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S T O A

The Future of European long-distance transport

Scenario Report

(IP/A/STOA/FWC-2005-28/SC27)

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Table of contents

Purpose and destination of document

This document is Deliverable 5 of the project on “The Future of European Long-Distance Transport'. It contains the report on the scenario process carried out in Phase II of the project. The scenario process is based on phase I, in which a general scoping and identification of key challenges took place. The third phase will include a citizen’s consultation to discuss the scenarios with European citizens from several countries. The project will be completed in October 2008.

Time horizon for the scenario is the year 2047. The scenario was worked out together with a scenario working group established for this project. The methodology used for building the scenarios is the backcasting approach, a normative methodology aiming at reaching concrete targets. It should be noted that in this project it is not first priority to “predict' what long-distance transport would be like in 2047 in terms of exact figures and shares. But the project aims at giving an idea of the magnitude of change that is needed if certain targets should be fulfilled and it aims at assessing and illustrating potential options for policy measures and technologies in the light of different situations.

The scenario was worked out together with a scenario working group established for this project. The working group met five times in Copenhagen at the Danish Board of Technology for a one day workshop. In addition, in February 2008, central elements of the scenario process were discussed at a workshop with 17 European experts see Annex D). This workshop was carried out to validate calculations and key-arguments and to further develop the scenarios.

We wish to thank all the contributors to the project, and not least the members of the scenario working group, who gave flesh and bones to ideas, inspiration and critical comments, lots of calculations and presentations – and made this project become real.

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Executive Summary

How could European long-distance transport - under different conditions and in different contexts - meet the following targets in 2047:

- Reducing oil consumption by 80%
- Reducing CO2 emissions by 60%
- High level of accessibility – to offer an efficient, effective transportation system at affordable prices

And what actions should be taken today and in the near future to make it happen?

These were the questions that the STOA project set out to explore in a 3-phase project on the future of European long-distance transport. The first phase defined the trends and targets to frame the subsequent phase II which concerns building scenarios for 2047. The third phase involved citizens' assessment of the different possible actions to reach the targets.

There are two central objectives of the scenario study which comprise the main part of the project:

- To give an idea of the magnitude of change required if certain targets should be reached in the long-distance segment;
- To assess and illustrate the potential options for policy measures and technologies in the light of different situations (scenarios or images).

In this report, the results of the scenario study are presented. The executive summary starts by highlighting the most important conclusions and then it gives an overview of the methodology and analysis made in the scenario study.

Conclusions

The challenges for the future of European long-distance transport:

- Huge **growth rates** in long-distance transport and no signs of decoupling from economic growth[1]
- Long-distance transport counts for more than 50% of total transport **GHG emissions**, and emissions increase much faster than emissions from short-distance transport
- Long-distance transport is almost **totally dependant on oil.** The growth of transport volumes and at the same time increasing oil prices call for alternative solutions to avoid negative consequences for mobility

From the analysis of the long-distance transport future images, it has become evident that to succeed in reaching the targets a combination of much improved vehicle technology, low carbon fuels, modal shift and strong demand management is necessary.

No single policy measures can solve the problems and reach the targets. We need to employ all measures available to achieve the 60% reduction of CO2 emissions and the 80% reduction of oil consumption. There are basically three parameters/three levers to work with:

- **Decoupling**: changing transport volumes. Shorter journeys, dematerialisation, teleconferencing – other ways of providing accessibility than by long-distance transport

[1] According to EEA report 1/2008, 'Climate for at transport change', TERM 2007, freight transport grows faster than the economy.

- **Technology**: changing specific carbon intensity of the different transport modes.
- **Modal shift**: inducing shift towards less CO2 emitting transport modes

The most important conclusion of the combined qualitative and quantitative assessments in the scenario study is that:

- Technology is only part of the solution and will probably only take us half the way to reach the targets in 2047
- Rebound effects should be taken into consideration - more efficient transport systems can create more travel
- Slower transport – in particular for aviation, but also for cars and trucks – is a low-tech measure right at hand that can reduce energy consumption significantly. The acceptability depends on the reliability and resilience of the transport system
- Scale of change is needed if targets are to be achieved. Combinations of policies are needed to tackle the challenges.
- European leadership is important and we need a vision of a carbon neutral transport system in Europe
- Engagement of population and other stakeholders is crucial to develop such a vision and make it reality
- Some institutional and organisational changes may be useful to reduce the number of responsible actors
- Urgent action is needed now - so far there are no signs of reaching the targets

In the analysis of policy measures, it was decided to put focus on the two modes of transport that will contribute most to CO_2 emission and oil consumption in the future: these are air transport in the passenger sector and trucking in the freight sector. From the analysis of possible policy measures the following actions are pointed out as important:

- Investments in rail infrastructure to encourage modal shift. Very high increase in capacities of the rail system is needed to make it competitive with other modes. Bottlenecks must be removed, intermodal options intensified. Cross-border high-speed rail needs investments in infrastructure and standardisation. Investments in electrification of the rail system to prepare for using alternative energy sources
- Reorganise distribution of airports to reduce travel. Only a few mega airports and integration of rail and air could be a strategy.
- Introduction of hybrid trucks. This could offer interesting potentials and could be combined with renewable energies, including hydrogen and biomass.
- Use the potentials of ICTs, teleconferences to enable virtual mobility and thus maintain or even improve accessibility
- Pricing measures to be gradually implemented - e.g. a 6% escalator of fuel prices and road pricing. Carbon based taxation; heavy emission standards and emission trading systems for all modes of transport could be incentives for developing CO2 lean fuels and propulsion technologies.

Is it possible to reach the targets? The methodology used is based on the concept of creating images that will reach the targets. In this study, it turned out that even with rather optimistic assumptions of the technologies to improve energy efficiency and carbon intensity, and by including modal shift, it would be necessary to reduce transport growth rates very much. Decoupling must take place.

This means that the accessibility target will be influenced. New concepts of accessibility – not only geographical but functional accessibility - will have to be considered by means of virtual mobility, shorter journeys etc.

Methodology and analysis

The methodology used for building the scenarios is the backcasting approach. It is a normative methodology: targets are defined and different 'images of the future', in our case for the year 2047, are designed. Following on this, policy packages that could serve as pathways to these images are discussed.

A baseline scenario was calculated on the basis of publicly available DG TREN data. It demonstrates in a business-as-usual way transport volumes and emissions for 2047. This is to give an idea of the magnitude of change needed in view of the targets chosen for this project. In the project, a definition for long-distance transport was worked out. Based on that definition the system delimitations of the baseline scenario are designed.

Four different steps can be distinguished required to build a scenario according to the backcasting method:

1. Identifying problems and targets
2. Calculating a baseline scenario
3. Designing images of 2047 to illustrate what a world, in which the targets are reached, would look like
4. Analyse and assess technologies and policy packages that could serve as pathways from the present to the images of 2047.

It should be noted that in general, the long-distance sector is a highly relevant part of the overall transport system regarding CO2 emission, oil reduction and accessibility. For example, calculations made on basis of DG TREN data illustrate that the long-distance sector (as it is defined in this project) contributes with more than 50% to the overall CO2 emissions of the European transport sector.

Three different images are designed for 2047. Image I and image II describe more or less desirable futures, whereas the third image serves as a contrast. According to their main settings the images are given the following titles:

1. Strong and rich high-tech Europe
2. Slow and reflexive lifestyles
3. Contrast image: economic pressure and expensive energy

2047	Image I Strong and rich high-tech Europe	Image II Slow and reflexive lifestyles	Image III (contrast image): economic pressure + very expensive energy
Governance	EU is cohesive and has a leading role in the world	Strong UN has established successful climate instruments	Weak EU, weak UN, limited international cooperation
Economy/GDP growth	Roughly 2.4%	Roughly 1.7%	Roughly 0.7%
Lifestyles	Consumption oriented, fast	Focus on health and quality of life	Consumption oriented, fast
Means for accessibility	Air & high-speed rail	Virtual mobility & comfortable rail (and slow air)	Air & virtual mobility
Main LDT fuels	Electricity, hydrogen, biofuels, CNG, kerosene	Electricity, biofuels, CNG, diesel, kerosene	Biofuels, CNG, diesel, kerosene
Biofuels share 2047	30%	25%	15%
Improvement Carbon intensity for aviation (2005-2047)	64.3%	58.3%	58.3%
Improvement Carbon Intensity for trucks (2005-2047)	57.2%	44.1%	40.1%
Transport volume 2047 compared to baseline[2]	- 30%	-45%	-60%

Calculations have been made to illustrate in which way the targets could be reached according to the settings of the three images. Looking at the results it becomes obvious that reaching the targets is rather challenging if at the same time economic growth should be realised. The calculation illustrates that the three different images or futures require very strong technical innovations to improve energy efficiency and carbon intensity as well as a strong modal shift towards the rail sector. The competitiveness of the rail sector has to be improved extremely over the next decades if the targets should be reachable. Heavy improvements within infrastructure and technologies in this sector are inevitable. Important policy measures must include pricing oriented measures as well as heavy investments in research and development activities.

In general, there is an urgent need for technical improvements. On the one hand, these technologies are directly related to emissions and energy consumptions. A wide range of non oil-based options for road and air transport has been developed in the last decade, and some technologies are already commercialised. However, it is currently difficult to predict which technologies will emerge as the front runners for Europe, especially for the long-distance sector. Recent discussions on biofuels illustrates that the assessment of the benefits of technological pathways is not easy in complex systems and needs some time to develop.

[2] Even -50% reduction compared to the baseline still means a growth in transport volume compared to 2005!

On the other hand, a broad range of ICT applications can be identified that have a potential to indirectly support the reduction of energy and emission by optimising travel flow and reducing travel volumes.

Furthermore, it is possible to identify areas in which technologies are available but not consequently implemented because of a lack in regulations and harmonisation of European standards. A typical example is the rail sector. But also for the future development and commercialisation of technologies such as cleaner fuels or propulsion systems, a European harmonisation needs to be accelerated. Also in the air sector there is a potential to increase efficiency by regulative and organisational measures. The settings in image II allow a significant reduction in emissions just by reducing travel speeds.

Regarding policy measures it was decided to focus on the two modes of transport that will contribute most to CO_2 emission and oil consumption in the future: these are air transport and trucking. It seems to be impossible to reach the targets if a considerable change will not occur regarding aviation and long-distance trucking. However, for all images it seems to be not at all easy to implement policies and technologies that allow reaching all three targets. It is quite ambitious to reduce CO_2 emissions and oil consumption without it having a negative impact on the accessibility as it is defined in this project. The question could be raised as to what extent it is realistic to reach all three targets in the settings given in the different images. Otherwise a new concept of functional accessibility could be developed, with strong focus on virtual mobility.

Below the line, the report illustrates that there is a broad range of options to reduce emissions and oil consumption in the long-distance sector. However, the calculations made in this report illustrate as well that the 'gap' between the baseline projections and emission target is huge. It appears to be impossible to reach the targets of transport volumes according to the baseline calculations for 2047. Lower growth rates are needed (which still means strong growth compared to 2005). But as image I illustrates, even with a 30% reduction in growth compared to the baseline, heavy investments in technologies and infrastructure would be needed to achieve the targets.

Crucial assumptions made in the images are very optimistic. One example is the extremely high shares of biofuels in all images. Supply (and climate benefit) of biofuels is highly uncertain. There is the conflict with food production or the discussion on more efficient use of biomass in power generation and in industry processes. Also the modal shift and general technological progress assumed in the images are very optimistic and extremely challenging. But it was not possible to make the targets reachable without such extremely optimistic assumptions. To have some chance of reaching the targets a combination of much improved vehicle technology, low carbon fuels, modal shift and strong demand management is necessary. There is no simple solution.

1. Motivation and Background

After publishing the last IPCC report on climate change in January 2007 (IPCC 2007), there are nearly no doubts left regarding an upcoming period of global warming. It is evident that the reason is the greenhouse gas emissions induced by human activities. In consequence, transport related GHG emissions are discussed intensively in the public sphere. According to the IPCC Report (2007), the transport sectors contribute with some 13-14% to global GHG emissions. For Europe, the European Environmental Agency states a 21% transport share of GHG emission (EEA 2007) and for Germany, McKinsey calculated 18% (McKinsey 2007). At the same time, the extraordinarily high oil prices as well as corresponding political instability in important oil exporting countries made us aware that nearly the entire transport sector depends on oil – a finite fossil resource.

Despite of these developments, oil consumption and GHG emissions within the transport sector are still growing on a global scale. During the last decades, the European transport sector has been characterised by an impressive increase in overall transport volume and by exceeding growth rates in road and air transport. Policy papers and statistical reviews indicate that this trend will continue with intensified speed. Important driving forces are the enlargement of the EU, the expansion of the economy in modern societies and an improvement of the general standard of living. An efficient transport system plays a key role for economic growth and social wealth of modern societies. But the increase in congestions and bottlenecks in the European transport network restricts the free flow of goods and people, especially in the centrally located and densely populated regions of the European Union. Such trends run counter the Lisbon strategy, which aims at making Europe the most competitive and the most dynamic knowledge-based economy in the world. At the same time, the increased amount of traffic has led to a strong reduction of the quality of life because of the large environmental consequences including emissions of air pollutants and noise as well as reduced spaces for living and the segregation effects caused by the expanding transport infrastructure. So, a paradox is that one of the basic pillars of today's quality of life also reduces that quality. Obviously, the future European transport will see a wide range of challenges if you look at it from various points of view. Transport is going to be on the agenda of the European Parliament's in the years to come.

As an answer to these challenges, the EU Commission worked out two documents of special importance in this context: in 2001, the Commission published the White Paper on transport. It lists a range of measures that should help to mitigate Europe's transport problems. In the White Paper, there is a general focus on a shift to the modes rail and ship. The paper identifies as a main reason for Europe's transport problems an imbalance regarding the modes of transport along with a lack in connectivity of the individual modes. Therefore, the key objective of this White Paper is to change the balance between modes of transport and to improve intermodality. Two corresponding objectives of major importance are mentioned in this context (EC 2001, 21):

1. Regulated competition between modes: the growth in road and air traffic should be brought 'under control', and rail and other environment-friendly modes given the means to become competitive alternatives.
2. A link-up of modes for successful intermodality.

In the year 2006, the Commission published the so-called Mid-Term-Review (MTR) of the White Paper. Even though only 5 years had passed, the MTR judges the measures described in the White Paper as being not sufficient; the MTR moves away from the modal shift paradigm towards the notion of co-modality, which means that the single modes of transport should be optimised. One reason for this critical perspective on modal shift is that since the publication of the White Paper there has been no visible change in trends within the road and air sectors extending their market shares. Especially the railway sector was blamed for having been too passive in the 5-year period since the White Paper was published.

Many of the instruments proposed in the MTR aim at harmonising technical and regulative systems in different countries and therefore at eliminating barriers that especially cross-border transport is facing. Prominent examples are harmonisations in the air (SESAR) and rail sectors (ERMTS). Another focus is on enabling competition in a free market. Furthermore, and in contrast to the WP, energy related issues are reflected in the MTR. The MTR asks in a more general way for a broad debate on transport scenarios with a time horizon between 2025 and 2045. The current STOA project fits well with this appeal.

It is surely one of the benefits of both documents that they do list a broad range of comparatively concrete measures. On the other hand, it is argued that both the WP and the MTR do not offer a coherent long-term vision for transport in Europe. Considering this background, the STOA project on 'the future of European long-distance transport' aims at focusing on the challenges mentioned above in order to contribute to transparency and improved governance in this highly complex field. The project discusses scenarios for a sustainable, efficient and less oil dependent European transportation along with related policy options. The time horizon for the scenario process is 2047. The focus is on long-distance transport including both passenger and freight transport. This focus excludes urban transport that is of a different nature in several aspects and addressed in many European studies. Innovative technologies, in particular such as intelligent transport systems (ITS), modern infrastructures as well as cleaner fuels and propulsion technologies will be central elements in the scenario process. In doing so, the project aims at supporting the political discussion on the long-term effect of political measures.

2. Methodology

A scenario is a description of possible future developments that seem plausible under different sets of assumptions within a chosen time horizon. There are numerous ways of building scenarios as a means to clarify policy options. For this STOA project on the future of long-distance transport, the 2047-scenarios should describe a future world with a transport system that would reach certain targets - a normative approach was chosen here.

The targets were discussed and adopted at a workshop at the European Parliament during the first phase of the project. Three targets were chosen: reducing oil dependency by 80% and CO_2 emission by 60% in the year 2047. Both targets are quantitative and to some extent linked to each other. The third target is on accessibility and of a more qualitative character (see chapter 4.1). It appears to be clear that these targets are highly challenging and not reachable in a business-as-usual way. It is crucial to break trends and to be open to new concepts and technologies.

It was decided to use the so-called backcasting approach to this project. It seemed to be the appropriate methods for dealing with such a complex and far-reaching issue. Especially within the transport sector it cannot be the aim to make an exact prognosis over a 40-year period; this is hardly possible. It is rather the aim to give an idea of likely developments and of magnitudes of change that are needed to reach desirable futures. That is possible with this method. Backcasting means designing 'images' of the future that seem to allow the reach of the targets and then describing options or pathways to get there.

Backcasting is a normative approach, focusing on targets and 'desirable' futures. The idea of shaping the future according to what is preferred is constitutive when focusing on the development of a sustainable transport system - there is always a normative component in such reflections. Several future transport studies aiming at sustainability or specifically on reducing CO2 emissions have used the Backcasting method, e.g. the POSSUM EU-project and the UK VIBAT project[1]. The method allows designing policy packages and a corresponding socio-economical environment that allows the reach of the targets. It is a rather integrated or holistic approach.

In Backcasting, the scenario covers the image of the future, in this case three 2047 snapshots, and a discussion of trajectories leading from the present state up to each image. Designing the images is the key innovative step in the process. In order to make the methodology applied for this project understandable, it is helpful to outline four different steps in the backcasting process:

1. Identification of problems and targets;
2. Calculation of a baseline to illustrate what scale of change is needed to meet the targets;
3. Design of 'images' of the future (2047);
4. Analysis and assessment of technologies and policy measures to form the trajectories leading from images of 2047 back to the present state and vice versa.

Step one is described in more detailed in chapter 4.1. A summary of the results of the baseline together with its system delimitations can be found in chapter 4.2. Chapter 4.3 gives some theoretical calculations of how to meet the targets.

[1] Banister, D (1998). POSSUM: Final report. Submitted to EC DG XVII Strategic Research. Also: Peter Steen, Karl-Henrik Dreborg and Jonas Åkermann, (2000). POSSUM: Policy Scenarios for Sustainable Mobility in Europe, the POSSUM Project, http://www.tft.lth.se/kfbkonf/4Steen_Dreborg_Akerman.PDF
Banister et al 2000; Hickman and Banister 2005

The images of 2047 are developed in chapter 5. Some methodological notes on designing images in a Backcasting process can be found there as well. Furthermore, chapter 5 illustrates how the targets could be fulfilled in the settings of the three images. Chapter 6 discusses technologies and chapter 7 discusses policy measures that have the potential of building blocks for the trajectories leading to 2047. Chapter 7.2 gives a summarising view on how the targets could be fulfilled in the three images.

3. Definition of Long-Distance Transport

There is no clear definition of what exactly is included in long-distance transport. Taking this situation into account, the following 'pragmatic' definition of long-distance transport was considered appropriate for this project:

Definition of long-distance transport:

Long-distance transport is defined as all movements by modes of transport that exceed a distance of 150 km. In this STOA project it includes both passenger and freight transport.

Since statistics on transport activity for this specific definition are not available, the following assumptions are considered to comprise our definition of long-distance transport. Modes of transport included are the same as in the data source (DG TREN, see below).

Passenger transport activity:

- 15% of all private cars and motorcycles included
- 15% of passenger rail included
- 100% intra EU aviation and approx. 50% intercontinental aviation included (to and from the EU)
- 100% inland navigation has been included

Freight transport activity:

- 80% of trucking included
- 100% of freight rail included
- 100% inland navigation included2

Geografical delimitation: EU27

Data source:

The data used for the baseline scenario are taken from the DG TREN report 'European Energy and Transport - Trends to 2030 update 2005'. This report uses figures calculated by the PRIMES model. It does not distinguish long-distance from urban transport. The PRIMES model uses figures from EUROSTAT for the year 1990 (sometimes 1995) and models transport volumes on the basis of these towards 2030. Definitions on modes of transport are therefore related to EUROSTAT.

This is explained in more detail below. In the Midterm Review of the European Transport White Paper, long-distance transport is defined as distances of more than approx. 500 km (European Commission 2006a). This definition is as well used in the TREMOVE model (and the ASSESS study on which the MTR is based), in which transport in non-urban areas is split into short (< 500 km) and long (> 500 km) distance trips. In the first phase of this project, it was suggested to add as criteria the travel time (more than 5 hours) and the crossing of borders. The aim was to distinguish LDT from any form of urban transport.

[2] Inland waterway transport: Any movement of goods and/or passengers using inland waterway vessels, which is undertaken wholly or partly in navigable inland waterways

Using distance as definition has the advantage that it gives a basis for a comparison of different modes of transport and, thus, for calculating the effect of modal shift. But for the different modes of transport, different distances become relevant in this context:

- >500 km seems relevant if the intention is to capture the point at which rail transport becomes competitive, and is, as mentioned, used in the Midterm Review and in the TREMOVE model.
- >250 km distance is when air transport can be competitive, and air transport has very high growth rates.
- >100 – 150 km will make it possible to include more non-urban car transport.

The Commissions Transport Research Knowledge Centre gives a definition of long-distance transport 'to cover passenger and freight transport over considerable distances of about 100 km or more', saying that this definition excludes purely urban, rural and regional transport, independent of the means of transport (European Commission 2005).

With this definition long-distance passenger transport comprises (European Commission 2005):

- Road and rail transport (car, motorcycle, coach, train), which is typically over distances of 100 to 400 km (but can of course be longer, especially for leisure purposes when users are more sensitive to price than travel time);
- Air transport, which starts to become competitive with land modes at distances of around 250 km or more, although where high-speed rail services exist, this increases the distance at which air travel becomes more competitive;
- Only limited water-borne transport (normally short sea ferry routes)
- Use of local or regional transport networks to access and egress the long-distance mode

Long-distance freight haulage comprises:

- The use of pipelines, inland waterways and coastal shipping (particularly for low-value, non time-sensitive goods), as well as the modes mentioned above;
- Urban and regional freight distribution (pre and end-haulage for origins/destinations not directly connected to major long-distance terminals), which is normally up to about 50 km (more in rural areas), and is almost always by road.

Based on figures from DG-TREN’s Statistical Pocketbook 2003 (European Commission 2003), the Transport Research Knowledge Centre document gives shares of freight transport on road, rail and inland waterways for the EU-15 states. The table below shows for transport volume that approx. 80% of freight road transport is over 150 km, approx. 90% of rail is over 150 km, and 65% of inland waterways.

Distance classes' freight transport (source: EU Statistical Pocketbook 2003; see above)

Distance classes by mode of transport

%

km	Road		Rail		Inland Waterways	
	tkm	tonnes	tkm	tonnes	tkm	tonnes
0-49	5.1	53.7	2.3	24.1	5.3	29.2
50-149	16.4	22.8	9.3	22.7	29.0	39.6
150- 499	41.9	18.4	49.1	40.4	54.1	28.9
500-	36.5	5.1	39.2	12.8	11.5	2.3
Total	100	100	100	100	100	100

Source: table 3.4.4

Figures on distance classes by mode of transport for passengers are not available in the Statistical Pocketbook, and have not been found in other documents. However, figures regarding EU-15 are given in the Statistical Pocketbook, and the Transport Research Knowledge Centre document indicates that the share of aviation is increasing with distances over 500 km, and the share of passenger transport by car is dramatically decreasing at distances over 500 km.

It could be argued that the assumption made in this project that a 15% share of car transport (pkm) exceeding 150 km is too small[3]. However, the figure corresponds quite well with the actual share of car kilometres that occur on trips over 150 km in Denmark, according to an extract from the Danish National Travel Survey Database made for this project. In the scenario working group of this project it was discussed that this is also generally the experience from Sweden and the UK. Hence, the working group agreed on using the 15% figure, meaning that around 15% of private car and motorcycle kilometres are assumed to stem from trips that are longer than 150 km.

Compared to the freight transport distance classes in the table above it could be argued that for rail the share of 100% should be reduced to 80-90%, since the share of rail transport is decreasing fast in the new member states, where it used to be rather high. In addition, 100% coverage for inland waterways may be too high. However, a reduced share of these two modes of transport would not induce a strong impact on the figures of CO_2 emissions. So, for simplification reasons, the 100% shares have been kept for calculating the baseline.

[3] This was pointed out at the expert workshop on the 19th February by one attendant saying that according to German statistics, the share should rather be 30-40%. This was not agreed on by all participants.

4. Targets and Baseline Scenario

A so-called baseline scenario is necessary to measure the scale of change needed to reach the targets in 2047. For building this baseline data from today will be projected into the future of 2047 in a business-as-usual (BAU) scenario in which no trends have been broken. It should show growth in transport volume and CO_2 emissions for each mode of transport. It will be used to identify what modes of transport will contribute mostly to CO_2 emissions from the transport sector, and what modes will show the highest growth rates in CO_2 emissions. It will indicate which sections of long-distance transport to concentrate on in this project – it highlights where dramatic trend breaking is needed in order to reach the targets of CO_2 and oil consumption.

The baseline will make it possible to calculate the gap between business-as-usual and the targets (figure 1).

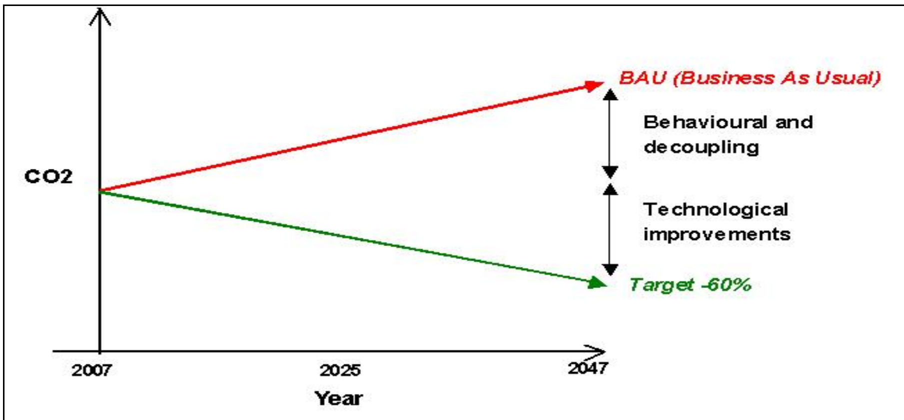

Figure 1: The relationship between Business as usual (BAU) scenario and the target.

(Note: the 60% reduction is related to the year 2005 and not to the BAU-2047).)

4.1 The Targets

The targets were discussed and adopted at a parliament workshop in the first phase of the project. It was decided to have two quantitative targets:

- Reducing CO2 emission by 60% in 2047 and
- Oil consumption by 80%

A third target is of qualitative character:

- Accessibility: to offer an efficient, effective transportation system at affordable prices

Accessibility must here be understood as a qualitative target that can be conceptualised under various aspects. We suggest characterising 'accessibility' in a rather pragmatic way, by making reference to the following paragraph which is adopted from the Commissions Mid-term review: 'The objectives of EU transport policy, from the transport White Paper of 1992 via the White Paper of 2001 to today's Communication, remain valid: to help provide Europeans with efficient, effective transportation systems that offer a high level of mobility to people and businesses throughout the Union. The availability of affordable and high-quality transport solutions contributes vitally to achieving the free flow of people, goods and services, to improving social and economic cohesion, and to ensuring the competitiveness of European industry.' (EC, 2006a, 3). In addition to this paragraph, in this project 'accessibility' is extended to concepts of virtual mobility and dematerialisation. This means that it includes 'access' to people, information and products via information and communication technologies (ICT) in form of video conferences, teleworking, teleshopping, E-books etc. This means that physical mobility is not the only way to achieve accessibility but is supplemented by a sort of 'functional accessibility' (see Akerman, Hojer, 2006).

Obviously, the CO_2 and the oil targets are strongly linked to each other, whereas the accessibility target may well be in conflict with these two since increasing accessibility may go along with an increase in emissions and energy consumption. Decreasing accessibility could be a means to reduce C02 emissions and oil consumption.

The CO_2 target and the oil target can be achieved by quite similar measures such as reducing transport volume, substituting carbon-based fuels by renewable ones or shifting transport to the most energy efficient modes of transport. But there is as well a significant difference between these two targets. Oil could be substituted by other fossil fuels such as natural gas or coal. Both are not CO_2 lean. CNG has significant carbon advantages compared to oil-based fuels, coal-based fuels are even worse than oil-based fuels in terms of CO2 emissions. The substitution of oil by hydrogen or electricity does not have to be automatically CO_2 lean if the energy is, for example, derived from coal-based power plants (technologies such as CCS could change the picture).

4.2 The baseline

4.2.1 System delimitations:

The design of system delimitation is crucial for the outcomes of the baseline scenario. It makes a huge difference to the results of the baseline how the system delimitation is made. Europe today consists of 27 member states - how many will there be in 2047? Should transport in and out of Europe be included as well, since globalisation as a driving force for both international trade and travelling is increasing? One part of the system delimitation has already been explained in form of the definition of long-distance transport in chapter 3. There is more detailed information in the Annex. Some of the most important basics and assumptions are explained in the following.

Searching for data for the baseline the project has made use of both existing sources and tested the possibility of using modelling tools. It has been decided to use existing data for calculating the baseline within a preliminary definition of long-distance transport, breaking the definition into different shares for different modes of transport (see chapter 3). The specific accuracy of figures has been given less priority since the future of 2047 already means operating in fields of huge uncertainty. The baseline should help illustrating the central trends that are expected for the next decades and give an idea of the magnitude of change that is needed to fulfil the targets.

