly in the case of new infrastructure projects, it is absolutely necessary to get a complete picture, i.e. knowledge of their direct as well as of their indirect environments, in order to investigate impacts (e.g. polluter-pays principle) with a long-term focus. Notwithstanding the possibility of a need for action regarding infrastructure (TEN-T initiative), the following recommendations concentrate on the most promising pathways in the context of eco-efficient transport. They are supporting fields of action in which the measurements should be understood as packages addressing technical, operational, and political actions:

- Supporting all measures to develop and introduce a secure, neutral, multimodal ICT transport network system (open interfaces) in order to increase load factors and multimodality (all modes);
- Forcing the introduction of technical innovations like alternative fuels and propulsion engines (e.g. LNG) via standardisation (e.g. EEDI – Green Ship Award) through smart-incentive regulations (e.g. step-by-step modernisation of vessel fleets and retrofitting of older vessels with auxiliary techniques (after treatment techniques));
- Resolving strategic infrastructure bottlenecks to increase multimodal freight flows (e.g. TEN-T projects) and retrofitting (maintain, repair, and upgrade) infrastructure (e.g. bridges, locks, as well as tri-modality of ports/hubs with viable ICT and alternative fuel requirements)
- Accompanying and enhancing technical innovations by R&D to enable a better assessment of positive and negative impacts of action (as to prevent rebound effects) and to adapt smart regulations
- Bringing stakeholders together and closer to an eco-efficient logistics market (e.g. support education and qualification as well as communication from R&D) in all modes in order to create a broad range of acceptability for infrastructure projects.[157]

5.10. Awareness of habit and attitude changes

"For us in Karlsruhe the car is not that important anymore as it used to be, I think."
Participant of the German interview meeting that was conducted as part of the STOA project on urban transport (12.07.2011).

User perceptions and attitudes are highly relevant if considering measures and approaches to eco-efficient transport. During the workshop stakeholders argued that there is a need for a better understanding of people's travel demands and user behaviour, not just as consumers but as citizens. It has been noticed that the industry could profit from a better understanding of the transport needs and behaviour in order to foster changes.

[155] Notteboom notes that this study was conducted from a purely economic perspective and further research should address its ecological impact in the overall emissions. Furthermore, he notes that if no backshift effect took place, the operational costs would be lower than calculated (cf. Notteboom 2011).

[156] See Lemper (2010); Notteboom (2011).

[157] See CE Delft et al. (2012), p. 155 ff., 169 ff.

In this project, two of the three scenarios explicitly consider user behaviour as a crucial element. To successfully foster modal split (scenario II) or to reduce trip length or volumes (scenario III) relies heavily on the users transport patterns and their willingness to and readiness for changing habits and routines. But also scenario I cannot be thought of without taking into consideration user preferences. E.g., when it comes to buying new cars that are cleaner or have even completely new propulsion technologies consumer decisions are also highly relevant. The consumers are the ones to accept or reject cleaner technologies, but other than decisions on the mode or trip length, these decisions are reflected more thorough and taken deliberatively. Daily transport behaviour is very much dominated by habits and routines. Habits and routines are behavioural patterns that, under ordinary circumstances, are repeated on a daily basis. They develop over longer periods of time and are usually carried out with very little conscious deliberation.[158] Especially medium and long-term decisions (frequency, mode choice, times and speed) are often habitual. On the other hand, long-term decisions, such as vehicle ownership, the type of vehicle, or the choice of residential location occur relatively rarely.[159]

In transport research and related prospective analysis, the focus is often on the potentials and on the environmental performance of new technologies and infrastructures. There is no lack of ideas and visions of how sustainable urban transport futures could look like. These are often expressed in scenarios that illustrate the implementation of new technologies and organisational concepts in order to make transport cleaner, support a shift to more environmentally friendly modes of transport, or to contribute to a substitution of trips. Much can be found on the technical and economic presupposition and performance of such innovative approaches but, in general, less attention is put on the demand side, namely, on the attitudes and perceptions of the users or 'consumers' of the transport system. However, it is increasingly acknowledged that users matter.[160]

And indeed, there is evidence that changes in transport related behaviour are happening, especially concerning long-term decisions. On the one hand, younger people in urban areas show a more pragmatic attitude towards cars and car ownership and they use the car significantly less compared to the same age group ten years ago. Car ownership and kilometres driven decrease in this age group in many industrialised countries[161] On the other hand, the generation 60+ has a more active lifestyle than the generation before which is also expressed by an increase in private motorised transport usage.[162]

Transport-related choices are more than rational economic decisions; decisions of where to go by which means of transport essentially depend on attitudes, perceptions, and on norms and values. Users matter for the success or failure of approaches towards sustainable urban transport systems. This is important to note since users are also consumers; and indeed, the stakeholders argued during the workshop that new transportation modes should be planned, developed, and implemented "closer to the costumers". But transport users are also citizens that might vote for or against certain transport policies. In order to understand successful pathways to eco-efficient transport it is essential to take into account the dynamics in user behaviour as well as the users' attitudes. Changes occur not only on

158 See Jackson (2005).

159 See Schlag & Schade (2007).

160 See STOA (2012) for more literature.

161 See e.g. STOA (2012); Vortisch et al. (2012); Kuhnimhof et al. (2012); Davis & Dutzik (2012); Institut für Mobilitätsforschung (ifmo) (2011); Frändberg & Vilhemson (2011); Sivak & Schoettle (2011); Fachhochschule der Wirtschaft – Center for Automotive (2010); tfactory (2008); Raimond & Milthorpe, (2010); Holz-Rau, Scheiner, Weber, & Klöpper (2010); infas and DLR (2010); Ruud & Nordbakke (2005).

162 See e.g. Vortisch et al. (2012); Rosenblom (2001).

the supply side of the transport system, driven by new technologies, business models, and policy measures. There is evidence that also on the demand side flexibility and potential for changes is present, and further changes in user behaviour can also be expected in the future.

5.11. Urban design

"Better planning can help cities benefit from greater mobility as well as better air quality, reduced emissions, less noise and a healthier urban environment. Moving towards a sustainable and efficient transport system will help enhance mobility and at the same time reduce pollution and improve the quality of life for citizens."
Janez Potočnik, European Commissioner for the Environment (2012)[163]

Scenario III of this project is about reducing the need for physical travel and about reducing distances, basically induced by a paradigm shift in land-use planning. During the workshop, stakeholders stressed that eco-efficient transport needs to consider what kind of cities Europeans want to live in – whether they are sprawled or compact and dense. European cities have traditionally been much more compact and dense compared to most cities in the US. However, today urban sprawl is also apparent in European cities, especially in southern, eastern, and central parts of the EU.[164] The compactness and density of cities have major impacts on transportation systems and on the way people use these systems. Urban design can either reduce or increase the need or distance to travel. Implying that urban sprawl induces more transport, it can be assumed that changes in the built environment have a considerable effect on mobility patterns.

In other words, urban forms and transport patterns are deeply intertwined. Different approaches of urban design and planning can assist in reducing travel demand. Key characteristics of sustainable urban structures are the distances from residential areas to city centres and to local facilities, mixing of land use, and the proximity to (public) transport networks. People who live and work in an urban environment with a suitable offer of public transport services within walking and cycling distance, tend to drive less than residents elsewhere (see Figure 19).

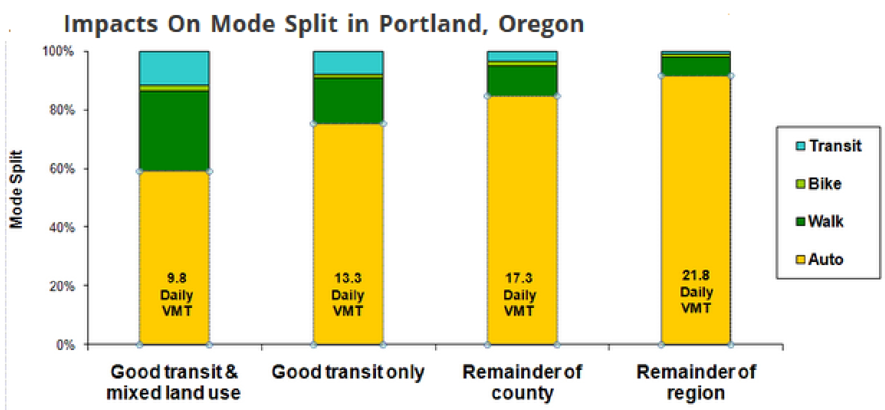

Figure 19: Impacts on modal split in Portland, Oregon. Source: Ohland, G. and Poticha, S. (2006), cited in Litmann, T. (2009).