The data source used is from the EU Commissions DG-TREN, 'European Energy and Transport - Trends to 2030 update 2005', published in 2006. The data covers 27 EU member states (source PRIMES model and Eurostat). This is no 'neutral' data set that just prolongs recent trends and growth rates over the next 20 years. The DG TREN data assumes a partial implementation of measures from the White Paper on transport (EC 2001). Accordingly, it is expected that some policy measures and technologies will be implemented over the coming decades. And it is expected that these measures will have a positive effect on growth rates of transport volumes and emissions. So, a certain degree in decoupling transport growth from economic growth is assumed to take place in Europe until the year 2030 - the time limit for the DG TREN data.

It should be note that the DG TREN 2030 calculations include other assumptions that make the resulting scenario look less dramatic as it could be:

- Intercontinental sea transport is NOT included
- Only approx. 50% of intercontinental aviation from or to the EU is included
- Air freight transport is NOT included

The following box summarises important assumptions for these data. More information can be found in Annex A.

Overview of assumptions shaping the DG TREN calculations:

The baseline scenario for EU-25 represents current trends and policies as implemented in the Member States up to the end of 2004. In particular, the baseline modelling assumes a continuation of policies on economic reform (Lisbon) and the completion of the internal energy market. The baseline scenario includes current policies on energy efficiency and renewables, without assuming that specific targets are necessarily met. For example, the renewables shares in electricity are modelling results (some 18% in 2010 for the EU) that show the effects of policies or their absence in the Member States. On transport, the baseline assumes that the targets agreed for 2008/09 for the car industry on the reduction of specific CO2 emissions for new cars are achieved without assuming a further strengthening of targets thereafter.

The growth of CO_2 emissions in the transport sector decelerates over the projection period. This slowdown in transport emission growth takes place in spite of modal shifts towards less energy efficient modes. Technological progress, the projected decoupling of transport activity from economic growth and the increasing penetration of biofuels blended in gasoline and diesel oil allowing for carbon intensity gains explain the above trend. In 2030 CO2 emissions in the transport sector (long and short distance) are projected to be 12.7% higher than in 2000 (with carbon intensity in the sector improving by 0.2% pa) accounting for 27.6% of total CO2 emissions, up from 26.4% in 2000.

The scenario working group considered this method as being slightly optimistic because of the underlying assumptions mentioned above. However, it seems to be quite likely that some significant policy measures will be implemented during the next decades to keep the European transport system, a basic pillar of the European economy, in function. A 'doing-nothing-at-all' scenario does not have to be more realistic. And even with this slightly optimistic data - assuming decoupling but excluding sea transport and parts of intercontinental aviation - the growth rates until 2047 are still exorbitant and a heavy challenge for both European transport and climate policy.

The definition of long-distance transport from chapter 3 was applied for this data set. So, according to this definition, the baseline calculation includes:

As regards passenger transport activity

- 15% of all private cars and motorcycles
- 15% of passenger rail
- 100% intra EU aviation and approx 50% intercontinental aviation included (to and from the EU)
- 100% inland navigation

As regards freight transport activity:

- 80% of trucks included
- 100% of freight rail included
- 100% inland navigation included

More information on DG TREN and PRIMES transport systems delimitation can be found in chapter 3 as well as in Annex A.

For the purpose of the project on long-distance transport the dataset was prolonged to 2047 (2050) by moving on with the growth rates assumed by DG TREN for the period 2020-2030. The assumption of decoupling is therefore included in the STOA baseline. Energy efficiency, reflecting the technological improvements, has in the STOA baseline been calculated on the basis of DG TREN, but from 2030 onwards it is kept constant - compensating a little for the optimistic scenario.

Another important assumption in the data set is the projected development of oil prices: 'The 2010 oil price is projected at 44,6 US$ (2005), from where it grows smoothly to reach by 2030 57,6 US$ (2005) (DG TREN 2006e, 19). Such a development does not seem to be very likely anymore, with oil prices up to 130 US$ already in the year 2008.

However, below the line this data set has proven to be useful in illustrating the gap between the baseline and the targets. On this basis, an idea is given of the magnitude of change that is needed to meet the targets.

The STOA baseline does not include international sea transport, since it has been chosen to strictly use the DG TREN data. But it should be mentioned here that several studies have stressed a rapid increase in maritime CO2 emissions. These emissions are not accounted for neither in the Kyoto Protocol nor in the European Emissions Trading Scheme. The IMO (UN International Marine Organisation) finalised an expert study in December 2007 showing that growing international seaborne trade and related fuel consumption will raise carbon dioxide (CO_2) emissions from ships by 30% to 1475 billion tonnes by 2020[4]. Furthermore, air transport with destinations outside the EU shows impressive growth rates and even air cargo seems to become a relevant factor. This underpins that the STOA baseline does at least not show the full picture. It must be noted that meeting the targets would become even more challenging if intercontinental aviation would be fully (100% instead of 50%) and sea transport would only to some extent be included in the calculations. In addition, for aviation the GHG gases NOx and H2O are supposed to have a high impact on global warming; both gases are not being considered in this report.

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[4] http://www.euractiv.com/en/transport/un-shipping-emissions-grossly-underestimated/article-170275

4.2.2 Transport volumes 2005-2047

Figure 2 shows the development in transport volumes in the long-distance sector as it was defined for this project. Total passenger transport activity nearly doubles, whereas aviation more than triples between 2005 and 2047. The lowest growth rates can be observed for passenger trains, which already start from a very low level with 65 Gpkm in the year 2005. It also becomes obvious that inland navigation does not play a major role and the situation will not change until 2047. This statement is underpinned by the modal split of 2005, 2025 and 2050 which is illustrated in figures below.

Total freight transport activity nearly doubles, whereas freight transport by truck increases by the factor 2.24 between 2005 and 2047 (see also figures 3-10).

	2005	2015	2025	2035	2045	2050	Growth 2050 over 2005
Long-distance passenger transport activity - Total (Gpkm)*	**1827**	**2431**	**2998**	**3542**	**4205**	**4585**	**2,07**
Private cars and motorcycles	700	833	944	1039	1150	1210	1,73
Rail	65	71	77	81	87	89	1,34
Aviation[5]	1026	1485	1929	2369	2911	3226	2,58
Inland navigation	37	43	48	52	57	59	1,59
Long-distance freight transport activity - Total (Gtkm)*	**2060**	**2505**	**2912**	**3283**	**3733**	**3983**	**1,9**
Trucks	1364	1751	2111	2438	2839	3064	2,24
Rail	410	438	457	476	498	508	1,24
Inland navigation	286	316	344	368	396	411	1,44
* please note system delimitations described in chapter 4.2.1							

Figure 2: Development of transport volumes (Basis: European Commission 2006e)

[5] This project did not have the resources to do elaborate calculations or any advanced modelling. The baseline calculations in this report is based on DG TREN data which was adopted – as far as possible – to the long-distance sector, which turned out to be practicable but also problematic in several cases. In order to guarantee a high degree in transparency, the DG TREN basis was not changed, apart from one exception: In the DG TREN Data the figure for aviation volumes seems not to be consistent with the energy demand for aviation. The value for energy demand in aviation (2108179 TJ for 2005 in DG TREN Data) appears to correspond with all kerosene that is used in the EU. In consequences, corresponding travel volumes should encompass all intra-EU air transport but as well about 50% of in-out air transport (for calcualtions see Akermann 2005). The underlying assumption is that 50% of the EU in and out air transport is fuelled in Europe, what might be a little to high. Therefore, in this case the baseline figure (372 Gpkm for 2005) was replace by an estimated value for intra EU + in and out volumes (1026 Gpkm for 2005).

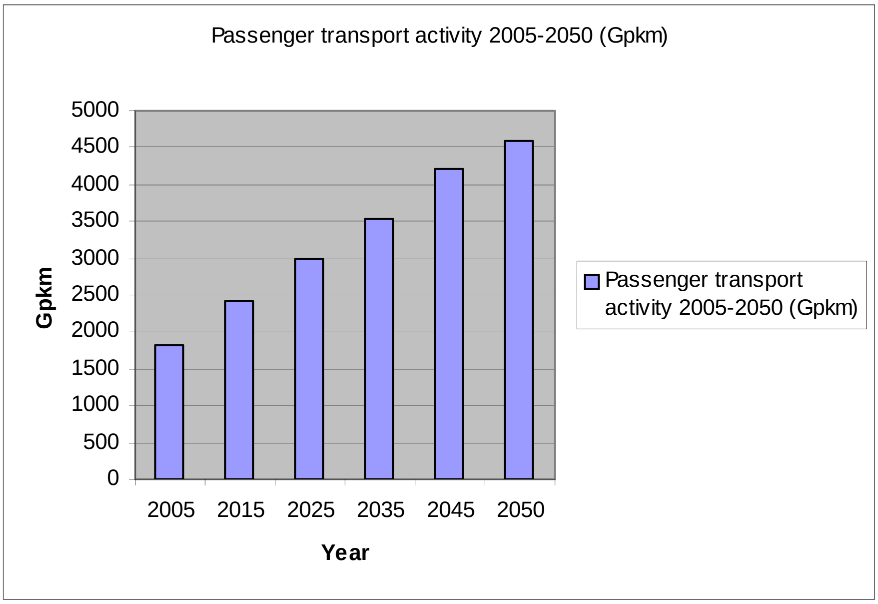

Figure 3: Long-distance passenger transport activity

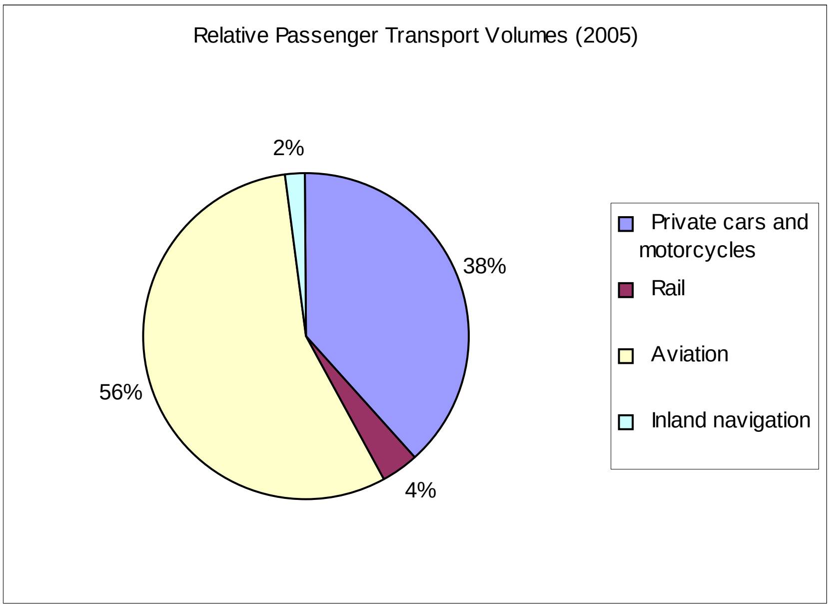

Figure 4: Modal split in long-distance passenger transport in 2005

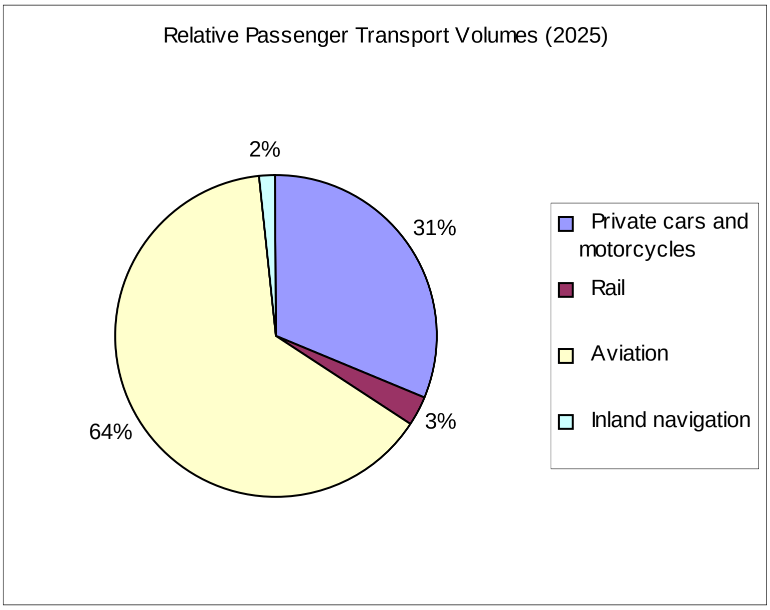

Figure 5: Modal split in long-distance passenger transport in 2025

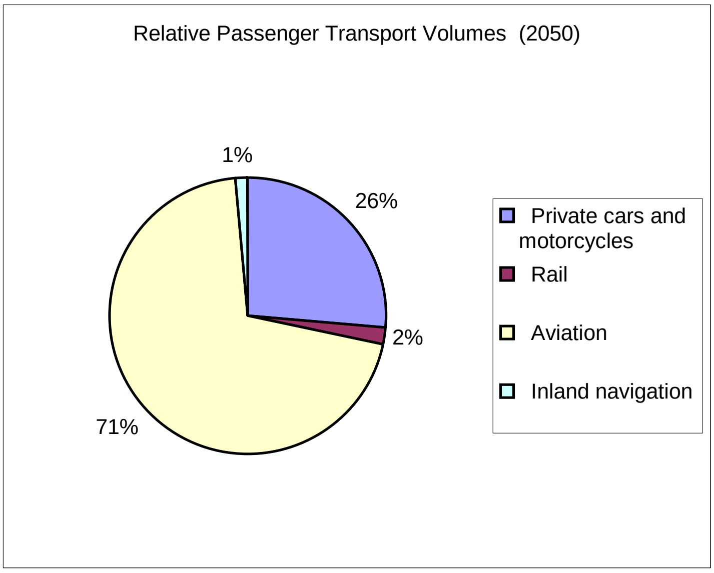

Figure 6: Modal split in long-distance passenger transport in 2050

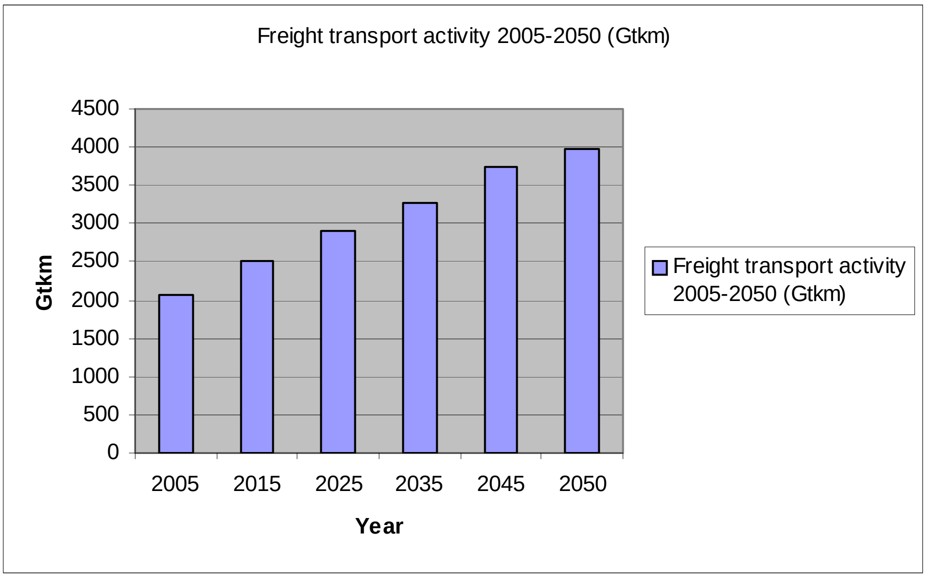

Figure 7: Long-distance freight transport activity

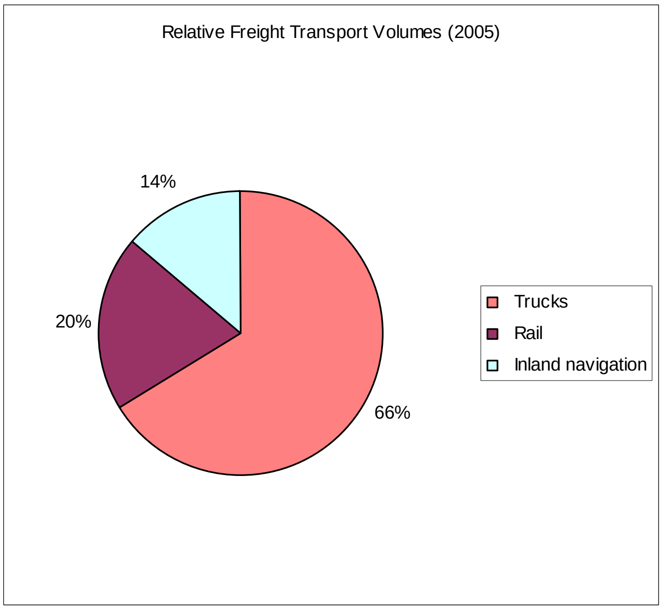

Figure 8: Modal split in long-distance freight transport in 2005

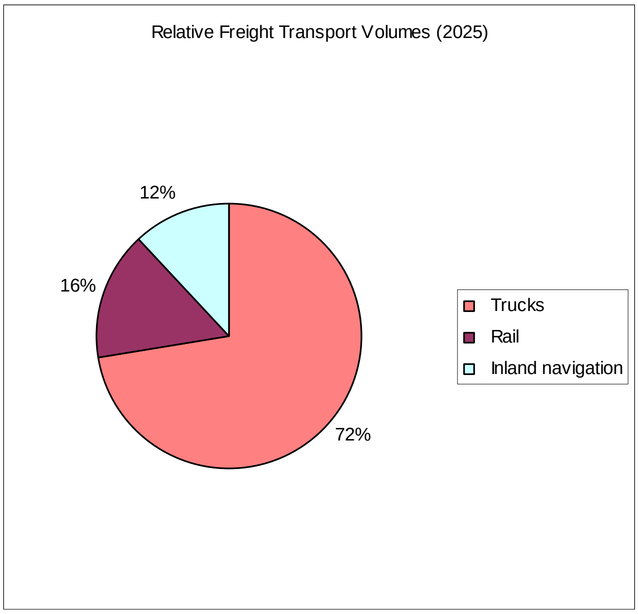

Figure 9: Modal split in long-distance freight transport in 2025

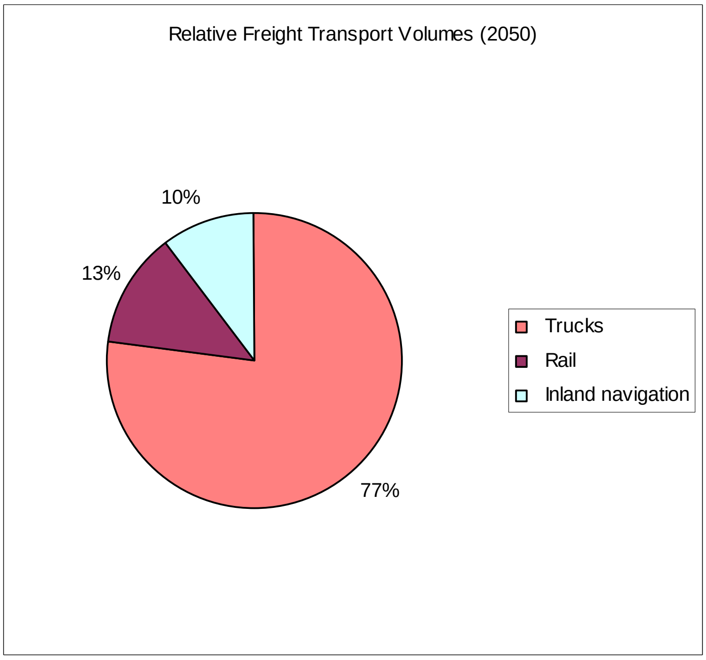

Figure 10: Modal split in long-distance freight transport in 2050

4.2.3 CO2 Emissions 2005-2047

Figure 11 shows the projected development of CO2 emissions by mode of transport for the long-distance sector. For 2050, CO2 emissions from freight are with 627020 kilotons very much higher than those of passenger transport with 381213 kilotons, which means that around 62% of CO2 emissions will come from freight transport in 2050. In 2005, the share of freight transport was around 59%. So, there was only a slight increase in shares but a heavy increase in the amount of emitted C02 (see Figures 12-17).

In the freight sector, the share of trucking is extremely high with 93,3%. To some extent, this may also be due to the system delimitations that exclude international sea transport. However, in 2005 and in 2050, trucks emit most C02 in European long-distance transport.

Also for the passenger sector, the influence of the system delimitations can be discussed. For example, it can be argued that including a higher share of private cars could change the picture. On the other hand, only half of intercontinental air transport is included. Furthermore, it should be kept in mind that C02 emission is only part of the GHG emission from aircraft. Air transport also emits NOx and water vapour. Both gases, but especially water vapour, are considered highly relevant for global warming. Below the line, it can be stated that passenger air transport is responsible for a very high share of GHG coming from long-distance passenger transport.

Furthermore, it is interesting to compare these figures with the overall emissions from the transport sector. The DG TREN data states for the year 2005 1,062,600 kt CO2 and for the year 2025 1,156,600 kt CO2 (European Commission 2006, 80). On that basis, the share of the long-distance transport would be approx. 54% in 2005 and, due to the heavy growth rates, already around 62% in 2025. So, according to the baseline data, the long-distance sector already today stands for about half of the CO2 emission of the entire transport sector and is expected to increase this share in the future.

	2005	2015	2025	2035	2045	2050	Growth 2050 over 2005	Share in 2050
CO2 emm., Well-to-wheel, LD passenger transport (kt)*	**236430**	**258118**	**265254**	**292564**	**348856**	**381213**	**1,61**	**100**
Private cars and motorcycles	79591	77923	79548	80744	89342	93979	1,18	24,6
Rail	2555	1987	1603	1597	1700	1754	0,69	0,5
Aviation	151789	175329	180912	206801	254066	281607	1,86	73,9
Inland navigation	2496	2878	3191	3422	3747	3872	1,55	1,0
CO2 emm., Well-to-wheel, LD freight transport (kt)*	**345789**	**420365**	**460041**	**503847**	**583067**	**627020**	**1,81**	**100**
Trucks	305686	383467	424312	467211	544053	587090	1,92	93,6
Rail	20527	15562	12762	12355	12903	13187	0,64	2,1
Inland navigation	19576	21336	22968	24280	26111	26743	1,37	4,3

* note system delimitations described in chapter 4.2.1

Figure 11: CO2 emissions 2005-2050 by mode (Basis: European Commission 2006e)

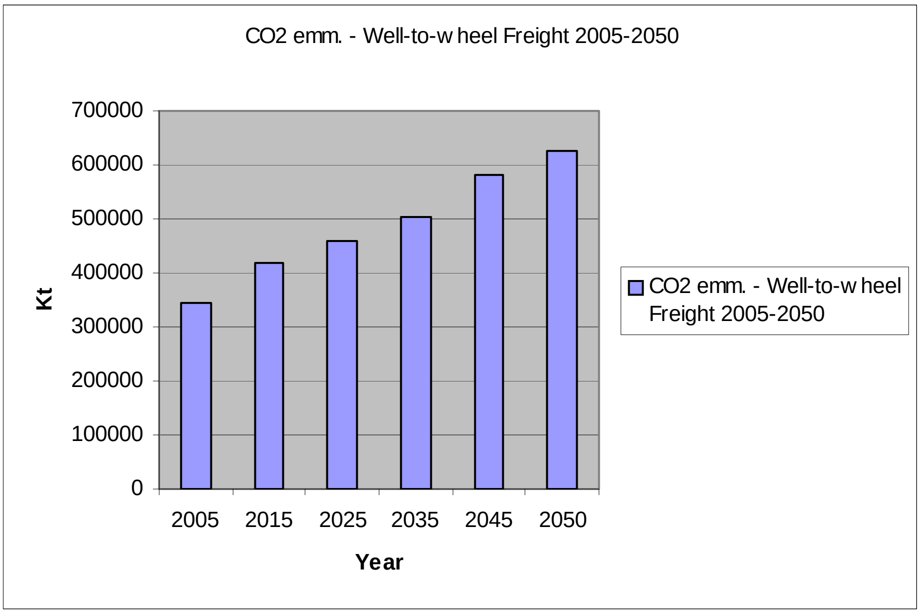

Figure 13: Growth in CO2 emissions from freight long-distance transport (on Well-to-Wheel basis)

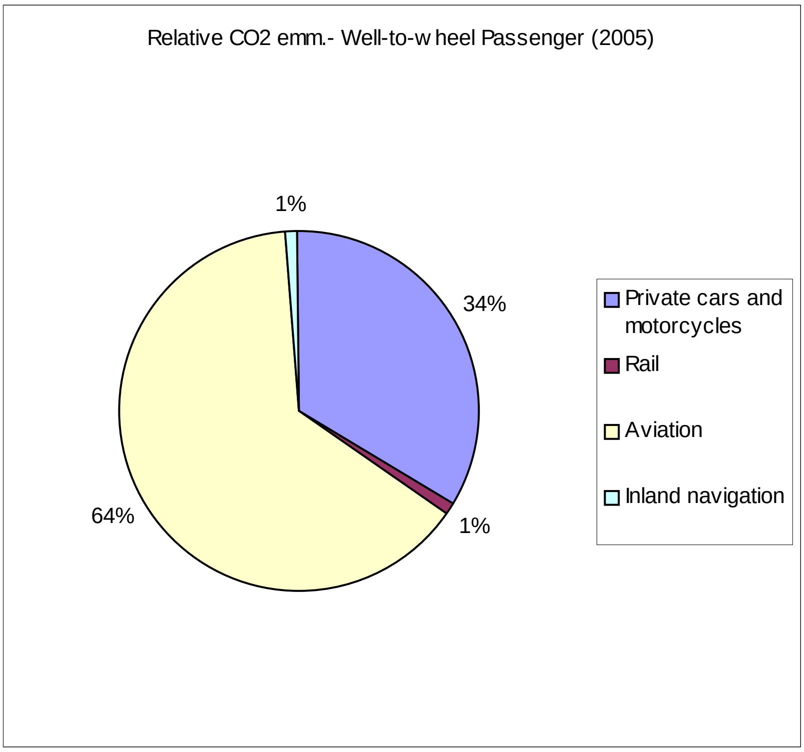

Figure 14: CO2 emissions from passenger long-distance transport. Share by mode in 2005 (on Well-to-Wheel basis)

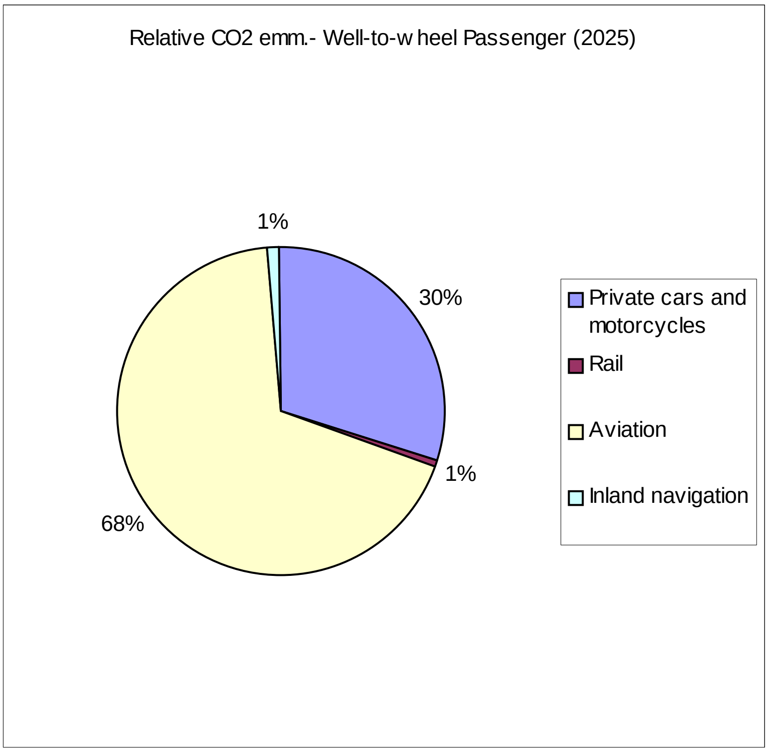

Figure 15: CO2 emissions from passenger long-distance transport. Share by mode in 2025 (on Well-to-Wheel basis)

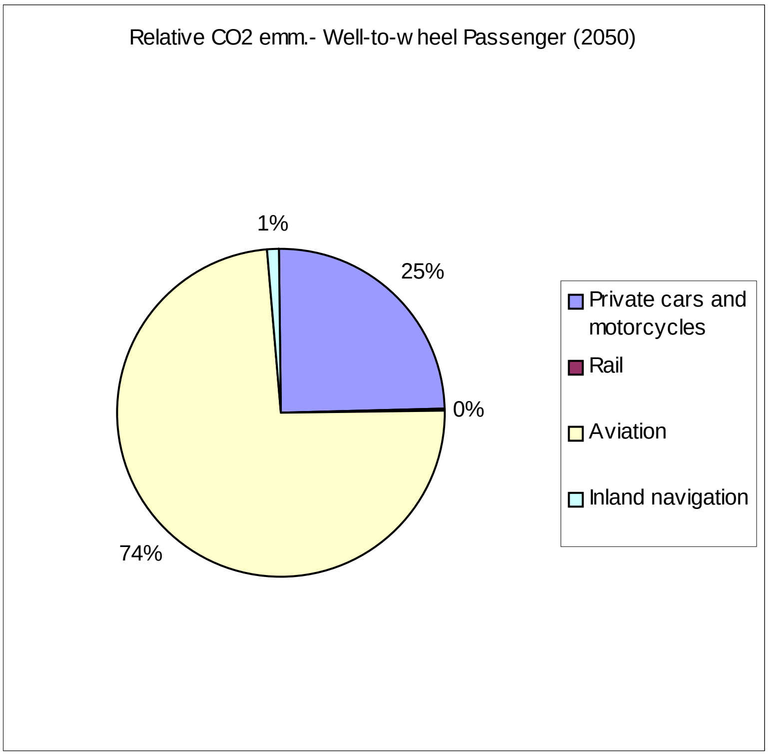

Figure 16: CO2 emissions from passenger long-distance transport. Share by mode in 2050 (on Well-to-Wheel basis)