[163] Retrieved from: http://europa.eu/rapid/press-release_IP-12-966_en.htm?locale=FR

[164] See EEA (2006).

In European cities, especially transport between suburbs has increased. Distances between areas of low density are usually too long for walking or cycling and do not generate enough travel volumes to make public transport economically feasible. Suburbanisation has increased the use and necessity of private motorised transport.[165] Urban planning must cater this development. A widely acknowledged planning strategy is "decentralised concentration"; the strategy aims at the improvement of existing infrastructures to suit the new framework conditions. It thus links the public demand for less dense living surroundings with the benefits of grouping together infrastructure and facilities.[166] Urban planners are important stakeholders to reduce transport volumes. According to Banister it should be the intention to "design cities of such quality and at suitable scale that people would not need to have a car."[167]

Plannig for an accessible urban area is essential for realising sustainable transport as land use often determines travel behaviour for many years. Walkable streets and a good and convenient cycling infrastructure foster most directly access to most local destinations such as schools, work, transit stations, and to items for daily supply. Further, encouraging mixed land use that integrates residential, commercial, institutional, and recreational areas tends to reduce distances and thus to increase the relative efficiency of transport modes.[168]

Increased regionalisation was a further aspect of this scenario meaning to produce goods closer to consumers. Many participants (42 %) answered not to know whether they found this development desirable or not, but five stakeholders found it desirabe or very desirable, compared to two who found it very undesirable or undesirable. The claim for a better integration of land-use and transport planning as well the related idea of decentralised concentration surely are not relally new appraoches. In many countries such approaches are discussed since decades.[169] However, it should be underlined here that such approaches are unavoidable to achieve long-term efficiency of the entire transport sector. These approaches need strong long-term political support. This should support be easlily possible since they seem top be compatible with nearyl all poltical agendas. Furthermore, it can be observed that new ideas are emerging that can support a reduction in trip length. One measure to reach greater regionalisation is urban agriculture or urban farming. The idea behind it is to move agriculture from the urban fringes to the centres, to rooftop gardens, backyards and balconies. Another example is vertical farming, technologically sophisticated skyscrapers several stories high situated at the heart of city centres that generate their own power from waste and cleaned sewage water.[170]

Of course, most policy measures are applicable at a regional level, but also the EU and national levels can promote sustainable urban designs. For example encouraging knowledge exchange and good practice guidance at all levels is something the EU is supporting and should further support. The EU could also promote sustainable urban designs through incentives, subsidies, taxes and funding programmes, e.g. by linking EU transport subsidies to sustainability guidelines to support integrated land-use planning at local levels or by offering assitance for new pilot projects.[171]

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165 See Pucher & Lefèvre (1996).

166 See European Conference of Ministers of Transport (ECMT) (2002).

167 Banister, D. (2008), p.74.

168 See STOA (2012).

169 See, for exmaple, Banister 2002

170 See Despommier (n.a.).

171 See CEC (2004)

5.12. Mobility pricing

"What was amazing was nothing went wrong. […] The only real problem we had were the buses were all running so ahead of schedule they had to wait at the bus stop for a couple minutes."

Ken Livingstone, former mayor of London, 10 years after the successful introduction of London's congestion charging system[172]

In the workshop discussion among stakeholders it was mentioned several times that also mobility management was needed to achieve more eco-efficient transport. However, there were definitely different opinions among stakeholders on how mobility management should look like. For example, the main controversies emerged on measures restricting car transport in urban areas. One of the potentially most effective and maybe also most controversially discussed approaches were pricing schemes for controlling or "managing" transport flows. Therefore, this approach was selected as a key area.

Fair and efficient mobility pricing can help to achieve the most "efficient" choices in transport behaviour. While different forms of road pricing are common by now (cf. e.g. the London congestion charging system introduced in 2003), mobility pricing approaches that cover all transport modes are more sophisticated and more ambitious. They can help to achieve modal shift to more efficient modes of transport (cf. scenario II) as well set conditions and incentives to decrease transport needs and to reduce trip lengths efficiently (cf. scenario III).

In densely populated areas, mobility pricing can reduce congestion and thus lead to higher average speeds in road transport, resulting in reduced travel time.[173] Road pricing can also contribute to improved air quality in cities and help to reduce casualties.[174]

Figure 20: Stockholm: Congestion charge pricing list. Source: Castleman (2007).

Directly reflecting the starting point of mobility pricing – that there is an imbalance between users' costs of mobility and the social costs of mobility, including externalities – mobility pricing also implies

172 Cited in Timms (2013).

173 Beevers &Carslaw (2005a)

174 Atkinson et al. (2009); Beevers & Carslaw (2005b) and Li, Graham & Majumdar (2012)

that "optimal transport demand is below current demand"[175] and its application will therefore consistently lead to reduced transport demand.

This leads to difficulties and burdens in the actual application of mobility pricing schemes. Viegas pointed out that the rationale of social marginal cost pricing is difficult to explain to the public but he also expressed that the various – today easily available – electronic pricing technologies might help to overcome this problem, as the electronic systems can offer flexibility and transparency.[176] The importance of acceptability of road and mobility pricing schemes has therefore been widely discussed.[177] Vold points at the need to take unevenly distributed burdens into account and to consider parameters of acceptability when designing mobility pricing schemes as costs and benefits of such schemes are not evenly distributed among the affected people.[178] Referring to the case of the road pricing trial in Stockholm in 2006 preceding the final introduction (cf. Figure 20), Hamilton shows the complexity of decision processes during the introduction of mobility pricing schemes including technical questions, system costs, social acceptability, and political processes intermingling.[179] The question of revenue use, for example, can be crucial for the acceptance of a system as spending the revenues within the transport system (as opposed to revenues feeding general budgets) is likely to be more acceptable for the users.[180] On the European level, the public consultation on "Charging of the use of road infrastructure" showed as well that there is indeed great support for the implementation of the 'user pays' and the 'polluter pays' principle.[181] On the other hand, the consultation shows that there is less acceptance for congestion charging and transparent use of revenues or that even a respective consultation is strongly required. Yet, there remains a trade-off between an easy acceptance of mobility pricing schemes and their actual efficiency. This reflects the transport system's challenges to be tackled by these mobility schemes. Additionally, policy packages that intelligently combine policy measures are needed.

Despite all difficulties, the study of de Groot and Steg states that affected people do indeed value compensating effects (e.g. improved environmental quality, less noise) opposed to the financial burdens arising from mobility pricing, subsequently leading to a reduction of a perceived loss of life quality through mere costs.[182]

When applied in a reasonable manner, mobility pricing can therefore play a significant role in achieving an eco-efficient transport sector, avoiding socially unacceptable side-effects and applying market-based mechanisms. This can be brought in line with the European Commission's call for "full application of 'user pays' and 'polluter pays' principles"[183].

[175] Proost & Van Dender (2008), p. 1220.

[176] Viegas (2001), p. 289.

[177] See Schade & Schlag (2003).

[178] See Vold (2006).

[179] See Hamilton (2011).

[180] Schuitema & Steg (2008), p. 221.

[181] See Skinner (2012)

[182] See Groot & Steg (2006), p. 468.

[183] CEC (2011a)

6. Conclusions

Transport is a complex system that is triggered by various kinds of demand, by different preferences and by different interests. A broad range of approaches towards more eco-efficiency was highlighted during this project. Here, eco-efficiency is understood as gaining access to a specific activity/purpose (working, shopping, recreation, etc.) with a smaller ecological footprint. General quality of life and economic wealth should explicitly not be reduced (see deliverable 1 of this project).

Three scenarios have been utilised to illustrate that the different approaches can have strong impacts on the eco-efficiency of the transport system. All three scenarios would be able to reach the 2011 White Paper targets on CO_2 emissions, but in very different ways. Scenario I relies strongly on technologies; in scenario II cleaner technologies also play a significant role, but even more important are the strong efforts towards modal shift. In contrast to scenario I, this scenario induces changes that directly affect travel patterns, meaning that – to a certain extent – goods and passengers would have to use different modes of transport than in the REF scenario. Scenario II appears to be more flexible and "robust" in comparison to the first one, since there is higher variability in the choice of assumptions and measures. However, in both scenarios the reduction of CO_2 emissions depends heavily on developments in the energy sector. The provision of "clean" energy is crucial for the overall eco-efficiency.