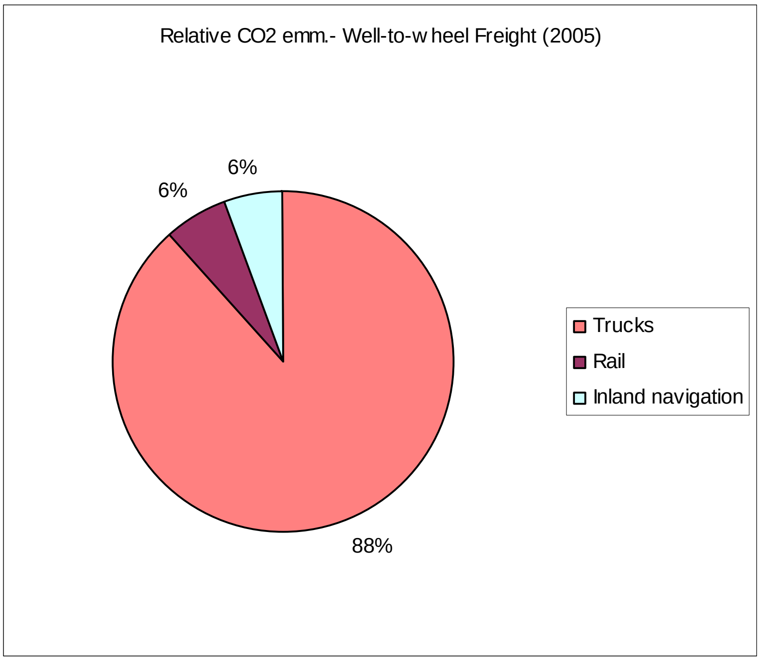

Figure 17: CO2 emissions from freight long-distance transport. Share by mode in 2005 (on Well-to-Wheel basis)

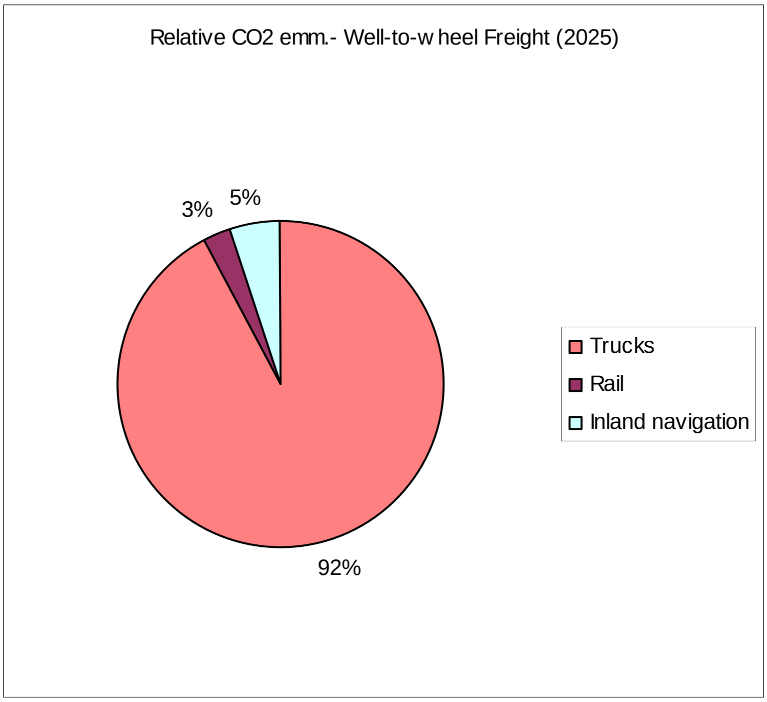

Figure 18: CO2 emissions from freight long-distance transport. Share by mode in 2025 (on Well-to-Wheel basis)

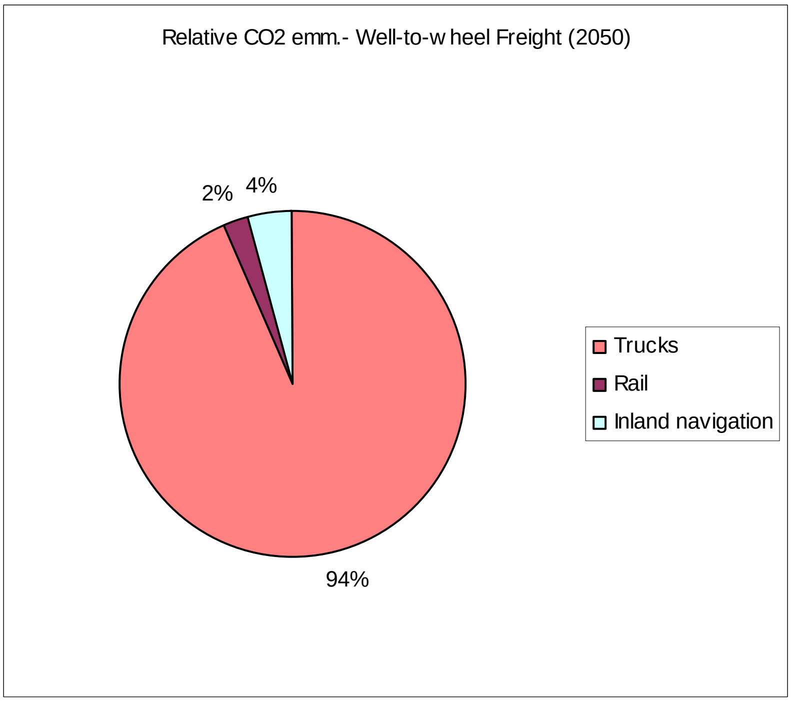

Figure 19: CO2 emissions from freight long-distance transport. Share by mode in 2050 (on Well-to-Wheel basis)

4.2.4 Energy consumption 2005-2047

Instead of dealing with oil, it turned out to be more meaningful to focus on general energy consumption in the long-distance sector. One reason is that this data was more easily available and more appropriate for comparisons between modes of transport. Reaching the target of an 80% reduction in oil consumption is in principle imaginable when using CNG, biofuels, hydrogen, batteries or combinations of these in hybrid systems. The development of overall energy demand is a good indicator of changes in energy efficiency of the transport system.

Again, heavy growth rates can be observed. Well-to-wheel energy consumption is projected to nearly double between 2005 and 2050. When looking at growth in volumes between 2005 and 2050 (chapter 4.2.2), which is 2.24 for trucking and 3.12 for aviation, it becomes obvious that energy efficiency is assumed to improve considerably over this period.

Trucks consume by far the largest amount of energy. Its shares are increasing from 54% in 2005 to 58% in 2050, with a peak of 59% in 2025. The second largest consumer is aviation, which is as well slightly raising its shares.

There are even decreasing figures for passenger and freight rail transport. In 2050, both together are reduced to an absolutely marginal amount of energy consumption which is around 0.8% of total Well-to-Wheel energy consumption in the transport sector. On the one hand, this illustrates that rail is loosing shares in spite of an absolute growth. On the other hand, it points at improved energy efficiency which is partly explained by ongoing electrification of the rail system.

	2005	2015	2025	2035	2045	2050	2050 over 2005	Shares in % for 2047
Well-to-wheel energy consumption in LDT transport (TJ)*	7722207	9080674	9738978	10712970	12554255	13592419	1.76	100 %
Private cars and motorcycles 15%	1082872	1060180	1082287	1098561	1215543	1278626	1.18	9.4 %
Trucks (80%)	4130898	5181986	5733940	6313667	7352062	7933648	1.92	58.4 %
Rail passenger (15%) (only diesel)	15446	13878	12160	12352	13153	13572	0.88	0.1 %
Rail freight (only diesel)	120270	101178	87546	88044	91949	93966	0.78	0.7 %
Aviation	2108179	2435127	2512666	2872240	3528699	3911214	1.86	28.7 %
Inland navigation, freight	264541	288325	310378	328107	352849	361394	1.37	2.7 %

* please note the system delimitations described in chapter 4.2.1

Figure 20: Energy consumption in long-distance transport by mode (on Well-to-Wheel basis)

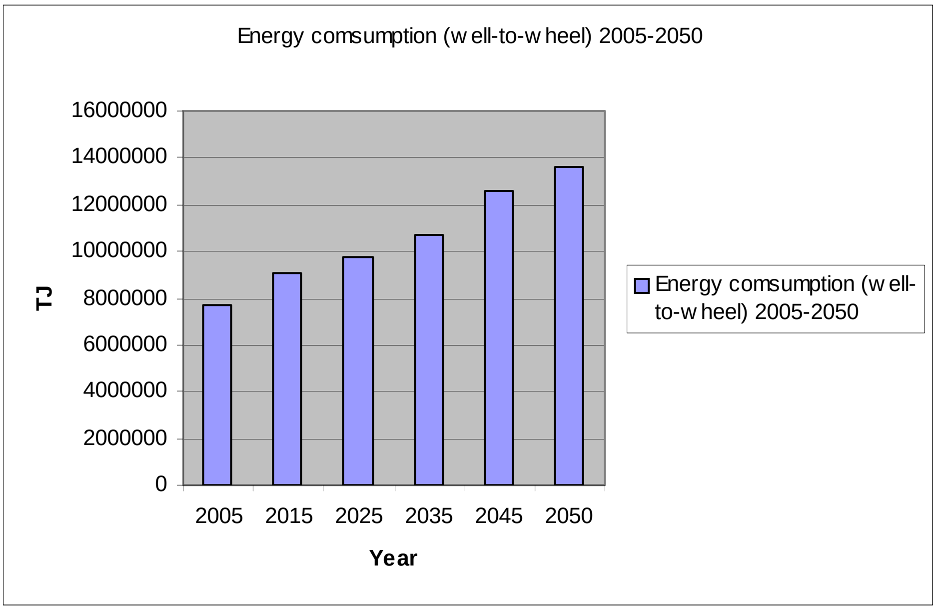

Figure 21: Consumption in long-distance transport (on Well-to-Wheel basis)

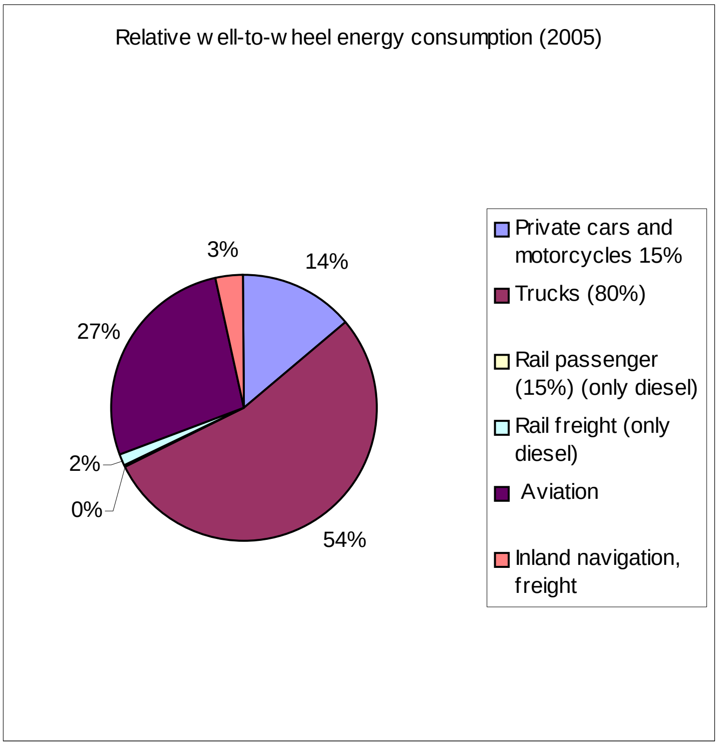

Figure 22: Energy consumption in long-distance transport - share by mode in 2005 (on Well-to-Wheel basis)

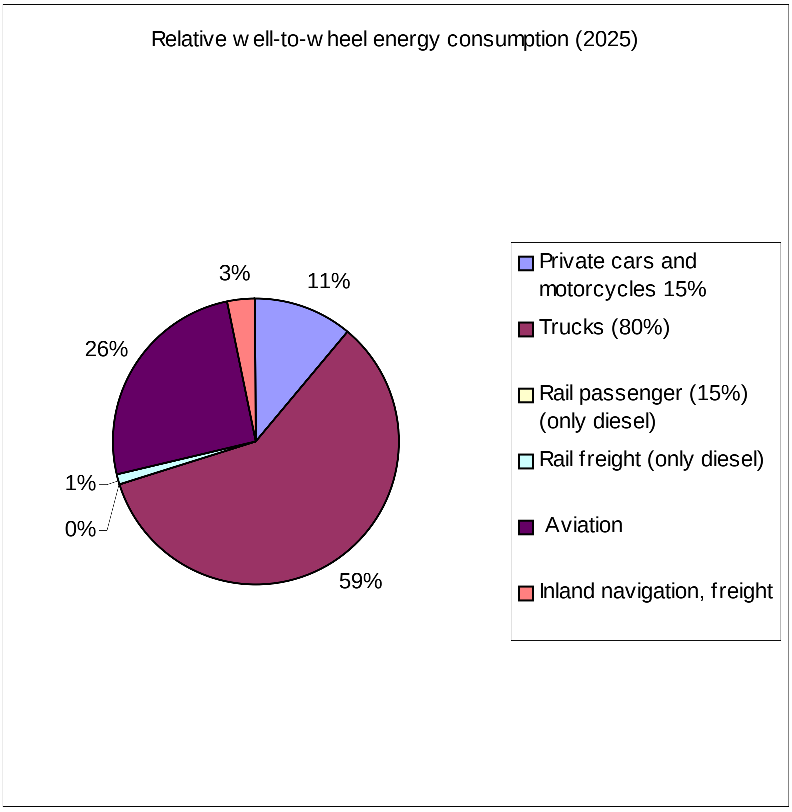

Figure 23: Energy consumption in long-distance transport - share by mode in 2025 (on Well-to-Wheel basis)

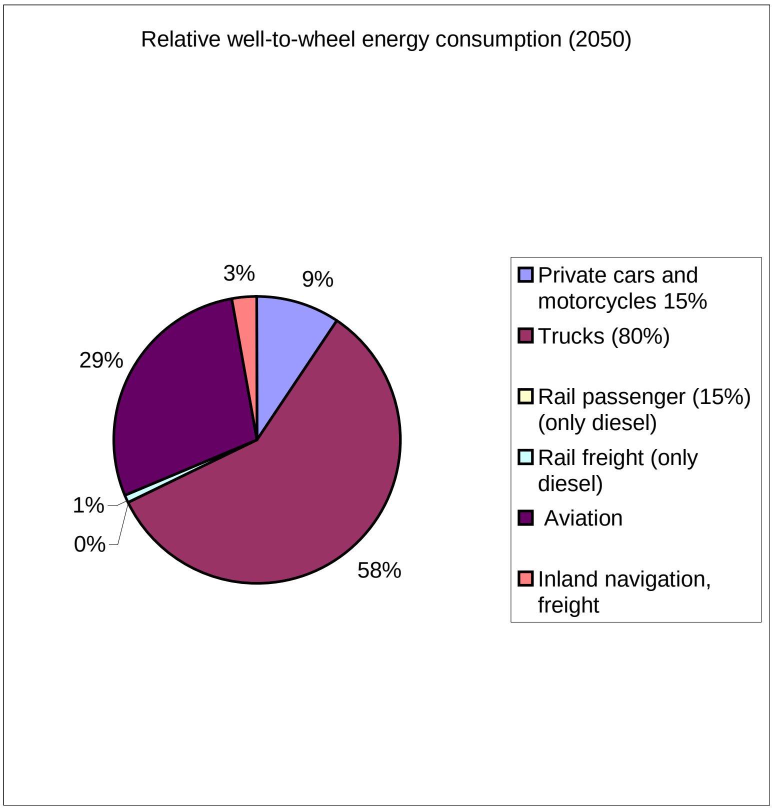

Figure 24: Energy consumption in long-distance transport - share by mode in 2050 (on Well-to-Wheel basis)

4.3 From the baseline to the targets - focus on CO2

In the chapter above, the baseline scenario gives an idea of transport volumes, CO2 emissions and energy consumption for the long-distance transport around the year 2047, based on the DG TREN data set. Now, it is important to understand the magnitude of change required to reach the targets and how the targets could be achieved, at least in theory. For simplification reasons, only CO2 emissions are presented, and not the oil target.

It has already been pointed out in the section on system delimitation (chapter 4.2.1) that the data used for the baseline is rather optimistic. Nevertheless, it clearly is an immense challenge to close the gap between baseline calculations for 2050 and the CO2 target.

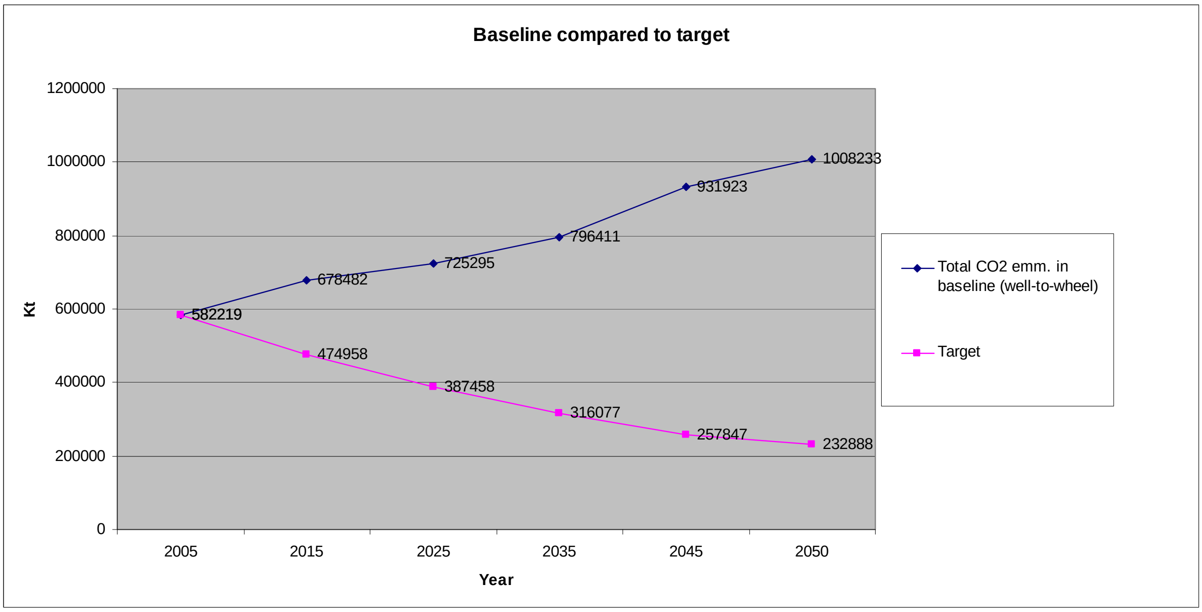

Figure 25: Gap between baseline and CO2 target

Inside the framework of the dataset, there are basically 3 parameters that could be used to close the gap and to reach the targets:

1. Changing transport volumes
2. Changing specific carbon intensity of the modes
3. Changing the modal split

Translated into policy praxis this could for instance mean: changing transport volumes could be carried out through demand management. Increasing the price of transport could have such an effect. Improving specific carbon intensity could be realised through new technologies. A modal shift to more energy efficient transport modes requires measures that increase the competitiveness of these modes.

Below is illustrated the magnitude of change needed to reach the targets *if only working with one* of these 3 parameters. For each of these parameters - transport volume, technology innovations and modal shift - there is a matrix indicating the level of change needed to meet the targets. This means that we keep two of the parameters constant and then calculate the amount of change needed in the variable measure.

At first, there is a matrix that illustrates the scale of change required if the targets should be reached through a change in transport volumes only. In this case, for passenger transport a 77% reduction and for freight a 78% reduction would be required in 2047. So, reaching the targets through a change of volumes only would mean a more than unrealistic reduction in transport activity.

TRANSPORT MANAGEMENT: VOLUME	Carbon intensity & modal shares as in baseline
Change in transport volume needed to reach target (change needed according to 2050 baseline with the resulting changes compared to 2005 level in parenthesis)	77 % reduction of overall passenger transport for 2050 (51 % reduction compared to 2005 level) 78 % reduction of overall freight transport for 2050 (57 % reduction compared to 2005 level)

Secondly, there is a matrix that shows improvements in specific energy intensity that would be needed to fulfil the targets. The figures in this example go up to nearly 80%. Reaching the targets by focusing only on improved energy efficiency would require massive innovation and technological breakthroughs. It should be noted that in this calculation a 40% share of biofuels is assumed - which is again very ambitious and could be critisised. On the other hand, the assumed fossil fuel input in the biofuels production could be considered rather high (with 50%). It is surely not unlikely and an effect of technological progress that in 2047 the fossil fuel input will be considerably lower than the 0.5 TJ fossil primary energy per TJ fuel suggested here.

TECHNOLOGY INNOVATIONS	Transport volume & modal shares as in baseline
Change in specific carbon intensity needed to reach target (+/- 1%) (Total improvement of carbon intensity compared to 2005)	74.1% in private cars and motorcycles 79.0% in passenger rail 72.0% in intra EU passenger aviation 57.1% in inland passenger navigation 76.1% in trucks 77.9% in freight rail 82.6% in inland freight navigation 40.0% share of biofuels 0.5 TJ fossil primary energy per TJ fuel (well-to-wheel)[6] 20 tons CO2 per TJ fuel[7]

The third matrix illustrates that the picture is even more unrealistic when looking at modal shift. In the example for 2047, an absolutely impossible increase in rail transport and inland navigation would be required to reach the targets.

[6] Indicates the use of fossil energy (well-to-wheel) for production, distribution etc. of biofuels viewed as TJ energy input pr. TJ fuel output.
[7] Indicates the corresponding CO2 emissions viewed as tons CO2 pr. TJ biofuel output.

MODAL SPLIT	Transport volume & carbon intensity as in baseline
Change in modal split needed to reach target (+/- 1%) (change needed in relation to the baseline in 2050)	75% reduction of private cars and motorcycles (= - 908 Gpm) 96% reduction of intra EU aviation (= - 1113 Gpm) 1850% increase in passenger rail (= + 1654 Gpm) 600% increase in passenger inland navigation (= + 357 Gpm) 97% decrease in trucks (= - 2972 Gtkm)) 96% decrease in freight inland navigation (= - 395 Gtkm) 660% increase in freight rail (= 3356 Gtkm)

It becomes obvious that working with one parameter only seems very unrealistic. Changes are required in various areas, not in one only. The images described in the following chapter illustrate what such a mixture would look like.

5. The Images: Three Snapshots of 2047

In the backcasting process it is a central element and one of the most crucial steps to design several images or snapshots of the future, which in our case means to design images of the year 2047.

These images should meet certain criteria (see 8):

- The images should reach the targets;
- Each image should be plausible but could be relatively extreme;
- They should be clearly different from each other in order to give an idea of the huge variety of possible futures;
- The images should cover a sufficiently wide range of possibilities;
- To keep research manageable a small number of images must to be selected.

In these images, the general situation is described including the most important socio-economic, technological and environmental trends and the most important key drivers. There has to be a statement related to the general global situation, e.g. if there is free trade, a high level of international cooperation; there have to be statements related to the status of the EU, e.g. if the EU is stronger or more centralised than today, if the EU acts as one strong entity or is more like a loose aggregation of single states that only work together temporarily and in certain fields of interest. The images should present an idea of key indicators, such as economic growth rates, GDP, population growth and others.

For the purpose of this project it is most important to describe what the transport and energy situation looks like within the frame of the different images. For example, a strong growth in global economy generally goes in line with a growth in transport volume. On the other hand, a decoupling of transport growth from economic growth may be observable. For this project, a qualitative way is applied to describe of the images.

However, as it was mentioned above, the backcasting process is a normative methodology, which means that the images should be designed to reach the targets (reduction of CO2 and oil consumption; high level in accessibility). Within the settings of the different images the third step now is to describe the specific technologies and policy measures that will support meeting the targets.

Calculations are made only for the CO2 target and not for the oil target, as it seems as if the CO2 target is obviously the bigger challenge. Oil can be substituted by several alternatives, amongst them CNG and biofuels, both available already today. In future, hydrogen and improved battery technology may support the portfolio. Different combinations of these energy carriers in hybrid systems are likely. However, there is no guarantee that these fuels will be carbon-lean or even carbon free (see chapter 6).

[8] Banister, D (1998). POSSUM: Final report. submitted to EC DG XVII Strategic Research. Also: Peter Steen, Karl-Henrik Dreborg and Jonas Åkermann, (2000). POSSUM: Policy Scenarios for Sustainable Mobility in Europe, the POSSUM Project, http://www.tft.lth.se/kfbkonf/4Steen_Dreborg_Akerman.PDF
Hickman, R.; Banister, D. (2005): Visioning and Backcasting for UK Transport Policy. Executive Summary. http://www.ucl.ac.uk/~ucft696/vibat.html.

It was decided to develop the three images described below. These images try to meet the criteria above and it should be possible to reach the targets within the framework of these images. Regarding image III, it may be contested to what extent the designed situation is really desirable (see criteria above). However, we developed this image since it provides an important contrast when comparing images I and II, and we named it a 'contrast image' in order to highlight its specific function.

There are plenty of other 'worlds of 2047' imaginable. Many other situations would be conceivable and probably plausible as well, or the reality of 2047 may come closer to a mixture of these images. But in order to reduce complexity and to keep the project manageable it was crucial to make a selection and to keep the number of images as small as possible.

The following chart illustrates the settings of the images

Three Images of 2047			
2047	**Image I** **High-tech Europe**	**Image II** **Slow and reflexive lifestyles**	**Image III (Contrast image)** **Economic pressure + expensive energy**
Key drivers	**Science and technology**	**Behaviour**	**Economics and energy**
General framework			
Governance	EU is strong and cohesive, it has a leading role in the world and also within climate policy; the rest of the world is fragmented; UN is weak; India, Russia and China and some American countries as global key players. EU has established efficient regulations to combat climate change. EU policy strongly promotes energy efficiency and renewables; not only because of climate change but also because of energy security and economic competition.	There is a very strong UN that is supported by all important nations and organisations around the world. The UN has established highly efficient regulations to combat climate change. Brussels has a lot of power in Europe, but national states are still very important.	Weak EU, weak UN, there are nearly no regulations to combat climate change. Low degree of international governance; international regulations are dominated by different trade agreements. Strong local identity and regional/national govern-ments. EU is a loose network of European nations and does not exert strong power. Targets are only reachable because of very high energy prices.

2047	Image I High-tech Europe	Image II Slow and reflexive lifestyles	Image III (Contrast image) Economic pressure + expensive energy
Key drivers	**Science and technology**	**Behaviour**	**Economics and energy**
Economy and innovations	A relatively rich Europe Very high growth in GDP (2.4%) + intensive research funding. Efficient and CO2 lean energy technologies are very advanced and a basic pillar of economic growth Medium degree of international division of labour. Cheap mass products are popular. EU economic strength is mainly based on growth in the high-tech sector.	Moderate GDP growth (1.7%) initially (but high potential). Medium degree in international division of labour. High quality regional products are dominating. There is a tendency to export knowledge instead of goods (dematerialisation).	Extremely high energy prices triggered by running out of oil (oil price ~ 250 €/bbl). Low growth in GDP (0.7%) ; Medium degree of international division of labour; considerable technological progress triggered by competition. Mixture of cheap mass products and regional products; National state trade barriers.
Population	Slightly growing because of people living longer and migration from many regions of the world. 'Internationalisation' of society .	Population is slightly decreasing; people live longer; migration to and from other parts of the world.	Significant decrease since migration between the continents is hampered by political and cultural barriers. Immigration mainly restricted to well-educated (economically useful) people
Society/standard of living	Comparatively homogeneous standard of living throughout Europe on a high level; Global: 'extremes' are visible; poor and rich regions exist	EU: strong middle Global: more even distribution of wealth.	Very heterogeneous society with very rich and very poor people living in Europe; middle-class is very weak Global: inhomogeneity

2047	Image I High-tech Europe	Image II Slow and reflexive lifestyles	Image III (Contrast image) Economic pressure + expensive energy
Key drivers	**Science and technology**	**Behaviour**	**Economics and energy**
Lifestyles	Consumption-oriented lifestyles; ‘fast' is important; fast travelling; fast food, fast carriers; cheap mass products are popular but there is also a market for luxury products; Status symbols are highly important.	‘Reflexive' slow lifestyle. Slow food; slow travelling Global networks are important for travel patterns	Consumption-oriented ‘fast' lifestyles; international networks are not that strong
Social values	Individualistic. Trust in democracy + information. Price important in consumption. Status symbols are important. Extremely high degree of belief in technology and the potentials of technological progress. There is a very optimistic view on technologies.	Strong focus on quality of life, on health, well-being, recreation, on safety and on the different ways to achieve these goals. Influence from Asian-Indian philosophical elements are visible; Counter-movement related to the stress-dominated lifestyle at the beginning of the century; Critical view on technologies	Individualisation, competition, pursuit of happiness, strong affinity to private property and status symbols.

2047	Image I High-tech Europe	Image II Slow and reflexive lifestyles	Image III (Contrast image) Economic pressure + expensive energy
Key drivers	**Science and technology**	**Behaviour**	**Economics and energy**
Framework of energy and transport system			
Energy generation and distribution	Very advanced high-tech is widespread throughout the energy sector 1. high share of renewables; broad mix of renewable sources; everything is used including oceans (tidal, waves,) 2. advanced batteries as well as hydrogen for energy storage 3. distributive power generation + European-North-African SuperGrid. Imports of energy are well diversified and coming from all parts of the globe. CCS Technology is established. CNG is important; also for the generation of hydrogen.	Electricity as the backbone of the energy system Efficient international regulations able to slow down emissions, energy and oil consumption; Alternatives to oil have been pushed and triggered by the same incentives and implemented successfully all over the world. Comparatively low energy demand CCS Technology is established and allows usage of domestic coal.	Very high energy prices; energy is used as a geopolitical instrument; energy efficiency is high because of high prices. All nations try to be as independent as possible. In different regions of the world; different fuels are dominating. Flexibility in feedstock is highly important Europe: biomass is very important; because of the extremely high oil price, natural gas and coal are the dominant fossil resources. Apart of that, renewable energies are of great importance. Ideas of a ‘SuperGrid' have been abandoned since too much international cooperation is needed. No CCS since this would be a purely political market based on international agreements.

2047	Image I High-tech Europe	Image II Slow and reflexive lifestyles	Image III (Contrast image) Economic pressure + expensive energy
Key drivers	**Science and technology**	**Behaviour**	**Economics and energy**
Fuels and propulsion technologies **(emission factors)**	Different fuels and propulsion systems are used. Battery electric vehicles as well as hydrogen + fuel cells are important. Biofuels and CNG (mixed with biogas) are important to LDT.	Battery electric vehicles are dominating propulsion technology for passenger cars in Europe; long-distance trucking is running on second-generation biofuels and CNG.	EU: Advanced biofuels with some hydrogen and CNG.
Development of transport infrastructure	Highly sophisticated intelligent infrastructure. There is a dense and extremely high-quality European transport network for all modes; investment in railway related infrastructure has been given priority. In many urban areas the transport networks are supplemented by sophisticated but very expensive tunnel systems for rail and road.	Advanced and intelligent infrastructure; some bottlenecks still exist; strong focus on safety; Priorities given to investment in an extra freight rail infrastructure; high-speed network was not changed that much but harmonised and used more intensively. Dynamic speed control.	No harmonised development of infrastructure in Europe > a lot of bottlenecks, especially for railways.
Intelligent transport system (ITS) and Telematics	ITS is widespread Passengers: there is a lot of intermodal travel including train and aviation in the transport chain. Advanced information and booking systems are well established. Freight: logistics are optimised by ITS and ICT. Also in freight transport, the harmonisation of standards in the EU pushed the rail sector.	Widespread. A very successful program for harmonisation of international standards has been established. Also within the EU, the level of harmonisation is high.	Moderate. Strong market penetration of ITS. Standardisation is still a serious problem. Train transport suffers most from this situation.

2047	Image I High-tech Europe	Image II Slow and reflexive lifestyles	Image III (Contrast image) Economic pressure + expensive energy
Key drivers	**Science and technology**	**Behaviour**	**Economics and energy**
Road pricing schemes	Widespread. Used to finance infrastructure. Used to optimise transport flow.	All encompassing, related to CO2-output. High occupancy lanes wherever possible.	Most countries have their own pricing system; foreign trucks are disadvantaged.
ICT	ICT dominates international relations; within the EU, people tend to behave like living in the same country, many people have friends everywhere in the EU and communicate via ICT, but still people visit each other relatively frequently.	A lot of cyber, virtual mobility; accessibility instead of mobility. ICT substitutes travel > less travel; need for travelling is reduced because of videoconferences, online shopping, teleworking etc. They are considered more convenient than travelling.	ICT plays an important role in everyday life. It is an important form of communication.
Impact on transport volume (and efficiency factors); figures are related to baseline 2047(= 100%)			
General	Sophisticated but expansive transport system with high growth rates but lower than in the baseline.	High degree of decoupling and substitution of transport.	Transport growth is hampered by high-energy prices, international trade barriers and low GDP growth.
Passenger transport in general	- 30% (compared to the baseline)	- 45%	- 60%
Freight transport in general	- 30%	- 45%	- 60%

5.1 Image I: Strong and rich high-tech Europe

2047 - IMAGE I: Strong and rich high-tech Europe

Europe is the politically and economically strongest bloc in the world. The EU itself is a very strong institution; the national states have lost influence. GDP growth is high (around 2.4 %) and heavy investments in science and research activities are being realised. The population is slightly growing. Europe is rich; its wealth is mainly based on its leading role in the high-tech sector. Clean energy technologies in particular are of utmost importance to the European wealth. Lifestyles are consumption oriented and focused on technologies. Cheap mass products are quite popular; on the other hand, there is a focus on status symbols and brands. Transport must be fast. People travel a lot and they do not want to loose much time when travelling.

Transport is running on a highly sophisticated intelligent infrastructure. There is a dense and high-quality European network of roads, tracks, rivers + motorways of the sea. In many urban areas the transport networks are supplemented by large tunnel systems. Due to this intelligent infrastructure rail transport for both passengers and goods is able to raise its market shares remarkably. In the meantime, harmonisation of technical and legal standards is heavily pushed forward by the EU. There is a strong focus on investments in both freight and passenger rail. In many parts of the EU freight and passenger rails have their own tracks. The high-speed passenger networks are heavily extended. For some destinations (mainly west-east from the seaports to eastern Europe), very fast freight rail is starting operation. The airport network is concentrated on some very huge airports in each country. There are attractive high-speed rail connections between the airports.

On the other hand, development and maintenance of this infrastructure are extremely expensive. In consequence, transport has become expensive. Several energy and emission related pricing systems have been implemented to reduce emissions and energy consumption but also to finance the expensive high-tech infrastructure. In spite of the attractive infrastructure, volumes of both freight and passenger transport are reduced by 30% compared to those indicated in the baseline. Still, there is a strong growth in transport volumes in the period 2007-2047.

Besides the general reduction in transport volumes and the shift to rail, the most important key drivers to reach the targets are the extreme technological progress that took place in the energy sector. It is possible to improve efficiency indicators and carbon intensity heavily. The energy sector changes a lot. Energy sources are highly diversified but dominated by renewables. An African-European SuperGrid is established. A mixture of biofuels, electricity, hydrogen and some compressed natural gas is used. The design of vehicles and aircrafts has changed dramatically.

In image I, a general 30% reduction of transport volumes has been assumed. These 30% are related to the baseline scenario. In other words, in 2047 for image I, transport volumes are 30% lower than they have been projected in the baseline scenario. Still, the growth of transport volume is huge. The 30% reduction alone is by far not enough to reach the targets. But it was assumed that the high level of technology enabled a strong modal shift to the railway system. For passenger transport a very strong increase in rail, 190%, and a relative decrease of 10% for aviation were assumed (related to the total 30% reduction). Of course, it may be discussed to what extent this 190% increase in the rail sector is realistic. But this figure illustrates, that heavy changes are needed; otherwise it is not possible to reach the targets.

Furthermore, it should be noted that according to the definition of long-distance transport (chapter 3) only 15% of total passenger rail is included. So, this 190% increase of long-distance passenger rail actually corresponds to approximately 30% increase related to total passenger rail transport - which should not be too much for a forty-year perspective and under the specific settings of this image.

For freight transport we assumed a 70% increase for the rail sector, whereas trucking is reduced by 15%. Some goods are shifted to inland navigation which raises it shares by 25% in relation to the 30% overall reduction compared to the baseline.

Image I **Change in total transport activity, %, compared to the baseline**	**2050: compared to baseline**
Passenger transport total (LDT) as compared to baseline	-30%
Freight transport total (LDT) as compared to baseline	-30%
Image I **Change in transportation activity in each mode, related to the global 20% volume reduction compared to the baseline**	
Total passenger transport	**0%**
Private cars and motorcycles	-5%
Rail	190%
Aviation intra EU	-10%
Inland navigation	0%
Total freight transport	**0%**
Trucks	-15%
Rail	70%
Inland navigation	25%

These changes generate the following modal shares:

Image I - modal share %	2005	Baseline 2050	Image I 2050
Passenger transport total Gpm	**100%**	**100%**	**100%**
Private cars and motorcycles	60%	48%	46%
Rail	6%	4%	10%
Aviation intra EU	32%	46%	42%
Inland navigation	3%	2%	2%
Freight transport total (Gtkm)	**100%**	**100**	**100%**
Trucks	66%	72%	65%
Rail	20%	16%	22%
Inland navigation	14%	12%	13%

It gets obvious that in spite of the extreme growth in the rail sector the image I modal split is not extremely different from what has been calculated in the baseline. But the remarkable changes in the railway sector become visible anyway.

On this basis, the following improvements in carbon intensity are needed to achieve the CO2 target (compared to the baseline):

Image I **Improvement of well-to-wheel carbon intensity in addition to baseline**			
Mode	**2050 in addition to baseline**	Baseline improvement of carbon intensity 2050 over 2005	Total improvement of carbon intensity 2050 over 2005
Passenger transport			
Private cars and motorcycles	60%	31.7%	72.7%
Rail	55%	53.4%	79.0%
Total aviation	40%	40.4%	64.3%
Inland navigation	40%	4.8%	42.9%
Freight transport			
Trucks	50%	14.5%	57.2%
Rail	50%	50.8%	75.4%
Inland navigation	30%	61.4%	73.0%
Assumptions for biofuels	**2050**		
Biofuel share, %	30%		
Biofuel, tons CO2 per TJ fuel - well-to-wheel	0		

Obviously, strong improvements of carbon intensity are needed for all modes. Some of the technical improvements required to reach this heavy improvement of carbon intensity could be critically discussed as being hardly realistic. But again, it illustrates that only through immense technical changes can the reach of the targets become to some degree achievable.

Especially within the rail sector, a strong progress could be realised in Image 1 due to far-reaching electrification of the extremely modernised European network and the usage of a high share of C02-lean electricity.

5.2 Image II: Slow and reflexive lifestyles

2047- Image II: Slow and reflexive lifestyles

In image II, transport volumes are 45% smaller compared to baseline for economic reasons, consumptions patterns, lifestyles, pricing related policy measures and others. A high degree of decoupling transport growth from economic growth took place. There is a moderate growth in GDP (1.7%), but clearly slower than in image I. Population is a little lower than in 2007.

In this image of 2047, global governance strongly matters and is shaped by a strong UN that has implemented strict regulations to combat climate change. The EU is one of several very influential blocs in the world. Politics are dominated by the European institutions, but still, the European national states have a considerable free scope of action. Sometimes, this multilevel governance structure hampers policymaking.

Lifestyles are notably different from those at the beginning of the century and dominated by a strong focus on the quality of life, on health, well-being, recreation, on safety and on the different ways to achieve such goals. Influence from Asian-Indian philosophical elements is visible. Being able to do things slowly and consciously is important. Regarding consumption patterns, Europeans favour regional high quality products; cheap mass products are also widespread in some sectors but not dominant.

Transport of people and goods is of course essential but to travel fast does not at all have first priority. Travelling must first and foremost be comfortable, making use of travel time is crucial; this could be sleeping, working or something else. For long-distance travelling, it is quite common to take the train and combine it with a car-sharing system at the destination if there is no convenient public transport option.

Sometimes, there is a critical view on technologies. But still, a lot of technological progress took place, especially when it comes to energy technologies. A lot of renewable sources are used. The energy system is based on electricity. Car transport is mainly running on battery electric vehicles, with many still using range-extending generators (mainly running on biofuels) over longer distances. For long-distance trucking, CNG and biofuels are widespread. ICT substitutes a lot of travel: videoconferences, online shopping, teleworking etc. are quite common and popular. So, 'accessibility' is not at all the same as 'mobility'. Dematerialisation (e-books) and the strengthening of regional networks also contribute to a reduction of transport volumes.

Transport infrastructure is advanced even if some bottlenecks still exist in Europe. Transport volumes are decreasing, the degree of decoupling is rather high. Comfortable trains gain importance, speed is not that crucial. In the meantime, car traffic decreases. Rail attracts passengers and especially goods from road and air. Priorities are given to investment in an extra freight rail infrastructure which, regarding the high-speed network, had not much extension, but activities were strongly concentrated on harmonisation of standards and optimisation of transport flows. So the capacities for high-speed trains were extended heavily without extending the passenger network too much. Of course the extension of a freight network relieved the passenger network. Furthermore, travelling safe is crucial. Maintenance of the network is put high on the agenda.

Characterising figures for the transport system in Image II could look as follows. The reduction of 45% compared to baseline is not equally allocated to all modes. Also for this image to reach the targets it is necessary that rail gains a lot of market shares. In the passenger sector, this goes at the expense of air transport. In the freight sector, it mainly goes at the expense of trucking. The assumed shift to rail does not have to be as extreme as it is in Image I since overall volumes are lower in image II compared to image I. But still, the figures may be considered highly ambitious.

Image II **Change in total transport activity, %, compared to baseline**	**2050: compared to baseline**
Passenger transport total (LDT) as compared to baseline	-45%
Freight transport total (LDT) as compared to baseline	-45%
Image II **Change in transportation activity in each mode, related to the global 35% volume reduction compared to baseline**	
Total passenger transport	**0%**
Private cars and motorcycles	5%
Rail	75%
Aviation intra EU	-12%
Inland navigation	0%
Total freight transport	**0%**
Trucks	-20%
Rail	100%
Inland navigation	30%

These changes generate the following modal shares:

Image II - Modal share %	**2005**	**Baseline 2050**	**Image II 2050**
Passenger transport total Gpm	**100%**	**100%**	**100%**
Private cars and motorcycles	60%	48%	51%
Rail	6%	4%	6%
Aviation intra EU	32%	46%	41%
Inland navigation	3%	2%	2%
Freight transport total (Gtkm)	**100%**	**100**	**100%**
Trucks	66%	72%	61%
Rail	20%	16%	25%
Inland navigation	14%	12%	13%

There is a strong growth in passenger rail but the most striking improvements in terms of market shares are realised by freight rail. This clearly goes at the expense of trucking. The shift in the passenger section is not that strong. In passenger transport aviation is loosing market shares but still plays an important role in the transport system.

Looking at the improvement in carbon intensity it becomes obvious that in spite of these striking changes still very strong technical improvements are needed to reach the CO2 targets. It is less than in image I but still highly ambitious. All modes must contribute to these changes in order to reach the targets.

Image II - improvement of well-to-wheel carbon intensity in addition to baseline			
Mode	**2050 in addition to baseline**	Baseline improvement of carbon intensity 2050 over 2005	Total improvement of carbon intensity 2050 over 2005
Passenger transport			
Private cars and motorcycles	40%	31.7%	59.0%
Rail	40%	53.4%	72.0%
Total Aviation	30%	40.4%	58.3%
Inland navigation	40%	4.8%	42.9%
Freight transport			
Trucks	35%	14.5%	44.4%
Rail	35%	50.8%	68.0%
Inland navigation	40%	61.4%	76.8%
Assumptions for biofuels	**2050**		
Biofuel share, %	25%		
Biofuel, tons CO2 per TJ fuel - well-to-wheel	2		

5.3 Image of contrast III: economic pressure and expensive energy

2047 CONTRAST – IMAGE III: economic pressure and expensive energy

This image is hardly desirable but serves as a contrast to the other images in order to complement the range of possible futures. Its settings surely add a fruitful perspective for policy options of LDT. In Image III, we assume that transport volumes are about 60% smaller compared to baseline mainly for economic reasons, together with exorbitant high energy prices. There is only a weak growth in GDP (0.7 %). Population is slow but significantly decreasing.

In this image, we assume a fragmented world, split into single nations. There are some loose forms of international cooperation; one of them is the EU. In the 2020'ies and 30'ies a sort of new 'nationalism' became widespread also in Europe. One of the reasons is the fierce international competition to attract industry and investors. Environment and social standards have been regarded as serious handicaps for a business location. This is slightly balanced by the fact that a clean environment is also seen as an advantage of location.

In 2047, the European institutions are comparatively weak. European regulations mainly focus on removing trade barriers. There are no European-wide environmental standards any more in order to keep the business locations attractive. Also on a global scale, international regulations are only partially established and reduced to economical affairs. But still, trade barriers are common. Lifestyles focus on consumption; trade barriers foster regional products to some extent, but cheap mass products are popular as well.

No mechanisms to reduce GHG-emission are implemented. There is not enough political power to enforce such regulations.

Climate change is only combated by the exorbitant oil and gas prices that slow down economic growth and push the implementation of efficient technologies including alternative fuels. Technological progress is highly important to keep economy growing. In different regions of the world different fuels dominate. Flexibility in feedstock and far-reaching independence from energy imports are crucial. In Europe, there is a new dominance of biomass that is purely market-driven. The extremely high price of oil also makes natural gas and especially coal more attractive. Apart of this, renewable energies are of great importance. Ideas for a 'SuperGrid' have been abandoned since too much international cooperation is needed. There is a lack of harmonised development of infrastructure, standards and regulations in Europe. A lot of bottlenecks in the trans-European networks still exist; especially for railways this is a serious problem.

Calculations made for this image are based on a 60% reduction in global transport volumes for both passenger and freight transport. Amongst the main drivers of this reduction are the high energy prices and the slow economic growth. Furthermore, trade barriers hamper international trade somewhat and thus international freight transport. For this image, it is assumed that the modal shares are not changed compared to baseline. So, it is assumed that there is no modal shift at all.

Image III: Change in total transport activity, %, compared to baseline	**2050: compared to baseline**
Passenger transport total (LDT) as compared to baseline	-60%
Freight transport total (LDT) as compared to baseline	-60%
Image III: Change in transportation activity in each mode, related to the global 50% volume reduction compared to baseline	
Total passenger transport	**0%**
Private cars and motorcycles	0%
Rail	0%
Aviation intra EU	0%
Inland navigation	0%
Total freight transport	**0%**
Trucks	0%
Rail	0%
Inland navigation	0%

Image III - modal share %	**2005**	**Baseline 2050**	**Image 2050**
Passenger transport total Gpm	**100%**	**100%**	**100%**
Private cars and motorcycles	60%	48%	48%
Rail	6%	4%	4%
Aviation intra EU	32%	46%	46%
Inland navigation	3%	2%	2%
Freight transport total (Gtkm)	**100%**	72%	**100%**
Trucks	66%	16%	77%
Rail	20%	12%	13%
Inland navigation	14%		10%

In doing so, it can be illustrated that in spite of a 60% reduction of volumes (again: compared to the 2047 baseline figures) heavy technical improvement related to carbon intensity is needed, if the targets should be within reach.

Image III **Improvement of well-to-wheel carbon intensity in addition to baseline**			
Mode	**2050 in addition to baseline**	Baseline improvement of carbon intensity 2050 over 2005	Total improvement of carbon intensity 2050 over 2005
Passenger transport			
Private cars and motorcycles	30%	31.7%	52.2%
Rail	30%	53.4%	67.4%
Total aviation	30%	40.4%	58.3%
Inland navigation	20%	4.8%	23.8%
Freight transport			
Trucks	30%	14.5%	40.1%
Rail	30%	50.8%	65.6%
Inland navigation	20%	61.4%	69.1%
Assumptions for biofuels	**2050**		
Biofuel share, %	15%		
Biofuel, tons CO2 per TJ fuel - well-to-wheel	3		

6. Key Technologies

A wide range of technologies to tackle European transport problems is discussed. This chapter will provide a closer look at certain technologies and instruments that are considered of specific relevance to this STOA project.

6.1 ITS and ICT

Intelligent Transport System (ITS), Information and Communication Technologies (ICT) and Telematics are keywords in many debates on the future transport system. They are not always used in the same context, but in general they are closely linked.

The objective of a flexible and efficient use of the existing infrastructure is mainly driven by two sets of factors that could be described in the categories of technology pull and technology push: The combination of increasing traffic volume and budget restraints in many European countries exert a technology pull, since ICT can contribute to tap the full potential of the existing infrastructure. Technology push roots in new options offered by technological progress and by breakthroughs in the field of Information and Communication Technology. Prominent examples are the real-time information for public transport passengers, intelligent infrastructure such as dynamic speed control on highways or the development of the Galileo satellite navigation system and its potential applications for both individual navigation and collective transport management or road pricing. Intelligent Transportation Systems (ITS) or telematic systems encompass a wide range of wireless and wire line communication based information and electronic technologies. Looking at the purpose of the systems, ITS /telematics can be divided into the following categories:

- Collective systems for intelligent infrastructure (mainly road transport);
- Systems used for public transport and freight transport by bus, rail, air;
- Intelligent systems for individual vehicles.

ITS is strongly related to optimised infrastructure under different aspects: it enables an optimised use of infrastructure in terms of capacities and it enables new options for financing infrastructure - which can as well lead to an extension of capacities. Apart from that, other benefits are related to improved security and improved environmental performance. ITS technologies focus on better organisations of transport through information and communication; on the steering of traffic flows and an optimised use of infrastructure capacities; on optimising logistic chains in freight transport. So, there are different applications for the single modes of transport as well as for passenger and freight transport. The following examples may become relevant for European long-distance transport over the next decades.

- Road pricing schemes tend to become a more widespread means to finance infrastructure and to control traffic flow.
- Train management systems (ERTMS) aim at improving interoperability between national networks. As illustrated by the calculations made in Chapter 5, it is of utmost importance to ensure an efficient long-distance transport on the railway lines in Europe. ERTMS which includes the European Train Control System (ETCS) is a key technology for an integrated and efficient rail transport in Europe.

- Again in the rail sector, ITS will enable the introduction of modern technology to substitute the hundred-year-old block based system to organise the traffic on the tracks. Such a 'revolution' would enlarge capacities considerably.
- The river information system (RIS) follows a similar approach for water transport.
- One single European sky for air transport: SESAR (Single European Sky ATM Research Programme) is an initiative that was set up by the European Commission to reach certain standards of harmonisation in European aviation.
- More flexibility in logistic chains will be enabled by RFID (Radio Frequency Identification) technologies. Together with GPS or GSM technologies such 'tracking and tracing' methods are becoming important elements of the so-called 'Supply Chain Management' in modern logistic systems (see. Lenz and Menge, 2007, 59). Such technologies are crucial for improving the reliability and competitiveness of intermodal transport chains especially in the long-distance sector.
- The Galileo Navigation System will be applicable in this context from approximately 2010 on. It will provide for a wide range of options to improve the coordination and management of transport in Europe.

There are many examples of successful implementation of road pricing schemes from outside the EU (see Halbritter et al. 2005), amongst them:

- USA: since 2003 charging of all vehicles via GPS is tested in the US State Oregon
- USA: high occupancy lanes are established in several states
- South Asia/South-East Asia: in many states, road pricing is a common tool used for financing an urgently needed infrastructure.
- Korea: congestions pricing is applied in Seoul.
- Singapore: Electronic Road Pricing (ERP) is aimed at managing transport demand through road pricing. Today, major city axes, arterial roads and expressways use ERP to regulate traffic flow and congestion through differentiated pricing measures.
- Japan: integrated railway system has improved the rails sector immensely.

ICT is not only related to an optimised infrastructure but as well to the avoidance of transport. It is discussed that improved communication facilities may substitute a certain amount of transport. Typical examples are videoconferences, online shopping, teleworking and others. Up to now, it cannot be proven that these ICT applications are able to entail a long-term effect. Probably these options will become much more attractive especially within long-distance transport in case transport prices would rise significantly.

6.2 Extending infrastructure and removing bottlenecks: examples

According to the Eurostat yearbook the length of the European motorway network has more than tripled over the last 30 years. Within the EU15 the motorway network grew from 45,264 km in 1995 to 53,267 km in 2002, which is approx. 18% in 7 years. However, in the same period the German network grew from only 11,190 to 12,037 and the Italian from only 6,435 to 6,478km. This indicates that a large part of the overall growth did not take place in the very central European countries such as Germany, Northern Italy or Austria which suffer most from the strong increase in the East-West traffic induced by European enlargement. Furthermore, it goes without saying that increasing kilometres of road network do not automatically mean an increase in capacities and accessibility.

The crucial point is to remove bottlenecks that restrict the growth of capacities of the overall network. Some examples are given here:

- A central problem is the hinterland of major seaports. The amount of goods dealt with in ports and hinterland is growing rapidly. As mentioned above, around 70% of the EU's trade with other countries is transported by sea. New solutions are required, amongst them the establishment of railway lines that are exclusively or at least partly reserved for freight transport. Other innovative solutions are discussed. For example, a recent study looks at the feasibility of double-deck container transport by rail on selected routes within Germany. This is connected to plans that call for a network of double-deck containers to be set up in the hinterland of Germany's seaports which could mean a relatively cost efficient way of extending capacities (Koch, 2006, 526).
- New ports for large containers (13,000 TEU). Because of the rapid increase in long-distance container transport an extension of port infrastructure is needed. First of all, investments in deep seaports will be necessary to handle the new mega-liners that up to now are not able to go into the large European ports such as Antwerp, Hamburg or Rotterdam. These mega-liners can carry 13,000 TEU on board which extends former standards heavily.
- Another central problem is large mountain areas such the Alps or the Pyrenees. The construction of tunnels is a crucial element in such regions. For example, in the near future, the 35 km long Switzerland's Lötschberg base tunnel will be put into operation as the first of such rail tunnels across the Alps. It will notably augment the freight transport capacity and reduce journey times for long-distance passenger service (Anreiter, Barth 2007).
- Regarding inland waterlines, high expectations are related to the upgrading of the Rhine-Main-Danube canal. This canal connects the river Danube with the North Sea and could serve as a perfect backbone for the European waterway network. However, these plans have to overcome many obstacles (technical, but also environmental, political and financial).
- Possible growing demands for improved airport capacities. However, a more climate-friendly solution would be to extend and improve the high-speed networks for passenger rail.

A central element of the Commission's strategy to remove such bottlenecks and enlarge capacities is the TEN-T network concept: 29 corridors plus the satellite navigation system Galileo were identified as being of particular interest to Europe. 75 projects along these corridors are considered important. It includes upgrading and building new airports, new high-speed railway lines, motorways of the sea and many other projects. The TEN was originally launched in 1996. This first phase was not too successful, so the program was updated in 2004. In the meantime, the EU finances up to 30 percent of investment costs for cross-border projects and 50% of planning costs. Such measures include facilities that help to improve intermodal transport chains.

All the facts and examples of extending infrastructure are highly crucial to accessibility, the third target in our scenario process. However, when looking at the images described in chapter 5, it is quite clear that there are considerable trade-offs in relation to the CO2 and the oil target. The images illustrate that these trade-offs can only be solved if investments in the rail sector have first priority.

Apart from these examples of extending the existing infrastructure another crucial issue is the maintenance and modernisation of existing infrastructure. 'Reflecting on the fact that politicians in general prefer to launch new projects rather than upgrade existing ones, it is safe to assume that even in periods of scarce budget funds new projects are still preferred and upgrading, reinvestment and maintenance are neglected.' (Rothengatter, 2006, 16).

The bottlenecks mentioned above are mainly related to geographical parameters. At least of the same importance are logistic bottlenecks, whereby the most crucial point is the shift of goods from one mode of transport to another, e.g. from truck to train, from train to ship or others. Technical improvements that allow more efficient operations at such interfaces are of utmost relevance for the success of intermodal transport chains. There is still a large potential for highly profitable innovations in this area. For example, advanced ITS together with RFID technology could significantly facilitate competitiveness of intermodal logistic chains. The calculation made in Chapter 5 illustrates that such improvements are urgently needed to make especially the comparatively energy efficient rail sector more competitive.

However, for example the TERM (2007, 12) report indicates that improvements in one mode such as the rail sector may attract additional transport and thus increase the overall volume instead of decreasing road transport. This illustrates that transport demand is a highly flexible factor. And it underpins that it is hardly realistic to solve future transport problems by single measures or technologies. It will surely be possible to remove some of the bottlenecks mentioned above. But it is not likely that the extension and optimisation of infrastructure will be able to cope with growth rates, as they are projected in the STOA baseline scenario.

6.3 Cleaner fuels and propulsion technologies

A wide range of non oil-based options for road and air transport has been developed in the last decade, and some technologies are already commercialised. Up to now, most of these technologies are designed for passenger road transport, mainly cars and public buses. Taking this into account, we will give a brief overview of the state-of-the-art. Wherever possible, we will have a look at the trucking and the air sectors, since in Chapter 4 those have been identified as being the biggest problems in terms of CO2 emissions from the long-distance sector.

Five technological mainstreams are discussed today, mainly in relation to passenger transport (JRC 2006; Schippl et al 2007):

1. Hydrogen and fuel cells
2. Hybrids
3. Battery Electric Vehicles
4. Biofuels
5. Natural Gas and LPG

All of these technologies have their advantages and disadvantages, and it is currently impossible to predict which technologies will emerge as the front runners of Europe. In the long run, especially for passenger cars and buses, hydrogen combined with fuel cells may be a promising technology whereby serious technological problems remain unsolved, amongst them questions concerning the performance of fuel cells, or from where large amounts of 'clean' hydrogen may be taken. Different routes are discussed including the generation of hydrogen from natural gas, from renewable sources, from coal and from nuclear power. Recently, the only affordable way of large-scale hydrogen production is via steam-reformation from natural gas. From a mid-term perspective, this route might support the market penetration of hydrogen and of fuel cells.

The crucial point is that, in this case, hydrogen is derived from a fossil source. Hydrogen production from renewable sources (wind, photovoltaic, solar thermal, water) via electrolyses is often regarded as a kind of silver bullet since it enables close to zero emissions of greenhouse gases (GHG). But it is not clear if, at which time, and in which regions the production of hydrogen from renewable sources will be feasible at larger scales and at reasonable costs. A 'clean' production of hydrogen from nuclear power is feasible as well. Controversies are related to nuclear power itself and to the finiteness of uranium resources. Hydrogen could as well be produced from coal. In terms of climate security the coal route will only be applicable if combined with CO2 sequestration and storing (CSS) – a technology that is still in the stage of basic research. In addition, the introduction of hydrogen would require considerable investments in infrastructure (and thus call for public-private-partnerships to share the risk).

Hydrogen is also discussed for the air sector. There are several specific reasons for that, such as the absence of alternatives to kerosene (apart of bio-kerosene) and the comparatively centralised infrastructure that may enable a large-scale production close to the airports. But the technological challenges are huge. Because of the low energy density hydrogen would probably have to be used in cryogenic form. However, already because of the security standards, it is not likely that hydrogen will be used in air transport until it had been established in the road transport sector. Taking into account that planes are commonly used over a thirty-year period or even longer, it is unlikely that in 2047 hydrogen will be used in significant amounts in the air sector.

Hybrid technology is currently high on the agenda and extends its market shares – again mainly for private cars and public buses. It offers a possibility to save energy and emissions by using established technologies and infrastructures. Whatever fuel and propulsion technology will be dominant in 20-30 years, it seems to be highly likely that hybrid technology will be part of the propulsion system, at least in cars. This 'hybridisation' at the same time means an 'electrification' of the drive train technology and thus supports a more dominant role of the electric engine in general. Hybrid technologies have their greatest potential in urban areas where driving means a lot of stops an goes. But in the meantime, it is as well discussed for long-distance transport. For example Volvo has developed a hybrid solution for heavy vehicles.