Scenario III is of a completely different character; many parameters are similar to the REF (reference scenario), but the amount of physical transport is heavily reduced. There is not as much focus on technological progress – apart from the general optimistic assumptions on technological developments in the AFS. To a large extent, the reduction in CO_2 emissions is achieved through an extreme reduction in transport-related energy consumption (93 Mtoe/y compared to 178 Mtoe/y in the AFS and 320 Mtoe/y in the REF). The achievement of CO_2 reduction comes closer to a WTW calculation. The "success" of this scenario is not very dependent on developments in the energy sector. The reduction of transport volumes is accompanied by other benefits in terms of eco-efficiency: fewer raw materials are used, emissions other than CO_2 are also reduced and less waste is produced. However, just reducing volumes would be a much too simplistic approach and not in line with the concept of eco-efficiency as applied in this project. It was stated in the stakeholder workshop that this scenario contradicted the idea of moving goods and people freely in a single European market. On the one hand, it was also argued that mobility management was needed to achieve more eco-efficient transport and that there was a need to think about the point of origin of consumer goods. The desirability and acceptability of the scenario were questioned, since the impacts on economic wealth and quality of life are likely to be negative. The crucial question that has been addressed by scenario III is the extent to which transport can be avoided without endangering other societal goals. Some of the measures in this scenario illustrate how this might become feasible. Aspects of virtualisation are still comparatively new to society and it is not yet clear what future developments in this area will hold for the transport sector. Fast changes and progress are not unlikely in this field. On the other hand, there is broad consensus regarding the need for more integrated transport and land-use planning to reduce the distances travelled (which is usually accompanied by saving time and thus an increase in the quality of life). But in contrast to the high dynamics in the strongly market-driven field of ICT and virtualisation, altering land-use structures requires time, a strong and persistent political will and corresponding policy goals. Still, eco-efficient land use and transport planning brings significant benefits regarding different aspects and should therefore be treated with higher priority on the agendas of all political levels.

There is often a strong focus on fuels and propulsion technologies when it comes to eco-efficient transport. The related but broader term "sustainable transport" is also frequently equated with more efficient and cleaner vehicle technologies. The findings from the scenarios and the stakeholder consultation underpin the importance of fuels and propulsion technologies. A shift to non-fossil fuels was mostly seen as a must for achieving more eco-efficient transport. However the findings from the project clearly point to two shortcomings linked with the focus on fuels and propulsion:

Firstly, non-fossil fuels are not necessarily eco-efficient. Also for non-fossil fuels, it is crucial to take the whole life cycle of the fuel into account. BEVs and FC vehicles play a crucial role in achieving the CO_2 target in scenarios I and II. But it was discussed at the workshop and illustrated in key areas 1–3 that the eco-efficiency of an energy carrier strongly depends on its WTT balance. Hydrogen or electricity is only as clean as the energy used to produce it. The same is true of biofuels, which need to be treated rather cautiously, since the cultivation, processing and transport of biofuels can be significantly criticised in terms of eco-efficiency. The potential for "clean" biofuels is definitely limited and it is not necessary to use them in the car sector, where other alternatives are available. Furthermore, the example of electric mobility described in key area 2 shows that an LCA perspective is needed to properly assess the eco-efficiency of an approach. This is generally costly and time-consuming. However, such a systemic perspective is unavoidable in order to provide orientation for an eco-efficient transport policy. The high relevance of the WTT balance underpins the fact that the fields of energy policy and transport policy are merging more and more. With hydrogen, FCs and also biofuels gaining in importance, energy policy is becoming increasingly essential for the eco-efficiency of the transport sector.

Furthermore, it was discussed that infrastructures for new fuels and propulsions technologies are needed in order to foster the market penetration of these technologies. The European Commission and the European Parliament recently published the proposal for a "Directive on the Deployment of Alternative Fuels Infrastructure".[184] It is surely cost intensive to apply a broader strategy, taking into account potential developments in hydrogen, batteries and also in second- or third-generation biofuels. However, as was pointed out in key area 3, it seems to be reasonable to pursue only strategies that do not "lock out" any of these technologies. It has not yet been decided whether hydrogen, electricity stored in batteries or some variety of biofuel will be the fuel of the future. All have pros and cons and there might well be a coexistence of different approaches, which would mean a diversification of infrastructure. The major problems are the costs involved in such a strategy and the fact that they can hardly be fully privatised at present (since it is not yet clear what the fuel of the future will be). However, as the scenarios illustrate, a substitution of fossil fuels in the transport sector and, consequently, also in the energy sector is needed to enable a transition towards more eco-efficient transport.

Secondly, too strong a fixation on fuels and propulsion technologies conceals the fact that most dynamics in the transport sector are actually triggered by technological developments in another field: ICT. In this field, changes have already been established, various new approaches are emerging and the potential for new developments supporting eco-efficiency is far from being fully tapped.

Policies need to be much more oriented towards these ICT-related options; several of them were incorporated in the scenarios, discussed in the workshop and taken up in several key areas. Support for improved logistics and cross-linked passenger transport are even more necessary. Approaches are already visible, but there is the danger of building islands, isolated approaches that are not sufficiently interconnected and adapted to each other. Harmonised concepts and standards are needed to push

[184] CEC (2013d).

the progress of ICT in the transport sector. Related services are currently deployed on a fragmented basis in Europe. Some issues need to be addressed from a European perspective, in order to avoid the emergence of a patchwork of ITS applications and services and attain interoperability of services and systems, geographical continuity and standardisation. Pan-European applications should be facilitated, as well as secure, accurate and reliable real-time data and an adequate coverage of all modes of travel. The European Commission ITS action plan[185] provides a good basis for such activities in this field. But it also highlights the need to create adequate – and more binding – framework conditions to accelerate and coordinate the deployment of ITS.[186]

Furthermore, a broad range of bottom-up approaches are emerging, and new business models – such as car-sharing, free-floating or private-vehicle sharing, bike-sharing or dynamic ridership – are described in key area 7 to illustrate that these approaches are becoming increasingly widespread. Even though they do not yet have substantial modal split shares, they show continuous and stable growth rates. Additionally, it is a highly dynamic and innovative field, with new ideas emerging rapidly. Business models like these have the potential to increase eco-efficiency in the sense of scenario II, by offering an additional option for flexible intermodal transport chains. Approaches such as car-sharing are frequently discussed in terms of enablers for alternative propulsion technologies, since they enable users to choose a specific vehicle for a specific purpose. In doing so, business models like these also support the leading strategy of scenario I.

Most of these approaches are based on private initiatives and private investments, not much public money is involved in this field. Policy strategies to foster such approaches can be both low cost and effective at the same time. There is no need for expensive infrastructures or for subsidies. Effective support can be given through:

- authorisation to enter congestion charging zones (as practised in London),
- reserving parking spaces in inner cities and near train stations,
- authorisation to drive in bus lanes,
- the public administration's participation in such schemes, instead of running their own vehicle fleet,
- encouraging local companies to also take part in such schemes, instead of running their own vehicle fleets.

Such measures are closely related to the field of mobility management, which was also raised as an important issue in the workshop discussion with stakeholders. The alternative would be to rely purely on cleaner technologies for achieving eco-efficient transport. Mobility management is about actively trying to influence the modal spilt or transport volumes, e.g., by carrying out information campaigns, organising services or coordinating the activities of different partners. Influencing the demand for private motorised transport is a key element in scenario II and scenario III. There was a broad consensus amongst the stakeholders that scenario II was the most meaningful one in terms of eco-efficiency. The main argument for this was its greater flexibility, and thus robustness, since it is based on different strategies. Several stakeholders argued that elements of scenario III would also be needed to cope with future challenges. In this context, the term mobility management was usually mentioned in order to express the need for strategies focusing on the development of transport growth. However, there were definitely different opinions amongst stakeholders about what mobility management

[185] CEC (2008a).

[186] See also DLR & KIT (2010).

should look like. For example, the main controversies emerged in relation to measures restricting car transport in urban areas. This was mainly triggered by thesis 3, on zero-emission zones, as well as by thesis 6, which assumes a modal share of 75% for non-car-based modes in urban areas in 2050. The majority welcomed these approaches, but there were clear critical voices as well, pointing out negative consequences for the economy. Controversial opinions related to desirability and impacts were also characteristic for thesis 7, which deals with the road-charging system. It can thus be concluded that there was a broad consensus on the need for transport management, but there was no clear consensus on how it should be applied.

Among the most desirable measures were those related to technological development and modal shift. The feasibility and desirability of alternative fuels for the freight sector and progress in battery technologies were assessed rather positively. Another thesis that was rated with both high feasibility and desirability was integrated ticketing (thesis 5). To a lesser extent, a relatively high desirability and feasibility can also be identified for thesis 12, involving tele-working, tele-shopping, etc.

Thesis 9, on harmonised standards for rail, was assessed as rather uncertain but highly desirable. Difficulties related to shift are highlighted in two of the key areas.