The commercialisation of pure electric cars (Battery Electric Vehicles) strongly depends on the development of suitable devices for the storage of electric energy (batteries or condensers). In spite of decades of research and development activities, decisive technological breakthroughs have not yet been achieved but seem to come closer, for example the promising lithium-ion batteries. A breakthrough in battery technology would surely entail radical changes of both the transport and the energy sectors. However, this would mainly be related to car transport. It is not expected that the energy density of batteries will be improved to a point where batteries would become an alternative to long-distance trucking. If there will be an electrification of the freight sector, it will rather be realised through electrification of the railway system and a corresponding modal shift of goods to the railways.

This text is written at a time when biofuels are discussed very controversially. Biofuels can be derived from a wide range of biomass and may serve as a relatively clean 'bridging' or 'additional' technology. So-called first generation fuel, mainly biodiesel and bioethanol, is the only renewable transport fuel option that is commercially deployed today on a broader scale. The production process is comparatively uncomplicated. Second generation biofuels are produced by synthesis, in most cases from synthesis gas which is then treated in a so-called 'biomass-to-liquid' process (BTL). A decisive benefit of BTL is the opportunity to define the properties of such 'designer fuels' by setting the synthesis parameters; engine and fuel can be very well adjusted to each other.

For second-generation biofuels the whole plant or other forms of biomass can be used to produce fuel, in contrast to the production of 'first generation' biofuels, where only parts of the plants (oil, sugar, starch) are used. Biogas also has the potential to contribute to climate and energy security. Blends with natural gas are imaginable. It is estimated that roughly between 20% and 30% of EU27 road transport fuels in 2030 could be covered by biofuels derived from European biomass (e.g. energy crops, agricultural and forestry residues, organic fraction of municipal solid waste). Imports of biomass are critically discussed since they may go at the expense of ecologically sensitive areas and they may be in competition with the production of food. In principle, biomass can be used for all modes of the long-distance sector. The second-generation 'designer' fuels are as well usable in trucks and aviation. Especially in the truck sector the admixture of second-generation biofuels could help to reduce emission and oil consumption. Labelling of biofuels will be important to get information about the Well-to-Wheel emissions and to make it transparent that there is a conflict of protecting environment and ensuring food supply.

Biofuels or Bio-Kerosene in the air transport sector are technically possible but not likely to come. For various reasons, among them high security standards, it is more likely that the potential of biomass will be fully tapped from its use in road transport and other applications (heating and power generation).

Natural gas technology (CNG) is feasible in the transport sector and has the potential to bring at least mid-term improvements in terms of energy security and GHG emissions – whereby it is crucial that real 'gas engines' are being developed. But in particular its possible contribution to energy security strongly depends on the overall demand for natural gas. It is likely that CNG vehicles will become at least established for niche applications (e.g. in major fleets, in inner cities). Again, the focus here is on private cars. But long-distance application for trucks is discussed as well.

Autogas (LPG) is a relatively uncomplicated technology. It offers environmental benefits at relatively low costs. It is becoming rather popular in several European countries. Since both CNG and LPG are based on fossil feedstock they must be considered as bridging technologies. They may help pave the way for 'cleaner' gaseous fuels such as hydrogen, bio-methane or DME. Autogas is already used for trucks. However, regarding the targets in this project, the potential CO2 saving seems to be too low (see JRC 2006) to make a significant contribution to the achievement of the targets.

Below the line, for long-distance trucking biofuels, CNG, LPG or blends of those fuels in combination with improved conventional engines (ICEs) appear to be the most suitable solution at least from a short and mid-term perspective. The situation in 2047 may be different and hydrogen may come into the game. However, one suitable solution may be to use the restricted potential of domestic biomass mainly for long-distance trucking and other fuels and propulsion technologies for urban transport.

Regarding air transport, there are even less options. There is a general consensus among experts that kerosene fuelled gas turbines will remain the relevant technology for air travel for the foreseeable future. At any rate, it is likely that innovative technological developments will be implemented and established faster in the road sector, since tight security standards in the air sector make it much more difficult to introduce new technologies, as they always present a challenge in terms of security.

According to the ICAO (2007, 110) an evolution of alternative fuels in the air sector may look like this:

- Present and short-term: synthetic jet fuel processed using the Fischer-Tropsch process.
- Medium-term: possible use of biofuels with necessary changes in the engine configuration.
- Long-term: cryogenic hydrogen and liquid methane are considered, but a number of technological challenges have to be solved prior to their use.

However, even if hydrogen can be used the question remains where it should come from.

Furthermore, it is argued that the construction of more radical aircraft configurations such as the so-called flying wing has a great potential to increase efficiency (see Akerman 2005). But still a lot of research is needed until such technologies will have a chance to be implemented. Akerman (2005) argues that a relatively efficient strategy would be to opt for a high-speed propeller aircraft with a cruise speed 20–25% lower than for a conventional turbofan aircraft. In that way, it should be possible to realise energy and GHG savings of 25% and even more.

In the air sector, research on alternative fuels and alternative fuel sources as well as on new propulsion technologies is at an early stage. The same is true for the rail sector where the use of fuel cells is discussed for some specific situations. However, regarding the rail sector, the central question in terms of energy and climate security is where the electric power should come from.

For ships, hydrogen and fuel cells may be more relevant and first prototypes are tested. Recently, the so-called Skysails system offers promising potentials to reduce energy and emissions. The system is a wind propulsion system based on large towing kites. It is said that by using the SkySails system a ship's fuel costs can be reduced by 10-35% on annual average, depending on wind conditions (www.skysails.info). Market penetration of this system is just about to start.

The technologies mentioned above are all promising but all have clearly weak points and bottlenecks. Each single technological pathway faces difficulties in terms of serving the complete future fuel demand of the EU27. Heavy innovations and huge investments in research will be needed to make significant progress in this field. In the mid- to long-term perspective, a phase-out of oil will probably exert pressure on the European innovation regimes. Policy strategies should remain flexible and open enough to support ground-breaking innovations (see Schippl et al. 2007).

7. Policy Packages to Reach the Targets

In this chapter it should be discussed which policy measures and policy packages are the most promising to reach the targets of the images. The following chart illustrates the different dimensions that must be taken into account when talking about policy packages.

Objectives (goal attainment)	Key actors	Technologies	Policies
Decreasing volumes Improving energy efficiency Improving carbon intensity (Improving transport flow)	Public institutions - Private investors Car Industry Engineers IT Industry Logistic operators Train companies Shipping companies Air carriers Private persons consumers	Fuels Propulsions Vehicles Materials Infrastructure Software: Telematics ICT ITS	ETS Carbon Taxation Fostering infrastructure Pricing Regulations, organisations, load factors Investment in research and development

Figure 26: relevant elements of policy packages

Successful policy packages look not only at policy instruments (regulations, incentives) but also at technologies and key actors at the same time. Key technologies are described in chapter 6 of this report. Policy measures are discussed in the following sections. Wherever possible the interests and perspectives of different actors are described in these sections.

In figure 27, in the row of objective and goal attainment the three basic options to change C02 emissions and oil consumptions are listed. These options were already discussed in chapters 4.3 and 5 to illustrate different ways of achieving the targets. In chapter 7.2 we will again refer to these three options. In many other publications these options or objectives are mentioned. For example Dalkmann et al. (2007) put it like this:

1. Transport Avoidance – the most pressing task is to influence spatial planning in order to prevent transport (growth) without jeopardizing citizens' mobility. Sustainable (urban) infrastructure thus sets out to serve mobility needs of the population without generating excessive transport.

2. Shift to more sustainable transport modes – a second-level task is to identify possibilities to make people choose more sustainable transport modes such as walking, cycling or public transport instead of driving a car.

3. Transport efficiency – the third-level task is to improve transport technologies and transport flows in order to orchestrate the needed transport in the most efficient way without wasting resources.'

7.1 Brief documentation of the discussion on policy packages

It should be noted that this section is strongly based on the discussion in the working group and in the expert workshop (see list of workshops in the Annex). It could be understood as a documentation of key arguments.

Since air transport and long-distance trucking according to the rough baseline calculations represent the highest contributions of CO2, the working group decided to concentrate the discussions of policy measures on these two transport modes. The high contribution of aviation (73.9%) and trucking (93.6%) is illustrated in figure 11 and again in figure 28 below. Taking this into account it is obviously inevitable to break trends in these sectors. Otherwise fulfilling the targets of CO2 and oil consumption would be impossible. This does not mean to restrict the discussion to these two modes, but rather to go into passenger transport via the air sector and to go into freight transport via the truck transport.

	2005	2050	Growth 2050 over 2005	Share in 2050
CO2 emm., Well-to-wheel, LD passenger transport (kt)*	**236430**	**381213**	**1.61**	**100**
Private cars and motorcycles	79591	93979	1.18	24.6
Rail	2555	1754	0.69	0.5
Aviation (intra EU)	151789	281607	1.86	73.9
Inland navigation	2496	3872	1.55	1.0
CO2 emm., Well-to-wheel, LD freight transport (kt)*	**345789**	**627020**	**1.81**	**100**
Trucks	305686	587090	1.92	93.6
Rail	20527	13187	0.64	2.1
Inland navigation	19576	26743	1.37	4.3
* note system delimitations described in chapter 4.2.1				

Figure 27: CO2 emissions from long-distance transport - 2005-2050 by mode (see figure 11)

7.1.1 Tackling air transport - key arguments

The following chart gives an overview of policy measures and their potential effects as they were discussed in the working group. Only the rows, where the group agreed on a high plausibility for a more or less strong effect of the specific policy measure, are marked.

AIR	**Travel volumes**	**Model shares**	**Capacity use**	**Oil consumption**	**Energy efficiency pr km**	**CO2 efficiency pr energy unit**
Carbon based taxation	++	+	+	++	+	+
Emission trading	++	+	+	++	+	+
Emission standards	++	+	+	++	+	+
Individual carbon allowances	+++	+++		+++	+++	
VAT on air transport	++	++	+			
Alt fuel promotion				+++		++
Regulative airport investment policy	++	++				
Land use planning	++	++				
ICT promotion			+	+		
ITS				+		
Speedy (C-free) Rail network investments:	++	++		++		

Figure 28: policy measure for tackling air transport

+ probable positive impact

++ clear positive impact

+++ strong positive impact

Please note the following explanations: positive/negative is related to the quantitative targets (reduction of GHGand oil consumption). So a positive impact means that the policy measures contribute to reach the target. For example regarding travel volumes, a '+' means that volumes are decreasing since this leads to a reduction of GHG emissions and oil/energy consumption. The qualitative target 'accessibility' is integrated as a category on its own.

In terms of oil consumption and emission of GHG gases the crucial issues about air transport are the projected high growth rates as well as the strong effect on radiative forcing. Already the greenhouse gas effect of CO2 emission is comparatively high. The relevance of water vapour for radiative forcing is still discussed and it is controversial.

This uncertainty mainly concerns the effect of cirrus clouds induced by aircraft emissions. Based on a publication from Sausen (2005) the IPCC report considers the impact of water vapour and to some extent also NOx, as probably being even higher than the impact of CO2 emission. In a 2006 paper the European Federation on Transport and Environment sees the contribution of air transport to climate change between 4 and 9% for the year 2000, on the global level (T&E 2006). This broad range underpins that there are still lots of uncertainties regarding the effect of air transport on climate change.

Different strategies to tackle oil consumption and CO2 emissions in the air sector are imaginable.

- Reducing volumes by reducing the amount of trips or the average distances per trip
- Reducing volumes by inducing a shift to other modes of transport
- Improving energy and GHG efficiency through alternative fuels and propulsion technologies or through a more efficient design of the airplane
- Improved airport management (reducing flight times)
- Better load factors

<u>Pricing related measures</u>

The policy measures listed in the chart above support one or several of these strategies. The chart shows measures of different natures. For the first group of measures pricing is a key element. At first glance the effect is pretty simple: costs of transport are increased, and consequently transport volume is decreased which goes along with energy savings and reduced CO2 emissions. The following pricing related measures were discussed in the working group.

- Carbon based taxation
- Emission trading
- Emissions standards
- Individual carbon allowance

It was discussed that the implementation of carbon based taxation could have an immediate effect by reducing travel volume because of higher prices; trips are avoided or shifted to other modes of transport. The potential of modal shift strongly depends on the availability of convenient alternatives, such as high-speed rail. The competitiveness of the rail sector is very important. In the long run effects in terms of technological improvements are likely as a result of carbon based taxation, which means that there is strong long-term effect to be expected for energy and CO2 efficiency. A clear effect of the utilisation of capacities cannot be identified – there may be incentives to increase load factors because of higher costs. Similar effects can be expected by including air transport in the emission trading system.

Regarding the implementation of emission standards the effects seem to be quite similar to those of carbon based taxation. There could be a stronger push-effect regarding the implementation of new technologies. Emission standards for airplanes would accelerate research and development activities for cleaner airplanes. One option could be the development of bio-kerosene as a second-generation biofuel (see chapter 6.3). This does not necessarily mean improvements of energy efficiency.

A more visionary or speculative measure would be to establish an individual carbon allowance. The basic principle is that each European citizen has the right to produce a certain amount of CO2. A lot of variations are imaginable but in the end, it is up to the citizens in which way to use his CO2 budget. A quite strong effect from such a measure on the air sector can be expected. There is a chance that it would increase the awareness of transport related CO2 emissions.

It was argued that for all these measures there is a strong correlation between the level of prices and the impact on transport volumes. The effectiveness also depends on the cost structure, or on the relation of carbon tax or fuel costs to the overall costs. It is likely that relatively high prices are needed in order to have a clear effect. In this context the question must be raised as to what extent higher prices are acceptable. In addition, it should be noted that a consequent and effectual implementation of pricing-oriented measures could mean a reduction of accessibility. Especially peripheral regions that do not have meaningful alternatives to air transport could suffer from higher prices and reduced accessibility.

Furthermore, it is critically discussed that there is no fuel taxation on kerosene and that international tickets are excluded from VAT. There are several reasons for implementing such rather classical mechanisms, amongst them the internalisation of external costs and a slight curb of volumes that is assumed if costs would be higher. According to a T&E (2006, 18) statement aviation fuel tax could have the following impact: 'A tax of 0.125€ per litre (only one-fifth of the level of road fuels) would already reduce aviation CO2 emissions by 10%'. Figure 30 gives an idea of the correlation between kerosene tax and emission reductions. However, for all pricing related measures, estimations of the potential impact are difficult to calculate and often cause controversies.

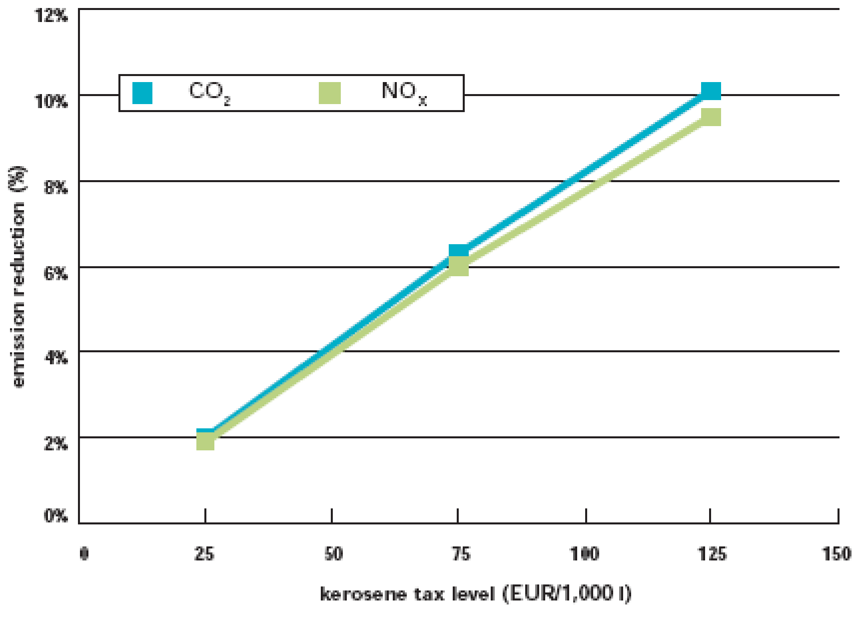

Figure 29: impact of a Kerosene Tax on CO2 Emissions from aviation in Europe. Source: T&E 2006, 20; based on a conversion of results from CE Delft, 2002)

The implementation of the Emission trading system (ETS) is as well discussed as a promising measure in the air sector. Several factors influence on the effectiveness of such measures (see T&E 2006; CE Delft 2005). It is crucial if only EU flights or all flights from and to Europe are included. There are the questions of the level of the cap and of the way permits are allocated. Furthermore, in the air sector it is crucial if only CO2 or also non-CO2 GHG emissions are included. There are different views on the potential of this measure.

A rather critical one is coming for T&E (2006, 25) regarding the consequences of ETS on fuel prices: 'CO2 prices that are likely to stay around 10 cents or so per litre or even lower are not expected to make much difference'. T&E therefore supports a combination of ETS with other pricing measures. However, it is likely that the price for CO2 will rise significantly in the future because of the strong increase in air transport. So in the long run, efficiency of ETS should increase as well.

Focus on technologies

The working group agreed that it is basically possible to accelerate the introduction of cleaner technologies also in the air sector. The 'promoting-alternative-fuels' measure can be tailored to foster more carbon and energy efficient technologies. The situation is not the same for propulsion technologies as it is for fuels. Whereas the introduction of cleaner or more efficient propulsion technologies is hampered by the long lifetimes of airplanes (up to 40 years), a switch to bio-kerosene could – theoretically - take place immediately. The situation is again different for hydrogen which would require a specific construction of the airplanes, and could thus only be introduced step by step through replacing the old kerosene fleet. Generally, alternative technology options for air transport are limited compared to various options that exist for road transport (see chapter 6.3). The high security standards in the air sector make it difficult for new technologies, especially when it comes to groundbreaking innovations. The question remains open, whether the limited global amount of biomass might better be used in other sectors such as road transport, heating or power generation where a more efficient usage is possible. The same question could be applied to 'clean' hydrogen.

Another problem is that the role of water vapour emission for global warming is not absolutely clear, as it was already mentioned above. But it seems likely that water vapour contributes with a very high share to the GHG balance of airplanes (see above). If these results are not going to be rejected, it would mean that changing to biomass or hydrogen would not have a too strong effect. Both alternatives to kerosene, hydrogen and bio-kerosene emit considerable amounts of water vapour as well. Whilst for bio-kerosene the water vapour emissions are expected to be similar to those of conventional kerosene, the water vapour emissions of hydrogen are discussed as being more than double. So, there are quite a lot of restrictions to improve GHG-balance through using cleaner and/or more efficient fuels and propulsion technologies in the air sector.

Flying slower

It was discussed in the working group that a rather efficient way of reducing energy consumption and emissions in the air sector is to opt for slower aircraft configurations. This would mean flying at less speed. According to Akerman (2005, 125) this could be an advanced turboprop aircraft cruising at between 640 and 700 kph. The overall potential is not easy to assess because of NOx and water vapour, but the reduction of GHG emissions would probably be significantly more than 25%.

Intelligent transport systems (ITS) / information and communication technologies (ICT)

Furthermore, in terms of technologies, there is the argument that a far-reaching implementation of ICT and ITS will lead to improvements in the air sector. This effect is supposed to have different reasons. First, a significant improvement in terms of energy consumptions and GHG emission could be achieved through better management and organisation, mainly at the airports. It was argued in the working group that a lot of energy is wasted just for the time airplanes have to spend in the air above the destination, waiting for a landing slot. Especially for shorter distances this waiting phase contributes strongly to the overall emission of a journey. The concept 'one single European Sky' aims at contributing to improvements regarding management and organisational issues.

The ICAO (2007, 110) supports the argument that more direct routings and the use of more efficient conditions such as optimum altitude and speed have a huge potential to contribute to energy savings. Shortening routes can indeed reduce CO2 emissions significantly.

Apart from this, there is the question as to what extent a stronger implementation of ICT will improve load factors. This potential was not regarded too promising by the working group, mainly since load factors are comparatively high in the air sector. However, a slight effect may be achieved.

It was discussed if there is a potential to avoid the need of travelling through usage of modern information and communication technologies. For example, videoconferences or teleworking could substitute personal meetings. Up to now, such an effect is hardly proven. However, there are several factors that influence on the attractiveness of such things as videoconferences, amongst them transport cost, the general willingness to do business trips, the social expectations of personal contacts or security issues (danger of terrorist attacks). So, depending on such conditions it cannot be excluded that in future a certain amount of long-distance travel may be substituted by information and communication technologies (videoconferences in particular).

Focus on land use planning

Land use planning was regarded as a relevant measure by the working group – but only in the long run. There is a chance to make influence on the distribution of airports in a country, e.g. to foster either the development of a few huge airports or to induce a more equal distribution of airports in a country. The latter would induce a lot of air trips whereas the concentration on only a few airports could strengthen high-speed railways, given there is a corresponding infrastructure. Such offensive integration of airport distribution would be much more effective if it takes place at the European level. However, this would mean to overcome national competition in this area, which is surely an immense challenge. Furthermore, this leads directly to the main argument in the field of land use planning: transport volumes in the air sector could be tackled by the implementation of high-speed railway lines. This would mean giving priority to high-speed railways when it comes to financing infrastructure. Again, this should be done on a European-wide level.

Below the line, it is difficult to say what the most promising measures in the air sector are. Several combinations of measures seem to be promising such as for example the ETS and fostering high-speed trains and videoconferences at the same time. Airplanes operate over periods of more than 30 years. If more efficient design of airplanes should become effective over the next decades, it is important to set the right incentives (emission standards, fuel taxes etc) already today.

7.1.2 Tackling trucking - key arguments

Similar to the air sector, a set of measures related to trucking was discussed in the working group. The following chart gives and overview of policy measures and their potential effects. Again, only those rows are marked, where the group agreed on a high plausibility for an effect of the specific policy measure.

Trucks	Travel volumes	Model shares	Capacity use	Oil cons-umption	Energy efficiency pr km	CO2 efficiency pr energy unit	Accessi bility
Carbon based taxation	++(+)		++		++	++	
Cab & Trade	++		++		+	+	
Emission standards					+	+	-
ITS Speed control Route guidance	+		+		+	+	+
Efficient Warehouse Distribution	+				(+)	(+)	+
Load matching	+		+(+)		+	+	(+)
Alt fuel promotion + Fuel Cells							
Road Trains			(+)		(+)	(+)	(+)
Hybrid	0				+	+	
Dedicated Freight Rail			+		+	+	+

Figure 30: policy measure for tackling trucking

+ probable positive impact
++ clear positive impact
+++ strong positive impact

Please note the following explanations: positive/negative is related to the quantitative targets (reduction of GHG and oil consumption), so a positive impact means that the policy measures contribute to reach the target. For example regarding travel volumes, a '+' means that volumes are decreasing since this leads to a reduction in GHG emissions and oil/energy consumption. The qualitative target 'accessibility' is integrated as a category on its own.

The policy measures in the chart are not identical with those for air transport; they were slightly adjusted to the truck sector. Again, strategies can be distinguished, amongst them:

- Tackling volume by reducing the overall amount or the distance of goods that are carried
- Tackling volume by shifting goods to rail transport or inland navigation
- Improving load factors
- Implementing cleaner fuels and propulsion technologies
- Saving energy by improving transport flow and optimising routes

Pricing related measures

Policy measures listed in the chart above support one or several of these strategies. Similar to the aviation sector there is a set of measures that will lead to increased prices for goods transport. It is assumed that there is a clear correlation between the level of pricing and the decrease in transport volumes. The policy measure of 'individual carbon allowance' that was discussed for air transport was replaced here by a 'Cap-and trade' system. The underlying idea is that a carbon allowance on an individual basis is not meaningful for the freight sector and should be replaced by a company allowance.

Similar effects are to be expected regarding carbon based taxation and the 'Cap-and-Trade' system: On the one hand, there should be a decrease in volumes induced by higher prices. This might induce modal shift to rail or inland navigation by increasing competitiveness of these sectors or it might reduce total transport volumes, which may go along with negative effects on the European economies. On the other hand, these measures should be able to foster the development and market penetration of cleaner vehicles.

Establishing ambitious emission standards may have a similar effect whereby in this case the emphasis is more on making trucks efficient and clean. When it comes to the implementation of cleaner engines and alternative propulsion technologies it will take 5-10 years until new technologies become dominant in the fleet and a significant effect can be observed.

Furthermore, these pricing measures could induce a better usage of load capacities. The consequences should be improved efficiency.

Again, it should be noted that a consequent and effectual implementation of pricing oriented measures could also mean a reduction in accessibility and have negative influence on the economy. Especially more isolated or peripheral areas may be negatively affected in term of accessibility and economic growth.

During the expert workshops it was critically discussed that carbon based taxation and other pricing measures must be extremely high to have a significant effect on volumes. Fuel costs are only one element of the overall cost structure in goods transport, meaning that the influence of carbon taxes on the price of goods and on freight transport should not be overestimated.

Furthermore, the question must be raised as to what extent pricing measures are acceptable and, in the same context, if there is at all an 'acceptable' way of meeting the targets of this project. Again, the problem is not pricing itself but the level of pricing. When pricing gets effective, it means that it prevents people from using a certain mode of transport. Therefore acceptability becomes a challenge at the point when pricing gets effective.

Logistics and Management

There is a set of measures trying to improve logistics, organisation and management. A key objective is a better utilisation of capacities by increasing load factors. The working group agreed that there is still a significant potential for such measures. A set of measures was summarised under the title 'load matching': this is a specification of 'ICT use' to improve capacity use and reduce empty running. It was discussed if it is better to have an empty truck driving the shortest distance, or if the CO2 emission accounts would benefit from a detour to fill up the trucks. It was agreed that the latter is most frequently the best option.

Land-use planning

Apart from this, there was a discussion on 'efficient distribution of warehouses': this leads to issues of land use planning. In the freight sector, the optimised distribution of warehouses should reduce transport volume. It should be possible to strengthen the railways by locating industrial areas and railway stations closer together. However, regarding land-use planning it was generally agreed that other factors outnumber it. If there is an effect, then it would only be realised in the long run.

Intelligent transport systems (ITS) / information and communication technologies (ICT)

In context of Intelligent Transport Systems the potential effect of intelligent speed control and route guidance was assessed. Both could improve traffic flow and thus accessibility. Route guidance has a potential to improve efficiency by avoiding detours or by circumnavigating congested areas (see also chapter 6.1).

Cleaner technologies

Directly promoting alternative fuels and propulsion technologies (including biofuels, Compressed Natural Gas, fuel cells + hydrogen) by various incentives should have an effect on emissions and efficiency. One of the striking advantages of these technologies is that their implementations do not have to go at the expense of accessibility. Regarding hybrid technology for trucks it was discussed if this would only be a technology for urban transport, since the recharging of the battery is connected to stop-and-go driving. However, it was argued that hybrid technology could be developed to be efficient also in the long-distance segment. Volvo recently started promising approaches in this context (see chapter 6.3)

A rather visionary and speculative example of striking changes in the transport systems was discussed in form of implementing road trains on European highways. A lot of details have to be considered if it comes to the integration of such a complex system in the established transport systems. Highly crucial is the installation of a trolley system in order to provide for electric power. This would mean a highly relevant reduction in oil consumption, for the GHG balance it is important where the electricity comes from. It is imaginable that individual trailers are connected to road trains at specific locations along the highways. When leaving the highway, the trailer could be reconnected to a tractor and run like a common truck outside the highways. This could be a way of combining energy efficiency with a high degree of flexibility. However, apart from many unsolved problems, considerable investments in infrastructure and equipment would be needed.

Focus on Freight Rail

The calculations in chapter 5 prove that a shift of volumes from both passenger and freight transport to the railway system is crucial for reaching the targets in this project. The railway system has to be able to compare on the parameters time and costs. In this context it was argued that it may be necessary to give more priority to freight rail than it has been the case up to now. Inter-city rail has been highly prioritized regarding passenger transport, but to get a modal shift from trucks to rail it is important to do something about freight rail. An integrated management of the railways will be an essential part here, because right now Europe has a range of different management systems when it comes to rail transport. Integrated management had accordingly a higher priority to the group than high-speed. Rail transport was considered the best way to introduce electricity in freight transport.

Furthermore, it was emphasised that potential rebound effects should not be overlooked. For example increasing capacities together with quality in the rail sector could induce a sort of rebound effect if total transport volumes are increased (e.g. a shift from road to rail; but additional goods on the road because of new capacities).

When talking about modal shares it was noted that with the oil prices going up, it will at some point be the case that other modes will be more competitive to the oil based forms of transport. The experts of the working group agreed that the railways have a logistics problem compared to trucks. One suggestion highlighted the role of the actors in the freight sector by saying that companies covering more than only one part of the transport chain can provide better integration of modes. In general, it was agreed that there is a huge potential to improve logistics in the rail sector.

In 2001, the European Transport White Paper formulated a 'fiction or prediction' for rail transport 2010. Even if this is only two years away, a consequent implementation of most of the ambitious measures mentioned there would still mean a great benefit for the rail sector and help turn the fiction into a prediction – beyond 2010.

Fiction or prediction? Rail transport in 2010 (European Commission, 2001, 33ff)

The *railway companies* enjoy access to the railway network on equal terms, published by the infrastructure managers: capacity is allocated in real time with reference to the entire European network, and charging principles are harmonised.

Railway equipment manufacturers ought to be benefiting from the introduction of Community provisions on the interoperability of the railway system to gain non-discriminatory access to the European market and enjoy the possibility of using innovative technology rapidly.

Engine drivers can drive anywhere on the trans-European network and are trained for European routes at European training centres open to all railway companies.

The *national infrastructure managers* are organised at European level and jointly decide the conditions of access to the network. Observing the competition rules, they decide on investment priorities together and establish a dedicated infrastructure network exclusively for goods.

The *railway regulators* meet regularly to exchange information on the development of the rail market and propose measures to adapt to competition from other modes.

All *rail operators* offer travellers integrated online services covering information, bookings and payment for both leisure and business travels.

The European network offers high safety standards, backed up by a Community structure responsible for ongoing appraisal of safety levels in the European rail system and for recommending any improvements necessary. An independent body investigates any accidents or incidents on the network and makes appropriate recommendations to reduce the risks.

Train punctuality is guaranteed and passengers and customers receive compensation if trains run late.

Average speeds for international goods trains in Europe are up to 80 km/h, four times faster than in the year 2000.