The recently published communication on the fourth railway package[187] emphasises a strategic, integrated approach in the rail sector. The relevance of non-technical barriers is emphasised. A shift to rail was considered desirable or even very desirable by most of the stakeholders, but opinions on its feasibility differed considerably. When these findings are taken together with the support for scenario II, the importance of harmonisation in the rail sector becomes even clearer. It seems as if this high level of relevance for European transport policy is poorly reflected in the public and political debates of the European member states. There is no clear "paradigm" for modal shift to rail. It will require further research to analyse the reasons for this and to assess whether this can be changed. The shipping sector (maritime and inland) is even less prominent in public debates, since this mode is of only minor relevance for passenger transport in many countries. However, political agendas should also be targeted more towards tapping their respective potential.

It can be concluded that rather different kinds of policy approaches emerge from the scenarios and from the stakeholder discussion:

- Basic research: There is definitely a need to push forward the development of technologies. For example, basic research is needed in relation to the development of technologies for mobile energy storage as well as new options for generating biofuels. The commercialisation of alternative fuels and propulsion technologies was assessed as desirable in the stakeholder consultation.
- As regards technologies, more attention should be paid to the development and application of ICT. There is a huge potential to further improve eco-efficiency with the help of ICT. It is an extremely dynamic area. The potential of this field is far from being fully tapped. ICT can be an enabler for new business models and more flexible mobility patterns, but also for electric mobility.
- Systemic perspectives are needed to assess eco-efficiency. There is a need for LCA, in order to assess the full ecological footprint of individual technologies or approaches. However, systemic perspectives that assess the relevance and impacts of approaches in a broader context are also of high relevance. For example, an assessment of new energy carriers needs to

[187] CEC (2013d)

take into account their potential role in the energy system as well. The linkages between different technology fields need to be addressed. This could mean developing cross-cutting roadmaps that cover developments in the energy, transport and ICT sectors.

- The scenarios and the stakeholder consultation illustrate that many developments are impeded by uncoordinated political actions and a lack of political vision. It was underpinned that non-technical factors are, in many cases, the reason for the hampering of eco-efficient transport's success. A striking example is the shift to rail, which was assessed by the stakeholders as highly desirable but hard to realise. Harmonised standards and regulations are needed in various fields.
- One highly crucial issue for optimising transport in the long term is a better integration of land-use planning and transport planning. It is highlighted in the key area on "urban design" that this is particularly true for urban agglomerations.
- Furthermore, it is highlighted several times that there is a need to better understand the consumers/users of the transport system. There was a broad consensus during the stakeholder consultation that the measures applied in scenario I are not enough. This means that, to a certain extent, behavioural changes will be needed in order to achieve sustainable transport. It is illustrated in one of the key areas that mobility patterns and related preferences and attitudes are not static, but show dynamics. It is crucial to take these dynamics more into account in scenarios on the future of European transport; however, they also need to be more fully taken into account in transport policy strategies. A basis for this would be offered by more research on the dynamics of users and customers' transport-related perceptions and attitudes.

Furthermore, in the STOA project on urban transport it was illustrated that more general societal paradigms are relevant for the political and societal acceptance of transport policies.[188] The paradigm of sustainable transport is deeply embedded on a programmatic level within the transport sector. It is a central objective for many mobility plans and it has been accompanied by many promising approaches. Recently, global competitiveness has become a paradigm of increasing relevance – for the transport sector, as well. It will be crucial to increasingly highlight the relationship between eco-efficiency and competitiveness to gain acceptance for eco-efficient policies in the future.

Last but not least, it should be emphasised that new and emerging technologies need to be taken into account: this does not mean falling into a technology-fixated attitude, however, recent decades have proved that the emergence of unexpected developments have had a significant influence on transport and also on the energy sector. The development of the Internet and mobile phones are oft-quoted examples. The unexpected catastrophe in Fukushima triggered the phasing out of nuclear power and a new paradigm for designing the energy system in Germany. So-called "radical innovations" have proved to display considerable impact on society in general and on economic growth and quality of life in particular. However, radical innovations, in particular, are often not anticipated by society and decision makers. It is highlighted in the respective key area that autonomous driving-related developments might considerably change the transport system. But the stakeholder consultation reveals that there is still a high degree of uncertainty regarding the potential impacts of that approach. Thus, foresight processes accompanied by technology assessment are needed for scanning the development of new and emerging technologies and concepts, particularly when they have the

[188] See STOA (2012b).

potential to become relevant on a systemic level. There is definitely a need for further science and technology options assessment in the field of transport and beyond.