7.2 How to reach the targets

In this chapter, it is discussed which policy measures and technologies seem to be appropriate to reach the targets - taking into account the different settings of the images for 2047. This means assessing the measures from a today perspective and understanding them as pathways to 2047. At the same time, it must be taken into account that the surrounding conditions will develop in a certain direction – as described for image I and image II. Combinations of policy measures can be interpreted as pathways leading to the images.

Again, this paragraph is strongly based on the discussions in the scenario working group.

7.2.1 Image I

In the world 2047 described in this image there is a very strong focus on innovation within science and technologies. There is 30% reduction in overall transport volumes compared to the baseline. However, this is by far not enough to come close to targets. It was calculated in chapter 5.1 that the targets have to be fulfilled by strongly increasing the energy efficiency and lowering the carbon intensity of long-distance transport. In addition, a strong modal shift to the railway sector is needed.

As described in chapter 5.1, a strong growth in passenger rail (+190%) but also in freight rail (+70%) is needed to change the modal split significantly. On the one hand, as a sort of pull factor, this means that capacities as well as the general competitiveness of the rail system have to be extremely increased. On the other hand, as a sort of push factor, prices for other modes have to be increased. Aviation looses shares in this scenario (-4% compared to the baseline).

Furthermore, carbon intensity must be heavily improved in the long-distance sector. The following figure was calculated in chapter 5.1 (improvement in carbon intensity compared to 2005):

Private cars and motorcycles	**72.7%**
Passenger rail	**79.0%**
Aviation	**64.3%**
Trucks	**59.2%**
Rail	**75.4%**

Therefore, policy measures focusing on the development of new and innovative technologies are crucial. CO2 lean fuels and propulsion technologies must be pushed into the market. This could include the slow but constant introduction of carbon based taxation, heavy emission standards or the establishment of an efficient emission trading system that includes the energy system and with it the transport system. The suggestion of a 6% escalator for carbon tax was discussed in relation to anticipated effect; in aviation, up to now, an increase in fuel price for aviation did not have a clearly visible effect on transport volumes.

In general, it should be rather easy to implement new technologies. But since there are relatively high transport volumes there is a need for groundbreaking technological innovation to have a chance to meet the targets. Therefore, massive investments in research activities are needed already today in order to get technologies ready for commercialisation over the coming decades. As it was described in chapter 6.3, a wide range of alternative technology options is discussed for the transport sector. Especially for the long-distance sector it is not clear yet which of these technologies will become dominant in the next decades.

To have a chance to reach the targets in Image I, a wide range of technological developments must be fostered already today. Market penetration of cleaner technologies that do not need an extra infrastructure should be fostered, since CO2 emissions accumulate over the years. However, all clean technologies must be pushed to the limit to reach the targets. Since a lot of biofuels will be needed in this case a labelling system for biofuels should be developed. From a certain point on, the use of biomass in the transport sector could be restricted to second-generation biofuels.

Regarding this image, the potential negative trade-offs of increased prices for transport can be balanced by the sound growth rates in GDP and the slight but stable increase in European wealth. There is even a certain danger of dilution effects meaning that pricing is outpaced by increasing incomes.

The settings in this image describe that there is a strong and powerful EU. This means that it is comparatively easy to implement European-wide policy measures. Harmonisation and standardisation, as they are envisaged with ERTMS for the rail sector and the 'Single European Sky' programme have to be implemented consequently. The underlying principles of transport behaviour in this image is similar to what we know from today. Therefore, it is important to offer convenient and fast transport alternatives for goods and people.

On the other hand, heavy investments in infrastructure are needed to change the transport system considerably. Sophisticated rail transport must become highly competitive, and inland navigation is optimised. Freight rail must become smart and efficient (automatic terminals) to enable a modal shift from oil-based road transport to electrified rail transport. ICT should be used for improving rail performance and interoperability (intermodality/multimodality). ICT could be used for tracking goods in the logistics system.

For high-speed railways many key technologies are already available today. There is a high potential in improving cross-border high-speed transport. It is an approved technology and the problem is to implement it. What we miss are the investments in infrastructure and a higher degree in international standardisation. It is primarily a political question. It is hardly imaginable that the targets should be reached in this image if investments would focus too much on the road network.

The ship sector as well should profit from technical progress. This means cleaner and more efficient but also innovative add-on technologies such as the so-called skysails approach (www.skysails.info).

The use of ICT can be supported with the aim of substituting certain amounts of transport by high-tech solutions like advanced videoconferences or video supported telework.

Land-use planning has long-term effects. It takes time to change the corresponding infrastructure. A high degree in international co-operation is needed to enable an efficient Europe-wide land-use planning. This should be feasible in the framework of image I with a powerful European Union.

Since the gap between the Image I projections and targets for oil and CO2 is huge, it seems likely that some striking new high-tech solutions are needed that may be hardly imaginable from today's point of view, amongst them could be

- Energy supply: European-African SuperGrid with clean energy coming form Northern Africa.
- Striking breakthroughs in technologies for energy storage.

- Energy efficiency: road trains (see chapter 7.1.2): a high degree of European regulation is needed to implement such measures effectively. In image I, such regulations are easy to implement on a European scale.

Research including technology assessment related to such visionary alternatives should not be neglected.

7.2.2 Image II

For image II, transport volume is 50% lower compared to the baseline. Still a remarkable modal shift and/or technological progress are needed to fulfil the targets. In chapter 5.2 a 75% increase in passenger rail and 100% increase in freight rail were used for the calculation. This means that here priority is given to freight rail. An extensive high-speed network is not that important since people accept it to travel more slowly as long as it is comfortable. Especially trucks are loosing shares (-11) compared to the baseline, but also the shares of air transport are significantly lower (-5%). But the calculations in chapter 5.2 illustrate that in spite of the reduced volumes and the modal shift still strong improvements in carbon intensity are needed to reach the targets.

The following figures are used for the calculations in chapter 5.2 (improvement in carbon intensity compared to 2005):

Private cars and motorcycles:	**59.0%**
Passenger rail:	**72.0%**
Total aviation:	**58.3%**
Trucks:	**44.4%**
Freight rail:	**68.0%**

Even if these figures are clearly lower than those in image I they are still highly challenging. This means that also to reach this image a strong promotion of cleaner technologies is needed.

In contrast to image I, image II shows that striking changes that go beyond what is imaginable today are not that much related to technologies but to behaviour. It is possible to easily create awareness amongst people on climate change etc. A higher acceptance for pricing measures is assumed here which affords a broad set of policy measures tackling transport volumes.

This image describes a development where technological progress plays an important role but is not such a crucial factor as it is in image I. A central idea in this image is to use technology in a notably 'intelligent' or intentional way in order to substitute the need for fast transport.

Travelling fast is not first priority but high comfort and advanced safety standards are important. Thus, adding comfort to the transport modes is crucial. It should be possible to get a significant effect of CO2 and energy reduction by reducing travel speeds for all modes of transport – a measure that would be absolutely unacceptable for the European society as it is described in image I. In line with this would be to give priority to optimising the freight rail network, which goes at the expense of an extension of the high-speed network for passengers. Significant energy and GHG savings can be realised by reducing the speed of aircrafts. For inner-European connection this would not result in too much longer flight times.

Apart from this, a broad set of policy measures and technologies mentioned for image I are as well applicable for image II. This clearly underpins the importance of such measures. Amongst them are: carbon tax, ETS for the air sector, strong investments in rail infrastructure, ICT use for tracking logistic chains, promotion of alternative fuels and others.

A far-reaching internalisation of external costs is needed to get to this image. Such a concept could in detail look like this:

- Road pricing: a differentiated charging system for using roads.
- Common carbon taxation systems for all modes of transport.
- On top an air carbon tax could be added, to address the specific problems of aviation. It will mean some drawbacks. The aim should be to at least reduce such trips for only a weekend, and to make it an attractive alternative to go by train and spend more time at the location – to make slow journeys make sense.
- There should be no need for too much investment in airports, since there will be less demand for air transport.
- Carbon-lean trains could be an alternative to air transport. With high quality and high-level service. It must be possible to do other things while travelling: working, being entertained, having Internet access etc.
- Regarding the levels of taxation it is important to start now and slowly change the taxation system. The cost of emissions should be increased. Incremental: 5% increase each year. The cap could be set according to the target.

Drawbacks and counter acts are imaginable: a lack of social equity may become more obvious with carbon tax. A carbon tax or road pricing could induce difficulties for rural settlements. To give a carbon credit for everyone means allowing everyone to travel a limited amount. A sort of compensation for a lack of social equity could be to allow selling of the carbon credits. This could make it difficult to foresee the impact of a carbon tax. (A threshold for selling the credits could be a solution). However, the social impact seems to be more difficult to assess than the climate effect.

Furthermore, in the working group it was discussed whether it would be possible to solve leisure and work travelling by flexible 'homes' and social networks. In the 'slow' image it may make sense to travel around Europe by train if one can work while moving slowly. It could be possible to bring your children to the different locations, provided there are nurseries etc. to take care of them. Or technology could help having virtual contacts. Arguments against was that too much virtuality in life will be in conflict with psychological factors such as having a family life and identity, workplace identity, to create a safe sphere of familiarity. Still, the slow and reflexive society offers many options for a 'carbon-lean' behaviour.

7.2.3 Contrast Image

In image III, we have a low economic growth and very high energy prices. Transport growth is hampered by this fact and stays 60% below the growth that is projected in the baseline. This image does not fulfil the criteria for images in the backcasting method since it is not desirable (see chapter 5). In addition, in this image there is not much scope for political actions since the political sphere especially on the European level is rather weak. For that reasons, policy measures were not discussed in relation to this image.

We called this image 'Contrast Image'. It is in this report since it illustrates one more variant of what the world would look like and it underpins that the surrounding conditions are of great importance to the transport sector. Furthermore, it illustrates that in spite of a 60% reduction in transport volumes still carbon intensity has to be improved remarkably.

For image III, the following figures are used for the calculations in chapter 5.2 (improvement in carbon intensity compared to 2005):

Private cars and motorcycles	**52.2%**
Rail	**67.4%**
Total aviation	**58.3%**
Trucks	**40.1%**
Rail	**65.6%**

These figures are clearly lower than in the other two images but still challenging. This is also because no modal shift was assumed in this image. It is not likely that a shift to railways takes place since in image III there is no significant progress in European harmonisation and standardisation. However, it can be discussed to what extent energy prices will have an effect here. At any rate, investments in cleaner fuels are needed – in all three images.

8. Conclusive Remarks

It was already mentioned in the introduction that the overall objective of this report is not to make predictions on what the world and the transport system would look like in 2047. It is just impossible to produce reliable data over a 40-year period in relation to a highly complex field such as European transport. There is a clear limitation to quantitative approaches in such fields, which is why a scenario approach allowing for the combination of quantitative data with qualitative elements was chosen.

Two central objectives of this project have been stated:

- To give an idea of the magnitude of change needed if certain targets should be reached in the long-distance segment;
- To assess and illustrate the potential options for policy measures and technologies in the light of different situation (scenarios or images).

Working with scenarios on a 40-year timescale means dealing with a lot of uncertainties. In spite of these uncertainties assumptions have to be made in order to be able to say something about what the world could look like in several decades. But still scenarios are appropriate and helpful instruments to support policymaking.

In the case of long-distance transport there is also a certain degree of uncertainty in relation to the current situation: there is no clear and widely accepted definition of what exactly long-distance transport is, which has implications for the quantitative side of the process. The problem of defining long-distance transport is linked to the difficulties of obtaining data for the long-distance sector. For this project it was decided to define long-distance transport by one simple criterion: all transport that is longer than 150 km is considered long-distance transport. This again creates another uncertainty: data do not exist for all modes of transport about the share exceeding a 150 km distance. Again, some estimations had to be used. These estimations have mainly been worked out in the project working group. It is clear and in a way as well intended that such system delimitation induces reflections and criticism.

It is important to take the system delimitations into account, especially when looking at the results of the baseline calculations in this project. Through the way the calculations were made here it became apparent that it is highly crucial to tackle air transport and long-distance trucking. Trend breaks are needed for these modes of transport. If not, it is likely that the ambitious targets for CO2 emission and oil consumption can never be reached. Different ways to tackle these modes can be distinguished and grouped around the following three strategies: reducing volumes, improving carbon intensity by new technologies and inducing a modal shift. The calculations in chapter 5 illustrate that for all three strategies really striking changes are needed to obtain the targets. Especially the rail sector needs a heavy upgrade over the next decades to be able to meet the demands from the passenger air and/or trucking. Extending and improving the network harmonisation of European rail standards are the most crucial measurements in the long-distance sector.

A broad set of policy measures has been discussed in the working group. Some of the policy measures are either feasible in image I or in image II. In image I, there is a stronger focus on technology developments. And there is a stronger need for decisive technological breakthroughs since only a comparatively low reduction in transport growth rates is assumed. In contrast, the settings in the second image indicate the need for behavioural changes. This could be that travelling comfortably becomes more important than travelling fast or a relatively high acceptance of pricing measures in this relation.

Below the line, it can be stated that a mixture of pricing measures and incentives for development and commercialisation of innovative technologies is required and applicable in both images. Most policy measures cannot be implemented in a 'soft' way since this will not enable the fulfilment of the targets. For example, road pricing on a low level will not change the situation significantly. The fact that certain policy combinations (including pricing) are needed in different images, meaning under different surrounding conditions, underpins the high importance of such policy packages. It becomes obvious that to reach or even get close to the targets both demand management and technical solutions are required. But demand management alone will only take us some of the way to the targets. Significant technical innovations are crucial to reach the targets in all three images. Heavy investment in research and development of cleaner technologies is needed on a broad scale, since especially in the long-distance sector it is hardly possible to predict which technology pathway will become dominant over the next decades. It is crucial to enable groundbreaking innovations.

On the other hand, it is possible to identify areas in which technologies are available but not consequently implemented because of a lack in regulations and harmonisation of European standards. A typical example is the rail sector that is supposed to carry the load in image I and image II, but urgently needs to increase its capacities in order to be prepared for this. But also for the future development and commercialisation of technologies such as cleaner fuels or propulsion systems, a European harmonisation needs to be accelerated. Also in the air sector there is a potential to increase efficiency by regulative and organisational measures. The settings in image II allow a significant reduction in emission by just reducing travel speeds.

For all of these images it seems to be not at all easy to reach all three targets. It is quite ambitious to reduce CO2 emissions and oil consumption and not reducing accessibility at the same time. The questions must be raised if it is realistic to reach all three targets in the settings given by the different images, even if transport growth is reduced compared to the baseline calculations. Doing so, the focus on the long-distance sector has to be broadened and the question should be asked if there are other sectors in the transport and energy system within which it is more feasible and efficient to reach significant reductions in CO2 emissions - in particular if a higher targets than 60% reduction is needed. Or it should be considered if reaching the CO2 target would only be possible if we accept to curb the growth in physical accessibility – supported by improving functional accessibility such as virtual mobility, shorter journeys etc.

Pricing oriented measures were discussed in this project as a tool with a high potential if used consistently. However, it is clear that the public acceptability of policy measures (especially pricing measures) and technical innovation is a crucial factor for the future of European long-distance transport. Therefore, in a third phase of this project, citizens will be involved in assessing the different possible actions to meet the targets.

Until recently, the transport system often was regarded as an isolated system in the energy sector since it is mainly running on oil. Whatever technologies will come after the phase-out of oil, the transport system will become much more an integrated part of the energy system. In this context it should be mentioned that another STOA project deals with the future of the European Energy System, including the transport sector.

There is a huge variety of the nature of useful transport related measurements and a wide range of actors affected by these activities. Consequently, stakeholder involvement in integrative approaches is needed to develop and implement such measures. The scenarios illustrate that the transport system is deeply embedded in the socio-economic environment. Many of the transport related policy measures have far-reaching effects; amongst them may be rebound effects or unintended side effects in other areas.

Again, an integration of stakeholder is needed to enable a profound technology assessment to make such potential rebound effects or unintended side effects visible.

Furthermore, integrating stakeholders is crucial when developing a long-term vision of a low-carbon or even of a carbon neutral European transport system – such a vision is still missing. Developing such broadly accepted 'guiding visions' again needs a broad basis. Scenarios and images as they have been used in this project seem to offer an appropriate basis for such an integrative task.

However, the main message from the report is rather simple: in order to reach these or similar targets in 2047 urgent action is needed right now.

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10. Annexes

Annex A: System delimitations

Data for the STOA baseline scenario

A major obstacle in defining long-distance transport is linked to finding data for the baseline scenario. In searching for data for the baseline the project has made use of both existing sources and tested the possibility of using modelling tools. It has been decided to use existing data for calculating the baseline within the above definition of long-distance transport. Covering the whole long-distance transport system and the accuracy of figures have been given less priority since the future of 2047 already means operating in fields of uncertainty. It is the scale of change needed that the baseline should illustrate.

The data used are taken from the EU Commissions DG-TREN, **'European Energy and Transport – Trends to 2030 update 2005',** published in 2006. The source for this scenario is the PRIMES model[9]. The model is based on the assumptions given below – and thus these are the assumptions in the long-distance transport baseline scenario as well.

Assumptions made in the DG TREN 2030 scenario:

The baseline scenario for EU-25 represents current trends and policies as implemented in the

Member States up to the end of 2004. In particular, the baseline modelling assumes a continuation of policies on economic reform (Lisbon) and the completion of the internal energy market. The baseline scenario includes current policies on energy efficiency and renewables, without assuming that specific targets are necessarily met. For example, the renewables shares in electricity are modelling results (some 18% in 2010 for the EU) that show the effects of policies or their absence in the Member States.

On transport, the baseline assumes that the targets agreed for 2008/09 with the car industry's reduction of specific CO2 emissions for new cars are achieved without assuming a further strengthening of targets thereafter.

The growth of CO2 emissions in the **transport** sector decelerates over the projection period and even becomes negative in the long run. This slowdown in transport emissions growth takes place in spite of modal shifts towards less energy efficient modes. Technological progress, the projected decoupling of transport activity from economic growth and the increasing penetration of biofuels blended in gasoline and diesel oil allowing for carbon intensity gains explain the above trend. In 2030, CO2 emissions in the transport sector are projected to be 12.7% higher than in 2000 (with carbon intensity in the sector improving by 0.2% pa) accounting for 27.6% of total CO2 emissions, up from 26.4% in 2000.

It should be stated that the DG-TREN 2030 scenario includes assumptions that make the resulting scenario rather optimistic:

- Sea transport is NOT included
- Air freight transport is NOT included
- Approx. 50% intercontinental aviation included
- A decoupling of economic growth from transport growth is assumed as projected in the White Paper of European Transport Policy.

[9] Assumptions made in the DG TREN report and the PRIMES model are thus included in the STOA baseline as well.

Regarding sea transport several studies have stressed that maritime CO2 emissions are rising rapidly but are not accounted for in the Kyoto Protocol, and neither in the European Emissions Trading Scheme. The IMO (UN International Marine Organisation) finalized an expert study in December 2007 showing that growing international seaborne trade and related fuel consumption will raise carbon dioxide (CO2) emissions from ships by 30% to 1475 billion tonnes by 2020[10].

The STOA baseline does not include international sea transport, since it has been chosen to strictly use the DG-TREN data. However, a rough calculation of the impact of sea transport and international aviation on the CO2 baseline has been illustrated.

The decoupling of economic growth from transport is most likely a too optimistic assumption. In the light of the above-mentioned about international sea transport and aviation, the resulting DG TREN scenario is at least not showing the full picture of how big a challenge it will mean to meet the targets of reducing especially CO2 emissions.

Adapting the DG TREN scenario for the STOA baseline means to project data from 2030 to 2050. The optimistic assumption of decoupling is therefore included in the STOA baseline. Energy efficiency, reflecting the technological improvements, has in the STOA baseline been calculated on the basis of DG TREN, but from 2030 it is kept constant – compensating a little for the optimistic scenario.

Assumptions for the STOA baseline

Rail passenger and freight transport:

Passenger and freight rail transport in EU27 is assumed to run on 70% electricity and 30% diesel.

Trucks:

Transport activity: values are taken from DG TREN.

Efficiency values are calculated on the basis of DG TREN.

For the add-ons to the STOA baseline, the following data sources and assumptions are still valid:

Sea Transport

Transport activity: includes international sea transport between EU-15 member states and international sea transport between EU and non-EU countries (50% allocated to the EU). (Source: TERM 2005 - indicators tracking transport and environment in the European Union.). This value has been adjusted to reflect EU27.

Efficiency values are from the Swedish report 'Tvågradersmålet i sikte - scenarier för det svenska energi- och transportsystemet 2050'.

Efficiency indicator for sea transport is assumed to improve by 35% towards 2050.

This value is estimated in the Swedish report 'Tvågradersmålet i sikte - scenarier för det svenska energi- och transportsystemet 2050'.

[10] http://www.euractiv.com/en/transport/un-shipping-emissions-grossly-underestimated/article-170275

Air passenger transport

Transport activity for EU27 share of intercontinental aviation has been calculated on the basis of the figures on CO_2 emission from 'Wit, Ron et al (2005), Giving wings to emission trading - Inclusion of aviation under the European emission trading system (ETS): design and impacts, CE, Delft'. Figures on CO_2 emissions are from the same report.

CO_2 emissions from long-distance transport have been calculated using the following three-step approach (figure 6):

Data on energy demand and transport activity were available in DG TREN and on the basis of these it was possible to calculate the efficiency indicator for all modes of the transport (step 1). Knowing the efficiency indicator and the CO_2 emission by fuel and mode of transport it is possible to calculate the carbon intensity for each mode of transport (step 2). Together the carbon intensity and the transport activity for each mode of transport make it possible to calculate the CO_2 emission for each mode of transport (step 3).

10% has been added to energy demand as a consequence of well-to-wheel (fuel cycle) adjustment.

Please keep in mind that all figures concern long-distance transport.

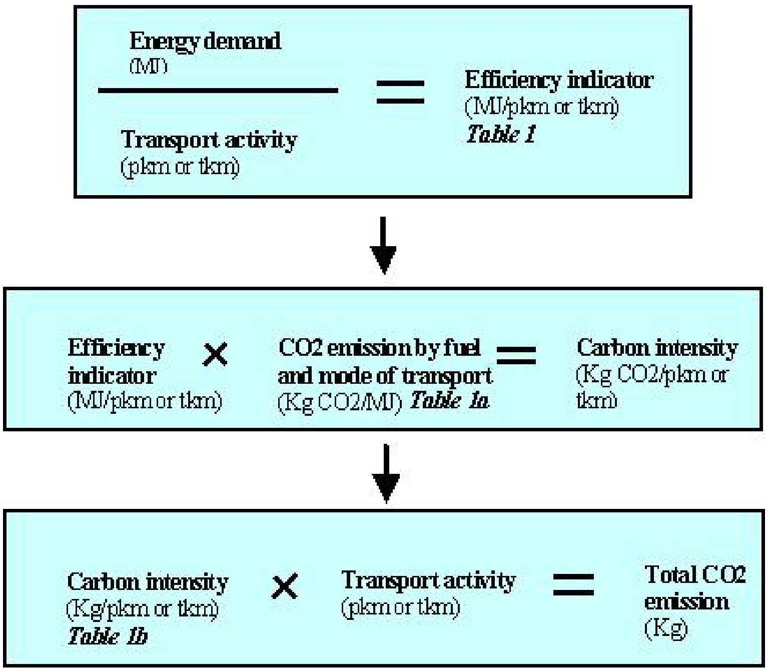


Figure 6: three-step calculation method

Further assumptions related to DG TREN Data

The baseline scenario for EU-25 represents current trends and policies as implemented in the member states up to the end of 2004. In particular, the baseline modeling assumes a continuation of policies on economic reform (Lisbon) and the completion of the internal energy market. The baseline scenario includes current policies on energy efficiency and renewables, without assuming that specific targets are necessarily met.

On **transport**, the baseline assumes that the targets agreed for 2008/09 with the car industry on the reduction of specific CO2 emissions for new cars are achieved without assuming a further strengthening of targets thereafter. The baseline scenario assumes that agreed policies addressing economic actors in the EU-25 member states, as known by the end of 2004, will continue. It presumes that all current policies and those in the process of being implemented at the end of 2004 will continue in the future. However, in the baseline scenario it is not assumed that the indicative targets as set out in various EC Directives (renewables electricity Directive 2001/77, Directive 2003/30 on renewable energy in transport and any additional follow-up Directives, etc.) will necessarily be met. The numerical values for these indicators are outcomes of the modeling; they reflect implemented policies rather than targets.

For the purpose of the baseline a **CO2 price** of 5 €/t CO2 has been assumed up to 2030 for those sectors covered by the EU Emission Trading Scheme (ETS) as a reflection of the medium-term price level of the emerging international carbon market (including Clean Development Mechanism) and the EU ETS being connected to it.

The projections are based on a **high oil price** environment with oil prices of 55$/bbl on average in 2005 and 58$/bbl in 2030 (prices are in 2005 money; in nominal terms this could be 95 $/bbl in 2030 if one can assume that the inflation target of the ECB of 2% p.a. would be achieved).1

Table 1-6: International price assumptions

	Average border prices in the EU-25 ($05/boe)				
	1990	2000	2010	2020	2030
Crude oil	32.4	31.3	44.6	48.1	57.6
Natural gas	18.3	16.8	33.9	37.0	44.7
Hard coal	15.4	8.4	12.5	14.1	14.9
		annual growth rate			
		1990-2000	2000-2010	2010-2020	2020-2030
Crude oil		-0.34	3.59	0.76	1.82
Natural gas		-0.88	7.29	0.89	1.91
Hard coal		-5.86	4.04	1.18	0.58

Source: POLES

The evolution of primary fuel prices is illustrated in Table 1-6. Oil prices in this modeling are projected to decrease over the next few years from their high 2005 level of 55US$(2005). The 2010 oil price is projected at 44.6US$(2005), from where it grows smoothly to reach by 2030 57.6US$(2005). Natural gas prices are assumed to reach 33.9US$(2005) per barrel of oil equivalent in 2010 to 30.3 US$(2005) in 2005. This means a medium-term decrease in the oil–gas price gap. With increasing gas-to-gas competition gas prices are decoupled from oil prices in the second part of the projection period as the difference between both prices will become larger. Coal prices decline from 13.3 US$(2005) in 2005 to reach 12.5 US$(2005) in 2010, and exhibit a smooth increase thereafter to reach 14.9 US$(2005) in 2030.

Table 1-1: Population trends in the EU-25, 1990 to 2030

	Million inhabitants				
	1990	2000	2010	2020	2030
EU15	365.75	378.06	390.65	397.46	398.74
NMS	75.04	74.85	73.40	71.81	70.63
EU-25	440.79	452.92	464.05	469.27	469.37
	annual growth rate				
	90/00	00/10	10/20	20/30	00/30
EU15	0.33	0.33	0.17	0.03	0.18
NMS	-0.02	-0.20	-0.22	-0.17	-0.19
EU-25	0.27	0.24	0.11	0.00	0.12

Source: EUROSTAT.

This approach allows the baseline scenario to be considered as the benchmark against which a number of alternative policies can be judged, assisting policy analysts in the evaluation of alternative measures. Hence, the baseline scenario takes into account:

- Technological progress, induced both by economic growth and by modernisation of installations in all sectors of the economy, thereby improving the efficiency of the energy system.
- Continuation of energy efficiency measures in the member states.
- The effects arising from the voluntary agreement reached between the European Commission and the European automobile industry on specific CO2 emissions from new cars (followed in 1999 by similar agreements with Korean and Japanese car manufacturers).16
- Concerning the use of biofuels in transportation, it was assumed that all countries would follow EU rules17 sooner or later. The impact of blending gasoline and diesel with biofuels on final consumer prices was assumed to be negligible, since higher fuel production costs will probably be set off by tax reductions scheduled to be implemented on these fuel blends.

Aviation

It should be noted here that, within the PRIMES model, aviation includes both national and international flights from the EU, without distinguishing between the two (data on the split between domestic and international aviation are not currently available) following the corresponding EUROSTAT convention as regards energy consumption in aviation. Consequently, total CO2 emissions from aviation are accounted for at the level of each Member State. However, consumption of international maritime bunkers is excluded from the analysis according to EUROSTAT conventions; consequently, it is not accounted for in national CO2 emissions. According to the Guidelines for National Greenhouse Gas Inventories of the Intergovernmental Panel on Climate Change (IPCC), both emissions based on fuel sold to aircraft engaged in international transport and to international maritime fleets should not be included in national totals, but reported separately.

Transport in general

The predominant role of the transport sector in final energy demand growth is projected to continue under baseline assumptions in the horizon to 2010 (+1.4% pa). However, beyond that period the combined effect of decoupling of transport activity from economic growth (especially in passenger transport in EU-15) and technological progress lead to a deceleration of transport demand growth in 2010-2020 (+0.8% p.a.) and even a decline in transport demand energy needs in 2020-2030 (-0.1% p.a.). Thus, the transport sector is projected to be the third fastest growing demand sector over the projection period (+20.8% in 2000-2030 compared to +18.6% in industry, +41.7% in the tertiary and +28.5% in the residential sector). Transport in EU-25 is expected to account for 30% of final energy demand in 2030, still remaining the largest demand side sector.

The projections for passenger and freight transport activity, which are a key driver for energy demand, stem from the **'partial implementation scenario'** of the ASSESS study prepared for DG-TREN in the context of the mid-term review of the Transport White Paper.

Under baseline conditions the **biofuels share** in 2010 rises strongly to almost 4% of gasoline and diesel oil consumption in the transport sector - however, falling somewhat short of the indicative target of 5.75.

Nevertheless, this target would be nearly met in 2015 (5.5%) and the share continues to increase up to 2030 to reach 8.3%. Thus, biofuels account for 1% of final energy demand in 2010 (from 0.05% in 2000) rising to 1.7% in 2020 and 2.0 in 2030.

The growth of CO2 emissions in the **transport** sector decelerates over the projection period and even becomes negative in the long run. This slowdown in transport emission growth takes place in spite of modal shifts towards less energy efficient modes. Technological progress, the projected decoupling of transport activity from economic growth and the increasing penetration of biofuels blended in gasoline and diesel oil allowing for carbon intensity gains explain the above trend. In 2030, CO2 emissions in the transport sector are projected to be 12.7% higher than in 2000 (with carbon intensity in the sector improving by 0.2% p.a.) accounting for 27.6% of total CO2 emissions, up from 26.4% in 2000.