• Previous Deliverables of the project

Deliverable 2:
STOA (2011a): Eco-efficient transport. Deliverable 2: Interim report on potentials of technologies and concepts supporting eco-efficient transport. Brüssel: European Parliament/Science and Technology Options Assessment (STOA) 2011 (IP/A/STOA/FWC/2008-096/LOT2/C1/SC10) (ETAG - European Technology Assessment Group (STOA-ETAG)). Authors: Schippl, J.; Puhe, M.; Meyer, S.; Edelmann, M. (2011).

Deliverable 2b:
STOA (2011b): Eco-efficient transport. Deliverable 2b: Overview of potentials for an increased eco-efficiency in maritime shipping. Brüssel: European Parliament/Science and Technology Options Assessment (STOA) 2011 (IP/A/STOA/FWC/2008-096/LOT2/C1/SC10) (ETAG - European Technology Assessment Group (STOA-ETAG)). Authors: Schippl, J.; Edelmann, M. (2011)

Deliverable 3:
STOA (2012a): Eco-efficient transport. Deliverable 3: Interim report on scenarios for eco-efficient transport futures. Brüssel: European Parliament/Science and Technology Options Assessment (STOA) 2012 (IP/A/STOA/FWC/2008-096/LOT2/C1) (ETAG - European Technology Assessment Group (STOA-ETAG)). Authors: Schippl, J.; Edelmann, M; Puhe, M; (2012)

Deliverable 4:
STOA (2013): Eco-efficient transport. Deliverable 4: Stakeholder Consultation. Brüssel: European Parliament/Science and Technology Options Assessment (STOA) 2011 (IP/A/STOA/FWC/2008-096/LOT2/C1/SC10) (ETAG - European Technology Assessment Group (STOA-ETAG)). Authors: Larsen, G.; Joergensen, M-L.; Lindegaard Juul, K.; The Danish Board of Technology (DBT) (2013)

Availability

Deliverables 2, 2b, 3 and 4, area available online at the STOA homepage at:
http://www.europarl.europa.eu/stoa/cms/home/publications/studies

Deliverable 1 is an internal document and not publicly available.

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List of acronyms

ADP	Abiotic Depletion Potential
AFS	Advanced Framework Scenario
ASTRA	ASsessment of TRAnsport Strategies (transport model)
BEV	Battery Electric Vehicles
CCU	Carbon Capture and Usage
CEC	Commission of the European Communities (or: European Commission)
CED	Non-renewable Cumulated Energy Demand
CNG	Compressed Natural Gas
DBT	Danish Board of Technology
DPF	Diesel Particle Filter
EEA	European Environment Agency
EEDI	Energy Efficiency Design Index
EEOI	Energy Efficiency Operational Indicator
EI99 H/A	Ecoindicator 99 H/A
EOL	End-of-life Treatment
ERRAC	European Rail Research Advisory Council
ETAG	European Technology Assessment Group
EU	European Union
EV	Electric Vehicle
FC	Fuel Cell
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GWP	Global Warming Potential
HDV	Heavy Duty Vehicle
ICE	Internal Combustion Engine
ICT	Information and Communication Technologies
ITAS	Institute for Technology Assessment and Systems Analysis
ITS	Intelligent Transportation Systems
IWT	Inland Water Transport
LCA	Life Cycle Assessment
LDV	Light Duty Vehicle
LNG	Liquefied Natural Gas

LPG	Liquefied Petroleum Gas
LSF	Low Sulphur Fuel
MEP	Member of the European Parliament
MEPC	Marine Environment Protection Committee
NFC	Near-field Communication
NGO	Non-governmental Organisation
NO_x	Nitrogen Oxide
pkm	person-kilometre
PM	Particulate Matter
R&D	Research and Development
REF	Reference Scenario
RFID	Radiofrequency Identification
RIS	River Information Services
SCR	Selective Catalytic Reduction
SEEMP	Ship Energy Efficiency Management Plan
SMS	Short Message Service
SO_x	Sulphur Oxide
STOA	Science and Technology Options Assessment
TEN-T	Trans-European Transport Networks
tkm	tonne-kilometre
TTW	Tank-to-wheel
WTT	Well-to-tank
WTW	Well-to-wheel

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