The **transport sector** is characterised by increasing energy needs over the projection period, although some decoupling of transport activity from economic growth is projected in the long run; and it also suffers from the lack of alternatives under baseline conditions as regards changes in the fuel mix towards less carbon intensive fuels.

Freight transport activity: expressed in ton kilometers (1 Gtkm = 109 tkm); one tkm = one ton transported over a distance of one km. It should be noted that inland navigation includes both waterborne inland transport activity and domestic sea shipping. However, international short sea shipping is not included in the above category as, according to EUROSTAT energy balances, energy needs for international shipping are allocated to bunkers.

Passenger transport activity: expressed in passenger kilometers (1 Gpkm = 109 pkm); one pkm relates to one person travelling over a distance of one km. Passenger transport activity includes energy consuming passenger transport on roads (public and private), by rail, in airplanes and on ships as far as this takes place on rivers, canals, lakes and as domestic sea shipping; international short sea shipping is not included as, according to EUROSTAT energy balances, energy needs for international shipping are allocated.

PRIMES model information

Transport sector

The transport module of PRIMES has been developed to study mainly the penetration of new transport technologies and their effects on emissions, besides the evaluation of the energy consumption and emissions in the transport sector. The emphasis is on the use of car technologies and on the long term (2030). The model structure is kept deliberately simple as it is made to interact as demand module with supply modules (refineries, new fuel production) of PRIMES.

The overall demand for transport (passenger kilometres, ton kilometres) is determined by income/activity growth and by the overall price of transport. The overall price of transport is determined endogenously, as a function of the modal split and of the price per mode. The split of the overall transport activity over the different modes is driven by the price per mode and by behavioural and structural parameters. The price per mode depends on the choice of technology for new investment and on past investment for each transport mode. The technologies for new investment are chosen, based on the lowest expected usage costs.

The stock of vehicles inherited from the previous period is expanded in function of the transport needs per mode. The new stock composition determines the stock for the next period and influences on the aggregate price per mode.

The structure of the transport sub-model is as follows:

SECTOR	***SUB-SECTORS***	***ENERGY TECHNOLOGIES***
Passenger transport	**Busses**	**Internal combustion engines**
	Motorcycles	**Electric motors and hybrid**
	Private cars	**Fuel cell**
	Passenger trains	**Gas turbine and CNG**
	Air transports	
	Navigation passengers	

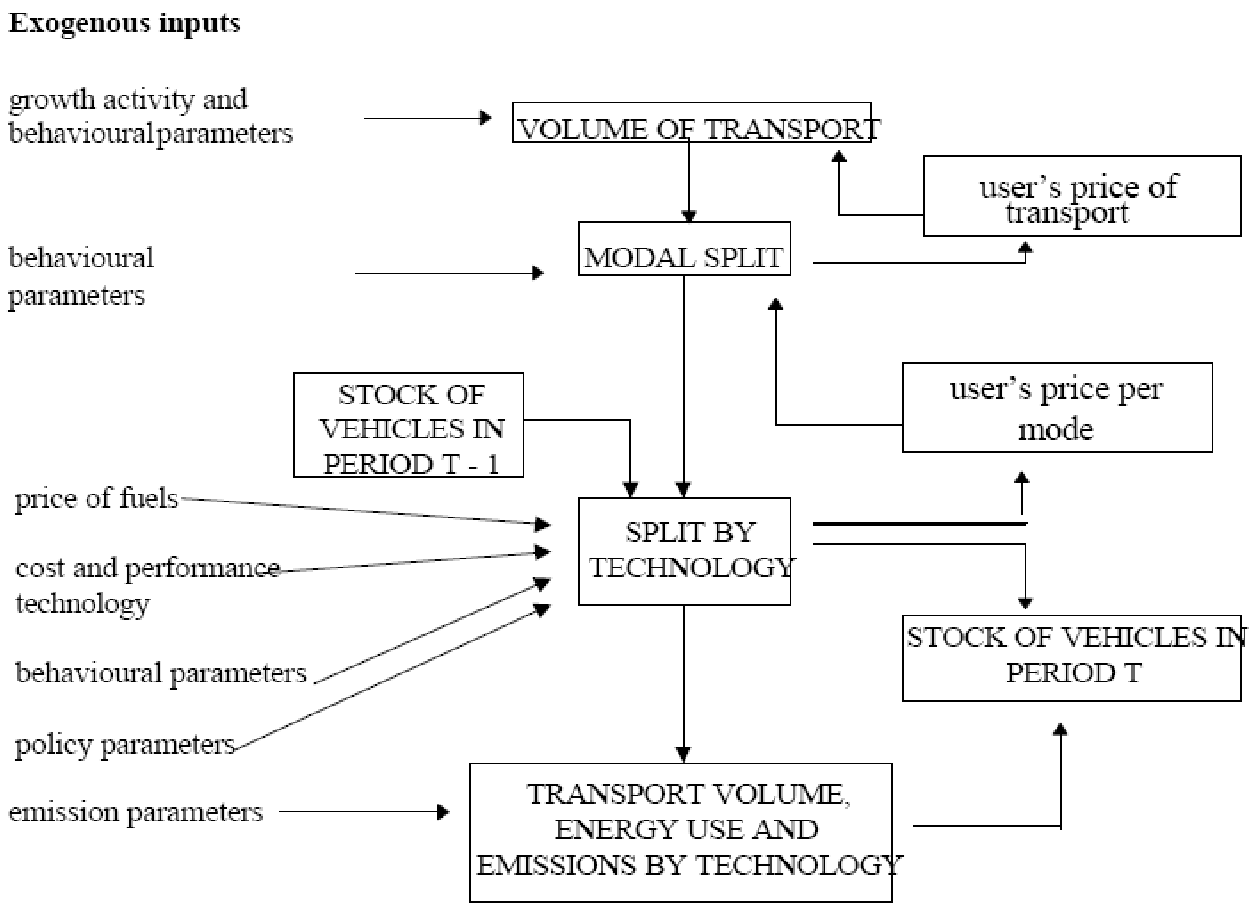
SECTOR	***SUB-SECTORS***	***ENERGY TECHNOLOGIES***
Goods transport	**Trucks**	**Internal combustion engines**
	Trains	**Electric motors and hybrid**
	Navigation	**Fuel cell**
		Gas turbine and CNG

Transports: the transport sector distinguishes passenger transport and goods transport as separate sectors. They are further subdivided in sub-sectors according to the transport mode (road, air, etc.). At the sub-sector level, the model structure defines several technology types (car technology types, for example), which correspond to the level of energy use. Within modes like road transport there is therefore a further subdivision, i.e. the model distinguishes for road passenger transport between public road transport, motorcycles and private cars. The model considers 6 to 10 alternative technologies for transport means such as cars, busses, trucks; the number of alternatives is more limited for rail, air and navigation.

The Transport model

The transport module of PRIMES has been developed to study mainly the penetration of new transport technologies and their effects on emissions, besides the evaluation of the energy consumption and emissions in the transport sector. The emphasis is on the use of car technologies and on the long term (2030). The model structure is kept deliberately simple as it is made to interact as demand module with supply modules (refineries, new fuel production) of PRIMES.

Figure 1 : General structure of the model



We see in the figure above that the overall demand for transport (passenger kilometers, ton kilometers) is determined by income/activity growth and by the overall price of transport. The overall price of transport is determined endogenously, as a function of the modal split and of the price per mode.

The split of the overall transport activity over the different modes is driven by the price per mode and by behavioural parameters. The price per mode depends on the choice of technology for new investment and on past investment for each transport mode. The technologies for new investment are chosen, based on the lowest expected usage costs.

The stock of vehicles inherited from the previous period is expanded in function of the transport needs per mode. The new stock composition determines the stock for the next period as well as the aggregate price per mode.

In the final stage, one computes transport volumes, consumption and emissions by technology as well as by the necessary aggregates.

The choice of technology and of mode is driven by relative user prices. In this model, the user price concept used is close to the generalised cost concept in transportation economics.

Component	function
fuel cost	cost element
vehicle and maintenance cost	cost element
(dis)comfort cost	in order to represent differences in trunk space, refueling time, driveability among technologies
time cost	in order to represent changes in average speed due to congestion or policy measures

The generalised price concept is useful to represent other quality characteristics than out of pocket costs. In transportation economics, one often uses the time cost per km (equal to the value of time multiplied by inverse of speed) as an important component in the choice of travel mode. This concept is particularly useful to represent growing congestion phenomena and their impact on the modal choice (second level in figure 1).

Annex B: Specific energy usage for trucking changed

In the following, some explanations and calculations are made in relation to the specific energy usage of trucking. In the baseline calculation the corresponding figure for trucking is 3.03 MJ/ tonne kilometre. It is reflecting an average for all trucking in Europe. However, depending on the characters of the trucks (van > 3,5t or truck > 20 tonnes), on the distance the load is carried (for example 150km or 1000km or 2500km) and on the driving cycle (high shares in urban routes or mainly motorways) the specific energy usage (MJ per tonne kilometre) varies considerably.

Since this project did not have the resources to do calculation, it was a basic principle to rely as much as possible on the DG TREN data. This way of proceeding guarantees a high degree in transparency. It was in general a methodological problem to adopt these data to long-distance transport. However, a combination of different data resources was considered as being not proper either, since this would clearly reduce transparency. However, regarding the specific energy usage of trucking it has to be assumed that the long-distance figure is lower than the one for trucking in general, since LDT trucking on highways is much more energy efficient than short-distance trucking in urban areas with many stop-and-go situations. Calculations that were made in other studies are clearly supporting this assumption (see for example Alsema 2001; van Essen et al. 2003).

Therefore, figure A – figure B illustrate to what extent the overall picture is changing if the specific energy consumption is reduced by 50% which should be at the lower end of the potential range or even below it. Of course, with such a 50% reduction in specific energy usage the CO2 emissions from LDT are significantly reduced. This means that the target as well would be lower since it is related to the 2005 overall emissions. However, this seems not to change the overall picture, saying that trucking accounts by far for the most relevant CO2-emission of the LDT sector. The overall conclusions remain the same in this case.

	Shares in 2005 "old" (3,03 MJ/tkm)	Shares in 2005 "new" (1,52 MJ/tkm)	Shares in 2050 "old" (2,59 MJ/tkm)	Shares in 2050 "new" (1,30 MJ/tkm)
Trucks	88%	79%	94%	88%
Rail	6%	11%	2%	4%
Inland	6%	10%	4%	8%

Figure A: Shares in CO2 emissions for trucking; (Basis: European Commission 2006e)
"Old": specific energy consumption for trucks as it was used in the baseline on basis of DG TREN data: 2005: 3,03 MJ/tkm; 2050: 2.59 MJ/tkm
"New": Specific energy use of trucking was reduced by 50%. 2005: 1,52 MJ/tkm; 2050: 1,30 MJ/tkm

	2005	2015	2025	2035	2045	2050
Trucks: Specific energy usage for trucking as it is in the baseline	305686	383467	424312	467211	544053	587090
Rail	20527	15562	12762	12355	12903	13187
Inland navigation	19576	21336	22968	24280	26111	26743
Total CO2 emm., Well-to-wheel, LD freight transport (kt)*	**345789**	**420365**	**460041**	**503847**	**583067**	**627020**
Trucks: Specific energy usage for trucking. Reduction of 50% compared to baseline.	152467	191774	212423	233650	272078	294734
Rail	20527	15562	12762	12355	12903	13187
Inland navigation	19576	21336	22968	24280	26111	26743
Total CO2 emm., Well-to-wheel, LD freight transport (kt)*	**192570**	**228672**	**248153**	**270286**	**311092**	**334664**

Chart B: Effect of reducing specific energy usage for trucking by 50% in kt CO2.

Annex C: Description of scenario working group and list of workshops

Workshop at the European Parliament (phase 1):

Wednesday, 28th of March 2007, European Parliament, Brussels

Objective: What trends and targets should be included in a 2047 scenario of long distance transport in compliance with needs for accessibility and yet reducing oil dependency and CO2 emissions?

Working Group meetings in Copenhagen:

1. Monday the 3rd of September 2007
2. Friday the 26th of October 2007
3. Wednesday the 21st of November 2007.
4. Monday the 21st of January 2008
5. Tuesday the 11th of March 2008

CV - Working Group Members:

Maria Giaoutzi

Professor of Geography and Regional Planning at the National Technical University of Athens, Department of Geography and Regional Planning.

Since 1991, Maria Giaoutzi is Fellow of the Netherlands Institute of Advanced Studies (NIAS) at the Royal Dutch Academy. Member of a number of research networks such as GREMI, TCM, NECTAR, URBINO, etc. Member of the Evaluation Committee for Large Scale Energy Projects in the 4th FP. President of the Board of Directors at the 'Hellenic Tourism Organization Land Development Company', for a number of years. Acting as a Consultant in International, Private and Public Organizations (OECD, EU, ERT, ESF etc.). She has a long experience on Foresight Methodologies, Impact of New Technologies on Spatial Structures, Transport Telematics, Trans-European Networks, Evaluation and Monitoring, Resource Management, Integrated Environmental Assessment, Regional Development etc.

Peder Jensen

Dr.,Project Manager for Transport and Environment.

European Environment Agency, Kongens Nytorv 6, DK-1050 Kbh K, Denmark.

Peder Jensen is responsible for assessments of the impact of transport on the environment throughout Europe, and he edits an annual report called Transport and Environment Reporting Mechanism (TERM) that tracks it. In addition the manages, coordinates and participates in a range of other projects dealing with transport and air quality in cities, transport and biofuels, transport noise, transport subsidies, etc.

Before joining the Agency in 2003 he worked on transport fuels policy for the European Commission, and further back as associate professor at the Technical University of Denmark.

David Banister

Professor of Transport Studies at Oxford University and Director of the Transport Studies Unit.

Until 2006, he was Professor of Transport Planning at University College London. He has also been Research Fellow at the Warren Centre in the University of Sydney (2001-2002) on the Sustainable Transport for a Sustainable City project and was Visiting VSB Professor at the Tinbergen Institute in Amsterdam (1994-1997). He was visiting Professor at the University of Bodenkultur in Vienna in 2007. He is a Trustee of the Civic Trust and Chair of their Policy Committee (2005-2009)

He is author and editor of 18 books, including (2007) *Land Use and Transport Planning – European Perspectives on Integrated Policies*, and (2005) *Unsustainable Transport: City Transport in the 21st Century.* He has also published over 200 papers in international refereed journals and as chapters to books. He is editor of two international journals, Transport Reviews and Built Environment, and on the editorial board of five other journals.

His involvement in the STOA project is a result of ten years interest in long term scenario building and the use of backcasting methods. This work was originally applied in the EU FP5 POSSUM project on policy scenarios for sustainable mobility in the EU, and then in a series of projects for the URBAN21, ICTRANS and VIBAT – these covered cities in Europe, the interface between technology and transport, and the potential for a 60% reduction in UK CO_2 emissions in transport to 2030. Current work using the method includes projects for the URBANBUZZ programme on applying scenarios to CO_2 reductions in London to 2030 and 2050 (VIBAT-London), and in Delhi (VIBAT-Delhi), as well as helping apply the method to the STOA project here..

Henrik Gudmundsson

Ph.D, Senior Researcher. Department of Transport, Technical University of Denmark.

Henrik Gudmundsson, is a Senior Researcher in Sustainable Transport and Mobility at the Department of Transport at the Technical University of Denmark (DTU-Transport). He is educated as Environmental Planner from University of Roskilde in 1988, and his PhD from the Faculty of Economics and Business Administration at the Copenhagen Business School from 2000.

Henriks main areas of research include sustainable transport strategies and policies, sustainable transport monitoring and indicators, and sustainable transport scenarios and outlooks.

Henrik has 10 years of experience with State-of-the-Environment Reporting from past employment at the National Environmental Research Institute (NERI). Before working as a researcher at he was with the Danish Environmental Protection Agency and the Danish Planning Agency.

Henrik is work package leader in the IMPACT project funded by TransportMistra, and in the EU 7th FP project POINT. He is currently the National Principle Contact Point (PCP) in Denmark on transport indicators for the European Environment Agency (EEA). He is involved in projects to advise on sustainable transport to the European Commission, the European Parliament, and the Danish government. He is member of two US Transportation Research Board committees

Henrik has an extensive list of international publication and conference presentations

Jonas Åkerman

Head of research at Environmental Strategies Research – fms at the Royal Institute of Technology (KTH) in Stockholm.

Since 1994 he has mainly been working with interdisciplinary future studies focusing on sustainable mobility. Between 1996 and 1998 he was working in the 4th Framework projects POSSUM (Policy Scenarios for Sustainable Mobility) and FANTASIE (Forecasting and Assessment of New Technologies and Transport Systems and their Impacts on the Environment). Since 2000 he has been in charge of the transport future studies programme at fms. This programme has consisted of research tasks in the following areas: sustainable air transport, a sustainable transport system for Greater Stockholm and decoupling of transport growth from economic growth. His overall research area is interdisciplinary future studies on sustainable energy and transport systems. These studies generally has climate change and energy use as key focus. More specific expertise concern scenario methodology (in particular backcasting), sustainable air transport and vehicle technology. He has recently led a scenario study focusing on achieving sustainable climate impact from the Swedish energy and transport system until 2050. At present he is working with a review for the Swedish Parliament concerning renewable fuels.

Kaj Jørgensen

Senior Scientist, Systems Analysis department, Risoe

Education/training:
1976: BSc. Engineering (electronics), Aalborg University
1978: MSc. Engineering (electronics), Aalborg University
1997: Ph.D., Transport and Energy, Technical University of Denmark

Work experience:
The National Association of Local Authorities in Denmark (1980-81)
Technical University of Denmark, Department of Physics and Department of Buildings & Energy (1981-87 & 1990-99)
Praxis Consultancy, Århus, based in Glasgow, Scotland (1987-90)
The Ecological Council (1995)
Rambøll Consultancy (1997-98, part-time)

Areas of work
Alternative fuels for transportation, notably electric, hybrid-electric, hydrogen and fuel cell propulsion

Technology analysis in transportation, focusing on energy conservation and introduction of renewable

energy. Transport systems analysis, e.g. of distribution systems for groceries. Energy and environ-mental effects of transportation. Fuel cycle and life cycle analysis of transport technologies

Current responsibilities and project participation
Hydrogen as Energy Carrier in the Future Danish Energy System

Electrical Vehicles in the Danish Heat and Power Supply System

CO2 Scenarios for the Transport Sector

Participation in Traffic Group under joint Risø/NERI Systems Analysis Centre

Otto Anker Nielsen

Professor, Institut for Transport, DTU Transport

Education

Ph.D. in Traffic Models, 1994. Technical University of Denmark (DTU).

M.Sc. in Civil Engineering, 1991. Technical University of Denmark. Specialised in infrastructure and transport. Highest possible mark gained for the Thesis (13).

Professional and Academic Experience

Visiting Professor at TUDelft, 2006-2007.

Full Professor at DTU, 2000-

Leader of the transport-modelling group at DTU since 1994. The group has 15 employees, incl. Ph.D.-students. The group has also the responsibility of the area of public transport.

Director of the Interdisciplinary Centre for Logistic and Freight Transport Research (www.clgdk.com), which involves several Danish, and foreign universities and firms. The Centre has a yearly budget of about 6 mio. DKK over a 7 year period, and involves 8 professors, about 15 senior researchers, 8 post.doc and 10 Ph.D. -Studies. 2000-2008.

Manager of Research and Development, ScanRail Consult (now Atkins Denmark Ltd), 1998-2000

1992-1998 Academic career at DTU Transport

1991-1992 Carl Bro Ltd. Development Road Design software

Project management experiences

Project manager for a number of large research, development and applied projects in traffic planning and traffic engineering – mostly with emphasis on traffic models, impact analyses, public transport, road pricing and GIS. The largest project – the development of the Copenhagen Ringsted Model System - had 55 employees in the main consortia. Several projects have been solved by international consortia, among these a number of projects for the European Commission.

International activities

Has participated in a number of EU-projects as Danish team-manager, international leader of work-packages, as well as member of scientific committees for European projects. Has in addition co-operated with researchers from – among others - Sweden, Norway, Switzerland, UK, Germany, Netherlands, USA, Canada, Hong Kong and Indonesia.

Has been visiting professor at University of Montreal and TUDelft (the latter for a one-year period).

Has given lectures in Denmark, Sweden, Norway, Finland, Greenland, England, Scotland, Belgium, Netherlands, Luxemburg, Germany, Czech Republic, Poland, Hungary, Switzerland, France, Spain, Portugal, Italy, Greece, Turkey, USA, Canada, Puerto Rico, Guadeloupe, Chile, Australia, Hong Kong, Korea, Thailand and Indonesia.

Has organised several Nordic and International conferences and is editor on two international books in progress.

Annex D: Expert workshop

The workshop took place at the 19th of February 2008 at Copenhagen. In addition to the 6 experts of the scenario working group, 11 experts covering different scientific expertise in the field of transport, energy and economy, and coming from several European countries were invited to give feed-back to the project at an interim stage of the scenario building process. Being the first opportunity to present the baseline and draft scenarios for experts outside the scenario working group, the workshop had a review function towards the methodology, assumptions and data used.

The main purpose of the workshop was to discuss the policy measures together with costs. The possible future energy situation was also taken up.

External participants:

Adolfo Perujo, European Commission, DG Joint Research Centre, Institute for Environment and Sustainability, Transport and Air Quality Unit Ispra, Italy

Camilla Hay, Ea Energy Analyses a/s, Technological and Socio-Economic Planning, Copenhagen, Denmark

Ángel Aparicio Mourelo, Spanish Research Center in Civil Engineering (CEDEX)

Axel Volkery, European Environment Agency, Copenhagen

Jean-Paul Ceron, CRIDEAU- Université de Limoges, France

Jens Borken, German Aerospace Center Transportation Studies Group

Katalin Tanczos, Department of Transport Economics, Budapest University of Technology and Economics, Hungary

Ming Chen, TNO, Mobility and logistics, The Hague Area, Netherlands

Niels Buus Kristensen, Technical University of Denmark, Institute of Transport

Paul Peeters, Centre for Sustainable Tourism and Transport, Breda University,Netherlands

Jørgen Henningsen, European Policy Centre

Short CV of external participants:

Jean-Paul Ceron

CRIDEAU/University de Limoges

PhD in Economics,

Researcher in Interdisciplinary Centre of Environment and Urban development.

Jean Paul Ceron is an associated consultant to TEC (Tourism, Transports, Territories, Environment, CONSEIL). He has a PhD in economics, and graduated a business school (Ecole des *Hautes Etudes Commerciales).* He is currently a researcher in the Interdisciplinary Center for Environment and Urban Development Law (CRIDEAU- Limoges University / CNRS). He worked for thirty years on environmental issues, and is besides a specialist of socio-economics of golf. He has been involved in research in the field of tourism and the environment for more than 10 years.

<u>Dr. Jens Borken</u>

Deutsches Zentrum für Luft- und Raumfahrt (DLR)

Research

- Global emission modelling of transport with respect to climate change and regional air pollution
- Environmental indicators and performance of transport

Selected projects

- QUANTIFY
- ASSESS "ASSESS - Assessment of the contribution of the TEN and other transport policy measures to the mid-term implementation of the White Paper on the European Transport Policy for 2010'." Commissioned by the European Commission, DG TREN. Brussels Oct 2005.
- COST 356 Environmentally Sustainable Transport' (2005-2009)

<u>Katalin Tanczos</u>

Department of Transport Economics from Budapest University of Technology and Economics

Katalin Tanczos is the head of department of Transport Economics at the Budapest University of Technology and Economics. She has got PhD and DSc. She received the highest national scientific acknowledgement (Szechenyi prize) in 1998 for her scientific work. She performs public scientific activity in the framework of several national and international organizations. She is the member of External Advisory Group of EU DG TREN (Sustainable mobility and Intermodality), the council member of Association of European Transport, the steering committee member of ECMT (Sustainable Urban Travel). She is the member of the Scientific Committees for Transport, Logistics and Environment of the Hungarian Academy of Science. She works regularly as invited consultant for the Ministry of Transport, the Hungarian State Railways (MÁV), the Budapest Transport Company (BKV), and as local advisor for international companies (Deutsche Eisenbahn Consult, Hamburg Consult, SOFRETU, SOFRAIL, Halcrow-Transman, WS Atkins). She has been invited to join the IDIOMA project (EU 4th FW). Her special field of interest is the economics related problems of transportation and logistics, like internalization of externalities, pricing, railway charging, project financing, institutional reorganization, privatization. She has several publications in these topics in Hungarian and foreign languages.

<u>Adolfo Perujo</u>

DG Joint Research Centre, Institute for Environment and Sustainability, Transport and Air Quality Unit, Ispra (VA), 21027 Italy. Project Leader of Sustainable Transport

Adolfo Perujo holds a PhD in "Applied Physics" by the University of Guelph (Canada). He has worked for the JRC since 1989 and he has carried his professional activity always in the area of energy.

He has been a project leader in the Renewable Energy field, particularly on energy storage and small PV autonomous systems.

In his present job he is addressing the sustainability of transport from both a technological (alternative fuels and alternative power trains-battery electrical, hybrid electrical and hydrogen, ICE and FC) and a non-technological approach (transport sustainable indicators and internalisation of transport external costs, as well as using backcasting techniques for transport scenario analysis).

Expertise

- Fuel and propulsion technologies.
- Socio-Economical aspects of Sustainable Transport

Camilla Hay

Energy advisor, EA Energy Analysis. MSc, Technological and Socio-Economic Planning.

Camilla Hay worked at Danish Transmission System Operator planning department for 2½ years, before she was employed in Ea in October 2006. She has worked with system analyses, spatial planning, environmental effects, Nordic projects and demand response.

Expertise

- Energy and Transport System Analysis
- Policy measures for reducing CO2 emissions
- Spatial planning and infrastructure planning
- Long term energy and climate scenarios

Axel Volkery

Project manager - Policy and scenarios analysis, European Environment Agency

Axel Volkery is a project manager for policy and scenario analysis at the European Environment Agency, Copenhagen. Prior to this engagement he worked for the German Advisory Council on the Environment and the Environmental Policy Research Centre, Berlin. Axel is responsible for managing and contributing to several European scenario projects and their outreach to key stakeholders. He is further responsible for developing the field of long-term strategy and policy analysis.

Paul Peeters

Associate professor in Transport and Tourism, Centre for Sustainable Tourism and Transport, Breda University for Applied Sciences, PO Box 3917, 4800 DX Breda, The Netherlands.

Expertise

Paul Peeters heads the NHTV Centre for Tourism and Transport. He studies the relation between transport, tourism and environmental impacts, with a focus on climate change and air transport. After four years at the preliminary design office of the former Fokker Aircraft factory at Schiphol, he diverted his interest to transport and environment studies at several consultancies including is own one for the past 12 years.

Main projects have been several scenarios for sustainable transport in the Netherlands, the MuSTT (2004, DG-ENTR) including a European tourism and transport projection for 2020 and recently emissions and scenario work for the UNWTO report on climate change and tourism (in press). Furthermore he organised and chaired in 2006 the first workshop on climate change mitigation dedicated to tourism and edited the proceedings (Tourism and Climate Change Mitigation. Methods, greenhouse gas reductions and policies).

Niels Buus Kristensen

Head of Department, DTU Transport, Technical University of Denmark.

Education

Ph.D. Economics, University of Copenhagen, Denmark, 1992.

Cand. polit.(Master in Economics.), University of Copenhagen, Denmark, 1987.

Current position

Head of Department (Director) DTU Transport, January 2008 – present.

(After merger of Danish Transport Research Institute with DTU's Centre for Traffic and Transport)

Expertise

- Transport Economics

Professional Experience

Danish Transport Research Institute, Managing Director, (2004 – 2007)

(Since 1. January 2007 as part of DTU)

COWI A/S Chief Economist, Division Head of R&D (2000 - 2004)

Chief Economist, (1999-2000)

Senior Economist, (1995-1999)

Economist, (1992-1995)

Univ. of Copenhagen, Senior Research Fellow, Institute of Economics (1991-1992)

Research Fellow, Ph.d. student, Institute of Economics (1988-1990)

Assistant Teacher at Institute of Economics (1984-1987).

Rockwool Foundation, Researcher (1987).

Ming Chen

Senior Advisor and PMC co-ordinator, TNO.

Ming Chen has in-depth expertise in the design of transport databases, transport modelling and forecasting transport, especially in a European context. He has participated in several studies developing and using passenger and freight models at a national and international level. He has been participating in studies for the development, construction and forecasting of freight transport databases for Western Europe, Eastern Europe, Kazakhstan and the complete Russian Federation. He is one of the developers of the NEAC model and has developed data models in INFOSTAT, MESUDEMO, IQ, OD-ESTIM, INFREDAT and TRANS-TOOLS (framework projects European Commission).

He has contributed to the EUN-STAT and TEN-STAC project (revision of TEN corridors) and has participates in projects concerning the development of the European Transport policy Information System, as **project co-ordinator** in ETIS-BASE (database development) and as partner in ETIS-LINK (thematic network) and ETIS-AGENT (software development). He has co-ordinated a project for the development of a transport database and forecasting model for Bulgaria and was key expert in the project Transport Infrastructure Needs Assessment (TINA) Turkey. Currently is co-ordinator of the REFIT project, is involved in corridor studies on the Iron Rine and a project for CER on internalisation of external costs. His areas of specialisation are transport research, transport modelling and econometric methods.

Expertise:

- Freight transport modeling
- Transport database development
- Coordinating international transport research projects
- Expert in transport modeling and forecasting.
- Expert in transport data.

Ángel Aparicio Mourelo

Director General of the Spanish Research Center in Civil Engineering (CEDEX)

Angel Aparicio is a Civil Engineer, graduated in 1986 from the School of Civil Engineers of Madrid. In 1993 he received his PhD from the Polytechnic University of Madrid.

In 1988 he became a civil servant and since then he has carried out his professional activity in the Ministries of Public Works and Environment. He has combined these responsibilities with teaching as part-time associate professor in the fields of transport and urban planning at the Civil Engineering School of Madrid since 1995, and became full-time professor in 2003. He has written more some 40 papers in the fields of transport planning, and urban development.

An important part of his professional activity has been devoted to international affairs. In 1995-96 he was awarded a Fulbright Scholarship to develop a research in the USA on public-private systems for financing singular projects in cities. From 1998-2000 he worked for the Economic Commission for Europe of The United Nations, as head of the areas of planning and economy of transport and railways. He has participated in several National and European research projects dealing with urban mobility, European politics of transport and development of environmental indicators for the transport sector. He is currently a member of the Advisory Group on Transport Research of the

European Commission.

In May 2004, he was in charge of the leadership of the technical team established by the Spanish Ministry of Transport for the drafting of the National Strategic Transport Plan (PEIT 2020), approved by the Government in July 2005.

Since September 2004, he is Director General of the Spanish Research Center in Civil Engineering (CEDEX), a 50-year old public agency for technical studies and research, reporting to the Spanish Ministries of Transport and Environment, with some 750 people working in the domains of transport planning, infrastructure development, coastal engineering, water policy and management, environmental impacts of infrastructure plans and projects, geotechnics and construction materials

(www.cedex.es).

Minutes of expert workshop (February 2008)

STOA: The future of European long-distance transport

Minutes from Expert Workshop February 19th 2008

Participants:

Adolfo Perujo, Camilla Hay, Ángel Aparicio Mourelo, Axel Volkery, Jean-Paul Ceron, Jens Borken, Katalin Tanczos, Ming Chen, Niels Buus Kristensen, Paul Peeters**,** Jørgen Henningsen.

Working group members:

Jonas Åkermann, David Banister, Henrik Gudmundsson, Peder Jensen, Kaj Jørgensen.

Project management:

Ida Leisner, Jens Schippl, Per Kaspersen, Anders Koed Madsen.

The STOA project on the future of European long-distance transport will produce 2047 scenarios meeting targets for reducing GHG emissions, oil consumption and accessibility. The overall purpose of the project is to contribute to clarification and to give advice to the European Parliament on policy options for the transport sector.

Purpose of the workshop

The workshop with an extended group of experts covering different scientific expertise and coming from several European countries served several purposes within the STOA project on the future of long-distance transport in Europe.

Being the first opportunity to present the baseline and draft scenarios to experts outside the Working Group, the workshop had a sort of review function towards the methodology, assumptions and data used.

The main purpose of the workshop was to discuss the policy measures together with costs. The possible future energy situation was also discussed.

The workshop thus included the following elements:

- Discussion of images and baseline.
- Discussing possible impact of some policy measures and technologies that will support the images to reach the targets
- Discussing possible cost-effectiveness of some policy measures
- Discussing possible energy mix for the three different images

Agenda:

The agenda for the workshop was adapted according to what was discussed in the first plenary session and the limited time of the workshop. There was one major group session assessing policy measures that was related to passenger and freight transport, and not as suggested to aviation and trucks.

Maria Giaoutzie, member of the Working group, was in the last minute prevented from participating in the workshop. Therefore David Banister gave the presentation on the backcasting methodology prepared by her.

Minutes:

The minutes are based on plenary discussions and results produced in the groups during the workshop. They are structured with a paragraph on baseline, one on images and methodology and finally some of the discussions in the smaller groups are given together with the matrix on policy measures for freight and passenger transport that were produced.

1. BASELINE:

Regarding the targets a question was raised concerning the oil dependency target. It was agreed that it should be made clear that this target is on oil *consumption*. Besides that there were some comments on the ambitious targets, and there was a general agreement that the targets are very demanding indeed. Ming Chen posed the question whether to opt for a high risk or low risk strategy.

Jørgen Henningen argued that within the framework of the project he did not see a low risk strategy as an option. It should be a clear message to the politicians that since there is a long turn over time for infrastructure investments, and since the targets are so ambitious, all possible measures at hand need to be taken quickly and with high stringency. He emphasised that long-distance transport is one of the most difficult sectors to reduce oil dependency in and the policy measures needed may be quite different regarding air and freight.

It was a general opinion that the STOA baseline for transport volumes and CO2 emissions are quite dramatic. Jørgen Henningsen argued that they have actually never been seen so dramatic – not in the World Energy Outlook, nor in the Commission reports. Jean-Paul Ceron added that a realistic assessment of the STOA baseline would conclude that the described 2047 situation would never occur. Congestions, lack of oil, lack of time to travel etc. would stop this development long before.

Jens Borken also had some comments on the STOA baseline, and he argued that we should double or triple the share of car transport in LDT: the baseline did only take 15% of all car travel as long-distance, which is too little, e.g. compared to German statistics. Rather 30-40% of car mileage seems to qualify as long-distance. In any case, the assumptions like this for the baseline are hidden in a footnote in the appendix. This should be made explicit and clearly transparent. In addition he argued for a decrease in the aviation share, otherwise the figure 3 is misleading: if the unit is energy demand or CO2 emissions, then no factor is justified. If the unit is climate impact, then a factor for aviation is justified – though you better discuss that there is a range. In any case, he agreed that it was a good idea to keep a strong focus on air transport. Furthermore, Jens also held the view that the growth rates for sea transport have been strongly underestimated. According to his judgement long-distance sea and trucking on the one hand and aviation and car travel could have about an equal share in oil consumption and related CO2 emissions.

All in all, the entire STOA baseline created quite an amount of discussion. Jens Borken and Jørgen Henningsen added to Jean-Paul Ceron's comments on the baseline that the baseline is very important for the credibility of the project. It is of huge importance that the report contains explanations to understand how the figures were made.

Niels Buus Kristensen recommended taking onboard a scenario that has already been made, as for example the DG-TREN scenario. In that case, we would be able to say, 'not our responsibility', regarding wrong assumptions. The huge challenge as to reaching the targets is obvious anyway, and the focus of the project should be on discussing policy measures that will be important. Niels argued that we should stop criticising the assumptions – we don’t have to change them, since we don’t have the authoritative strength to do it. Changing them would mean running the risk of not getting through with our key messages, because technical discussions could block them.

There was a general agreement to use an already existing scenario and add comments concerning weak points and questionable assumptions. Most of the participants suggested that we use the DG-TREN and then add some information concerning transport external to EU, as this is crucial in particular for sea and air transport. A qualitative argument concerning cross-border transport would probably be sufficient and such an argument only requires a rough estimate to make its point. Furthermore, it was suggested to make one chart with RFI (aviation factor) and one without. There is no need to engage in questionable calculations and quantifications, and Niels Buus added that it is better not to have too pessimistic or optimistic scenarios when addressing political decision makers. Jørgen Hennigsen furthermore argued that with a 40-year time horizon it is not worth using our energy on discussing the baseline in details. The important point is the qualitative argument it provides us with.

David Banister suggested that we separate freight (covering sea and trucking) and passenger transport (covering aviation and cars) when suggesting policy measures. He also saw a possibility of having intermediate targets.

→ *It should be made clear that the target on oil dependency is based on oil consumption.*

→ *We should use an already existing baseline (DG-TREN) and make critical comments on the assumptions made, in particular the decoupling of economic growth from growth in transport*

→ *STOA baseline makes stronger assumptions than the overall qualitative argument needs.*

→ *We could add comments to the baseline regarding the added RFI effect on CO2 emissions from aviation, the CO2 contributions from sea and air transport outside of EU.*

→ *Important to be clear about our assumptions and calculations – the credibility of the baseline is vital.*

→ *The values of sea transport should be re-examined*

→ *Car travel should not be downplayed or even ignored completely, but may be left out of focus, as more measures, technologies and attention seem to be devoted already anyway.*

2. IMAGES and METHODOLOGY:

There was quite an amount of discussion regarding the role of the images and the methodology of the project.

Regarding the specific content of the three images, Axel Volkery made some comments about the coherence of the images. He argued that it should be made clear that some key drivers and external factors are general for all three images. In line with this reasoning Jean-Paul Ceron held the view that the images are too detached from the things that drive them. They both asked for a specification of the drivers behind the images – which factors are needed in order to realize the images? Paul Peeters argued that the global frame EU is situated in should be made clearer, and Katalin Tcanzos pointed out that Image 1 does not reflect the European role according to the Lisbon strategy; to take a proactive leadership in research etc.

Ming Chen suggested to use only images 1 and 2, and he provided two arguments to support this. The image does not reach the targets of especially mobility and it is a politically controversial image to present to the EU, because it involves the vanishing of EU as desicionmaker. Katalin argued that demand management should be included as a tool/policy measure. She backed this up with the example of air transport where we do not pay the real costs, and therefore a lot of unnecessary transport is created.

There were also some comments of a more methodological kind. Jørgen Henningsen felt a need for more information concerning the role of the images in relation to the policy measures. Which are developed first? In general, there were discussions concerning the interpretation of the backcasting methodology.

David Banister explained that the purpose of the methodology is not to decide what image is best. The images should function as a framework. Some assumptions are built in and they give an overview of driving forces. The idea of the method is therefore not to draw a picture of *the* preferable future, but to illustrate a range of possible changes with different consequences. Some pictures will call for more action than others, depending on the transport volume. A rough calculation is that the transport volume should be reduced to a factor 6 in image 1, a factor 5 in image 2, and a factor 4 in image 3. Policies should be linked to this kind of thinking. And to assumptions like: is hydrogen in or out in 2047?

Paul Peeters argued that a stage is missing in this scenario process. The first question should be: what does a future that reaches the targets physically look like in terms of transport volumes and transport efficiency as well as modal split. Paul's suggestion was that we should first assess what best available technologies can contribute to these targets. Secondly, we should focus on what volumes of transport can be allowed for the different modes of transport to reach the targets. Depending on the amount of modal shift that the EU is prepared to gain, the final transport volume fitting within the targets can be determined. This means that the transport volume should be reduced if necessary. Paul made some calculations showing that based on the DG-TREN baseline we need to reduce transport volume by air and trucks by 70-80% and increase rail by a factor ten (1000%). Still, the total volume in 2047 should be reduced by 20% with respect to the baseline. This will bring us within the 60% reduction of CO2 emissions target, but we will loose a little mobility/accessibility. These figures are very rough, but at least show the huge changes required by the targets.

David Banister agreed that the report as it is now does miss an important step in quantifying the effect of the different images towards the targets, to get a picture of the gap. What are the trade-offs for meeting the targets, or the other way round for keeping travelling and transport at the forecasted level.

The images should be made clear with regards to what the 'key drivers' of change are. Policy measures should be thought of in the framework of the images. In relation to that Camilla Hay suggested that the demarcation between passenger and freight transport should be clearer. These sectors need different policy solutions to meet the targets, and this should be reflected in the images. She also found it relevant to describe how the production patterns would differ in the 3 images.

Niels Buus Kristensen took a view that differed a little from the one above in arguing that the images are the consequenses of the decisions made, and therefore they cannot function as a framework for these decisions. He emphazised that it is policy measures that drive human behavior and not the other way around. The lifestyles in the images are accordingly produced by the policy decisions made on the road to the image. In a similar vein, Jens Borken suggested that we begin by producing a list of policy measures and test what effect each will have on the different transport modes. After that we should design the images.

Niels Buus furthermore suggested that if we want to take everything into account in the images it will be difficult to be heard in the political process. It is better to choose the significant measures which will really change the world.

Jens Borken had reservations to the one-sided presentation of energy technologies; the dominance of hydrogen in Image 1, CNG and electricity in Image 2, and biofuels in Image 3.

→ The key drivers of the images should be clarified, and there should be a clearer distinction between external and internal factors

→ Image 3 may not reach the target on mobility and it is politically controversial.

→ We should be very clear about the role of the images in the report, and it is still an open question which function they will serve. As a framework for policy measures? A way to make a physically defined future transport system more tangible in terms of lifestyles, economy etc. that will be available within such a transport system?

→ We need to be clear about the scale of change needed to reach the targets. This means to quantify the effect of the different images towards the targets, e.g. what volumes of transport can be allowed within the different modes of transport.

→ We may need quantified intermediate steps in the images.

→ Images should reach the targets, and efficiency goals should be included in the images

→ Focusing on a few policy measures could create stronger political impact.

There was no discussion of the details of the images.

POLICY MEASURES FREIGHT:

Group members: Peder Jensen, Jens Schippl, Ming Chen, Camilla Hay, Angel Aparicio Mourelo, Jean Paul Ceron, Anders Koed Madsen.

From the group discussion:

The freight group quickly decided to focus on a qualitative discussion of the policy measures.

The group started out with a discussion of the pros and cons of carbon taxation. The effect of this measure depends on the level of transportation, and it also depends on how big a share the carbon costs is in the overall expences for the companies that are transporting the goods. If the cost of transport is just a small part of the overall costs of production, it will not do much. Peder Jensen argued that unless the carbon tax is major we will not see any differences to the transport volumes. The question is whether this would be acceptable to the the involved parties. Angel Aparicio Mourelo emphasized that we should keep the more isolated areas in mind, when we discuss carbon taxation, because it will influence more onthese areas than on the well populated areas. Jørgen Henningsen argued that carbon taxes will probably only influence on the price of goods in a quite minor way – up to 1/3 of the prices will be under the influence of the taxes. But there is a possibility that it will influence on both modal shift and volumes.

In relation to capacity use it was argued that it is important to do something about the fact that millions of empty trucks travel to far Eastern Europe. It was in relation to this argument that we are in need of better integrated logistic systems linked to better utility of capacity.

When talking about modal shares it was noted that with the oil prices going up it will at some point be the case that other modes will be competitive to the oil based forms of transport. The group agreed that the railways are having a logistic problems compared to for example trucks when it comes to transporting goods. The group agreed that this is an important issue, because it would be positive to get some modal shift here. It was suggested that there could maybe be established a better integration between the two modes of transport by having shared companies. There were a general agreement that logistic managers care about time and costs, and this is accordingly the key word when thinking about modal shift. The railway system has to be able to compare these parameters.

This led to a discussion on rail investment and it was argued that it mey be necessary to give higher priority to freight rail than has been the case up to now. Inter-city rail has been highly prioritized regarding passenger transport, but to get a modal shift from trucks to rail it is important to do something about freight rail. An integrated management of the railways will be an essential part here because right now Europe has a range of different management systems when it comes to rail transport. Integrated management accordingly had a higher priority to the group than high-speed. Jørgen Henningsen argued that rail is the best way to introduce electricity in freight transport and supported the focus on rail investments.

Jørgen Henningsen argued that if you want to move from freight to rail you cannot rely on the market to make that shift. The prices as a single measure will not handle this. You can probably use individual carbon allowances to make that shift, but you also need a strong focus on the infrastructure.

Regarding land-use planning it was generally agreed that other factors outnumber it. Peder Jensen suggested looking at Jutland in Denmark as a case for land-use planning. The question of ICT was only discussed briefly, but an effect is possible if it is embedded in infrastructure.

→ *The effect of carbon taxation may not be large because it is only part of the overall transport costs. The effects will however depend on the level of transport.*
→ *It is important to do something about the capacity use of trucks.*
→ *The logistic problems concerning rail are important – shared companies may be needed.*
→ *Integrated management in rail has higher priority than speed.*
→*Rail may be the best way to introduce electricity in freight transport.*

MATRIX 1: **Assessment of policy measures - trucking**

<u>Trucks</u>	**Travel volumes**	**Model shares**	**capacity use**	**Oil cons-umption**	**Energy efficiency pr km**	**CO2 efficiency pr energy unit**	**Accessi bility**
Carbon based taxation	++	+	-/+	+	+	+	
Individual carbon allowances							
Rail investment high-speed rail network							
Land-use planning							
Emission standards							
ICT promotion							
Alt fuel promotion							
Emission trading							
ITS							

+ probable positive impact on meeting targets
++ clear positive impact
+++ strong positive impact

- probable negative impact
-- clear negative impact
--- strong negative impact

<u>COMMENTS:</u>

Carbon based taxation:

- Strongly depends on the level of taxation; must be extremely high to have an effect on volumes
- Fuel costs are only a (small) share of overall costs for transport of goods
- May induce modal shift to rail (increase competitiveness of railway sector)
- May reduce volumes (negative impact on economy)

Individual carbon allowances:

- Problem acceptability: only efficient if extremely high
- If shift is induced, this must go somewhere (infrastructure needed)
- Question: is there an 'acceptable' road to meet the targets

Rail investment - high-speed rail network:

- Needed: stronger focus on logistic managers (actors); integrative approaches;
- Heavy infrastructure and logistic package is needed for the railway sector
- Is focus on high-speed networks helpful; alternative could be promoting freight-priority (may induce shift from LD trucking to short-distance car transport)

Land-use planning:

- Significant effects are hard to imagine; apart from infrastructure measures (see above)

ICT promotion:

- Effect possible if embedded in infra

POLICY MEASURES PASSENGER:

Group members: Henrik Gudmundsson, Paul Peeters, David Banister, Katalin Tanczos, Jens Borken, Axel Volkery, Ida Leisner

The results of the group discussions are represented in the matrix and the comments made for it.

MATRIX 2: **Assessment of policy measures - passenger transport**

Passenger Transport	Travel volumes	Modal shares	capacity use	Oil consumption	Energy efficiency pr km	CO2 efficiency pr energy unit	Accessibility
Carbon based taxation	++	+	+	+++	++	+++	_ _
Individual carbon allowances							
Regulative airport investment policy	+	+	+	+	+	0	_
Speedy (C-free) Rail-network investments:	-	++	+/-	+	++	+++	+
Land-use planning							
Emission standards							
ICT promotion							
Alt fuel promotion							
Emission trading							
ITS							

+ probable positive impact on meeting targets
++ clear positive impact
+++ strong positive impact

- probable negative impact
-- clear negative impact
--- strong negative impact

<u>COMMENTS</u>:

Carbon based taxation:

- <u>First, - level playing field all modes should have a (same) carbon tax</u>
- <u>Gradual escalator of annual price increase of 6% in real terms</u>
- High impact on travel volume from an economist point of view – price elasticity
- Problems: the acceptance among citizens?
- The quota system is based on trust in completely rational behaviour, and this is not the case?

- Incentives
- Carbon tax is a first step, but not enough for aviation
- CO_2 efficiency: if there is scarcity of energy/emission rights it will promote efficiency
- Accessibility/affordability – travelling becomes more expensive with a tax. However, happiness is not linked to travel distance. Accessibility is a relative concept. And is about a potential, not actual travelling
- How do we actually define accessibility? How does it differ from mobility? Accessibility is about what destinations you can travel (points of activity), mobility about kilometres you travel.
- Be careful with definition of accessibility

Infrastructure investment

- Changed to: regulative airport investment policy
- Airport investments on private basis
- Removing bottlenecks – dependant on transport mode
- Redirecting and regulating investments – from airports to rail

(To add in implementation phase: thoroughly done environmental

impact assessment)

- Ban small airports? This would be controversial, but effective. Or would it? If it forces passengers to make a combined travel of several legs, longer distance compared to flying. On the other hand, Paul Peeters said, since an important driver behind mobility is speed, it would mean that if people were forced to make many detours, the reduction of number of trips would most likely outpace the extra volume by those who still travel and have to take the detour.

Speedy rail network investment

- It will increase travel demand

- Investing in speed of the network means increasing the travel speed in the rail system as such, can include high-speed trains
- Energy efficiency could be increased by less stops outside stations and then higher speed will be compensated for in terms of oil consumption
- On the other hand, high-speed trains could result in an increase in oil consumption
- Investments in existing and new hardware, organisation and institutions, incl. human resources
- Investments in electrification – technically possible
- Renewables

Emission standards:

- Emission standards are fixed
- Proactive integrated policy….
- If there is a decision on emission standards at the European level, this cannot be overheard by national governments

Further suggestions for policy measures dimensions:

- Cost
- Time horizon
- Land-use planning
- Demand management

From the plenum discussion:

In the matrix the highest score is carbon taxation in relation to oil consumption and on rail investments in relation to a better CO2 efficiency per energy unit. Niels Buus Kristensen differed a little from this conclusion through his argument that rail investments should not be promoted as a measure for reducing CO2. Such investments, he thought, should be based on cost-effectiveness assessments incl. CO2.

The suggestion of a 6% escalator for carbon tax was discussed in relation to anticipated effect; in aviation, an increase in fuel price has not affected travel volume at all. The oil price may be unpredictable, but it seems as if air companies do not expect prices to go down, said Jørgen Henningsen.

Niels Buus Kristensen argued that internalisation of costs for reducing CO2 will not have much effect. It is better to get prices right before doing investments.

ENERGY MIX Images:

Group members: Niels Buus Kristensen, Jonas Åkermann, Kaj Jørgensen, Adolfo Perujo, Jørgen Henningsen, Per Kaspersen

There was no matrix to fill out in this group. The task was to suggest the plausible energy mix for the three images. The group members joined the other groups after lunch.

From the group discussions:

In the discussion on energy a couple of people argued that peak oil is not going to save us, and Niels Buus Kristensen argued that is not important in the long term. If oil prices stay high and energy companies believe in this they will exchange oil with coal as the energy prices are now.

Niels held the view that oil should not be treated separately but be part of fossil fuels.

Besides that Niels argued that demand management will only take us some of the way (postpone the problem), and we therefore need technological change globally in the long run. Jean Paul argued that we need regulation on what the different technologies should accomplish. Niels Buus pointed at the fact that we need economic incentives to get the investments and the private and the public sectors need to share the risks when investing – public/private partnership. Regarding the hydrogen issue, it is clear that this will require huge investments in infrastructure and thus call for public-private partnerships to share the risk. In the 2047 perspective, hydrogen may play a role. Jean-Paul added that we could reduce the risk for the private sector through clear policies and goals on emission standards.

Both Niels Buus and Jean-Paul emphasized that the faith in the market to solve our problems is questionable. There is a problem in letting the market forces regulate aviation since there are only two suppliers – Boeing and Airbus.

The topic of CNG also came up, and it was argued that CNG is an issue if we want to substitute oil. CNG will make us independant of oil and this seems more important than reducing CO2 (the target is higher). Jens Borken complicated this picture by arguing that resources of CNG are limited to certain areas. Both Jens and Jørgen Henningsen held the view that it may be possible to use CNG for trucks, but they were more reluctant when it came to aviation. Are there fuels we can use for aviation in 2047?

It was suggested that we can solve the problem by not flying as much as we do now. Jonas Åkerman argued that in meeting the targets both demand management and technical solutions are needed.

STOA - The Future of Long Distance Transport in Europe - Baseline data

Transport activity	2005	2015	2025	2035	2040	2045	2050	05-'50 %/a	Total change 2005-2050 (%)	Share 2005	Share 2050
Passenger transport total (Gpkm)	**1827**	**2431**	**2997**	**3542**	**1232**	**4205**	**4585**	**2,1**	**151%**	**100%**	**100%**
Private cars and motorcycles	700	833	944	1039	1093	1150	1210	1,2	73%	38%	26%
Rail	65	71	77	81	84	87	89	0,71	38%	4%	2%
Aviation	1026	1485	1929	2369		2911	3226	2,58	214%	56%	70%
Inland navigation	37	43	48	52	54	57	59	1,09	63%	2%	1%
Freight transport total (Gtkm)	**2060**	**2505**	**2912**	**3283**	**3500**	**3733**	**3983**	**1,5**	**93%**	**100%**	**100%**
Trucks	1364	1751	2111	2438	2631	2839	3064	1,8	125%	66%	77%
Rail	410	438	457	476	487	498	508	0,5	24%	20%	13%
Inland navigation	286	316	344	368	382	396	411	0,8	43%	14%	10%

CO2 Emissions by sector (kt)	2005	2015	2025	2035	2040	2045	2050	05-'50 %/a	Total change 2005-2050 (%)	Share 2005	Share 2050
Tank-to-wheel (onboard) passenger transport (kt)	**214937**	**234652**	**241140**	**265967**	**290347**	**317141**	**346557**	**1,1**	**61%**	**100%**	**100%**
Private cars and motorcycles	72356	70839	72316	73404	77213	81220	85435	0,4	18%	34%	25%
Rail	2322	1807	1457	1451	1498	1545	1595	-0,8	-31%	1%	0%
* electric	1283	873	639	620	640	661	682	-1,4	-47%	1%	0%
* diesel	1039	934	818	831	857	885	913	-0,3	-12%	0%	0%
Total aviation	137990	159390	164465	188001	208381	230969	256007	1,4	86%	64%	74%
Inland navigation	2269	2616	2901	3111	3255	3406	3520	1,0	55%	1%	1%
Well-to-wheel, passenger transport (kt)	**236430**	**258118**	**265254**	**292564**	**319382**	**348856**	**381213**	**1,1**	**61%**	**100%**	**100%**
Private cars and motorcycles	79591	77923	79548	80744	84935	89342	93979	0,4	18%	34%	25%
Rail	2555	1987	1603	1597	1647	1700	1754	-0,8	-31%	1%	0%
* electric	1411	960	703	682	704	727	750	-1,4	-47%	1%	0%
* diesel	1143	1027	900	914	943	973	1004	-0,3	-12%	0%	0%
Total aviation	151789	175329	180912	206801	229219	254066	281607	1,4	86%	64%	74%
Inland navigation	2496	2878	3191	3422	3581	3747	3872	1,0	55%	1%	1%
Tank-to-wheel (onboard) freight transport (kt)	**314354**	**382150**	**418220**	**458042**	**492705**	**530061**	**570018**	**1,3**	**81%**	**100%**	**100%**
Trucks	277897	348606	385738	424738	458337	494593	533718	1,5	92%	88%	94%
Rail	18661	14147	11602	11232	11479	11730	11988	-1,0	-36%	6%	2%
* electric	10570	7340	5712	5309	5426	5545	5666	-1,4	-46%	3%	1%
* diesel	8091	6807	5889	5923	6053	6186	6321	-0,5	-22%	3%	1%
Inland navigation	17796	19396	20880	22073	22890	23737	24312	0,7	37%	6%	4%
Well-to-wheel, freight transport (kt)	**345789**	**420365**	**460041**	**503847**	**541975**	**583067**	**627020**	**1,3**	**81%**	**100%**	**100%**
Trucks	305686	383467	424312	467211	504170	544053	587090	1,5	92%	88%	94%
Rail	20527	15562	12762	12355	12626	12903	13187	-1,0	-36%	6%	2%
* electric	11627	8074	6284	5840	5968	6099	6233	-1,4	-46%	3%	1%
* diesel	8900	7487	6478	6515	6658	6804	6953	-0,5	-22%	3%	1%
Inland navigation	19576	21336	22968	24280	25179	26111	26743	0,7	37%	6%	4%

Tank-to-wheel energy demand (TJ)	2005	2015	2025	2035	2040	2045	2050	05-'50 %/a	Total change 2005-2050 (%)	Share 2005	Share 2050
Total	**6952391**	**8175227**	**8767902**	**9644656**	**10438819**	**11302037**	**12236463**	**1,26**	76%	100%	100%
Private cars and motorcycles	974585	954162	974059	988705	1040015	1093989	1150763	0,37	18%	14%	9%
Trucks	3717808	4663787	5160546	5682300	6131799	6616856	7140283	1,46	92%	53%	58%
* diesel	13902	12490	10944	11117	11471	11837	12215	-0,29	-12%	0%	0%
* diesel	108243	91060	78792	79239	80978	82754	84569	-0,55	-22%	2%	1%
Aviation	1897361	2191614	2261399	2585016	2865235	3175829	3520092	1,38	86%	27%	29%
Inland navigation, freight	240492	262114	282162	298279	309321	320772	328540	0,70	37%	3%	3%

Well-to-wheel energy demand (TJ)	2005	2015	2025	2035	2040	2045	2050	05-'50 %/a	Total change 2005-2050 (%)	Share 2005	Share 2050
	7722207	**9080674**	**9738978**	**10712970**	**11595251**	**12554255**	**13592419**	**1,26**	76%	100%	100%
Private cars and motorcycles	1082872	1060180	1082287	1098561	1155573	1215543	1278626	0,37	18%	14%	9%
Trucks	4130898	5181986	5733940	6313667	6813110	7352062	7933648	1,46	92%	53%	58%
* diesel	15446	13878	12160	12352	12746	13153	13572	-0,29	-12%	0%	0%
* diesel	120270	101178	87546	88044	89975	91949	93966	-0,55	-22%	2%	1%
Aviation	2108179	2435127	2512666	2872240	3183594	3528699	3911214	1,38	86%	27%	29%
Inland navigation, freight	264541	288325	310378	328107	340253	352849	361394	0,70	37%	3%	3%

Well-to-wheel energy efficiency	2005	2015	2025	2035	2040	2045	2050	05-'50 %/a	Improvement 2005-2050 (%)
MJ per pkm/tkm									
Private car and motorcycles	1,55	1,27	1,15	1,06	1,06	1,06	1,06	-0,84	32
Aviation	1,7	1,6	1,4	1,3	1,2	1,1	1,0	-1,14	40
Trucks	3,03	2,96	2,72	2,59	2,59	2,59	2,59	-0,35	14
* electric, net (at train)	0,73	0,46	0,31	0,28	0,28	0,28	0,28	-2,09	61
* diesel, net (at train)	0,79	0,65	0,53	0,51	0,51	0,51	0,51	-0,99	36
* electric, net (at train)	0,96	0,62	0,46	0,41	0,41	0,41	0,41	-1,85	57
* diesel, net (at train)	0,98	0,77	0,64	0,62	0,62	0,62	0,62	-1,02	37
Inland Navigation	0,92	0,91	0,90	0,89	0,89	0,89	0,88	-0,11	5

Well-to-wheel carbon intensity	2005	2015	2025	2035	2040	2045	2050	05-'50 %/a	Improvement 2005-2050 (%)
(gCO2/pkm or tkm)									
Private car and motorcycles	114	94	84	78	78	78	78	-0,84	32
Aviation	125	114	103	92	86	80	75	-1,14	40
Trucks	224	219	201	192	192	192	192	-0,35	14
* electric, net (at train)	31	19	13	12	12	12	12	-2,09	61
* diesel, net (at train)	59	48	39	37	37	37	37	-0,99	36
* electric, net (at train)	41	26	20	18	18	18	18	-1,85	57
* diesel, net (at train)	72	57	47	46	46	46	46	-1,02	37
Inland Navigation	68	68	67	66	66	66	65	-0,11	5