EU Transport GHG: Routes to 2050?

Review of projections and scenarios for transport in 2050 (Task 9 Report V)

Xander Rijkee and Huib van Essen
(CE Delft)

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A.G. (Xander) Rijkee and H.P. (Huib) van Essen (CE Delft) 10 March 2010

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Contact details

Ian Skinner

AEA
Central House
14 Upper Woburn Place
London UK
WC1H 0JN

T +44 (0)870 190 2817
E EUTransportGHG2050@aeat.co.uk

Ian Hodgson

Clean Air and Transport Unit
Environment Directorate General
European Commission
ENV.C.3 Brussels
Belgium

T +32 (0)2 298 6431
E Ian.Hodgson@ec.europa.eu

Project

www.eutransportghg2050.eu

Partners

www.aeat.co.uk

www.cedelft.nl

www.tno.nl

www.isis-it.com

www.milieu.be

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Executive Summary

In the field of transport and GHG emissions, many other reports have tried to model or develop scenarios with respect to how transport's GHG emissions might develop and be reduced into the future. These studies include the identification of the options that might have to be taken up, and policy instruments that might have to be introduced, in order to achieve this reduction.

The aim of this report is to provide an overview of the main long term scenario studies on the EU transport sector (up to 2030/2050) which include GHG emissions. By summarising and comparing the scenarios developed before some context is provided to this project in general and the illustrative scenarios produced in particular.

In this paper more than twenty scenario studies relating energy use and CO2 emissions and transport in the more distant future were reviewed. The studies differed greatly in approach, methodology and objective. Even when the studies were broadly similar, there remained a large number of degrees of freedom in presentation and aggregation of the data. This dissimilarity made a direct comparison of the visions described in the studies difficult. In some cases it was possible to convert the presented information to a common format enabling quanitative comparison.

The studies show that if no action is taken on top of current agreed policy (usually referred to as the business as usual or BAU scenario) the **total global GHG emissions** for all sectors are expected to increase by 150 - 200% compared to 1990 levels. Also most scenarios which assume additional measures and policies to be implemented (reduction or vision scenarios) expect an *increase* in the overall global GHG emissions compared to 1990 levels. Only a minority of the scenarios show a decrease of global GHG emissions compared to 1990 levels and only one scenario approaches 80% reduction.
Global transport emission trends in the vision scenarios show reductions of the same order of magnitude as the total of all sectors. This is in disagreement with statement in most of the studies that transport reductions will lag behind. A possible cause for this discrepancy is that many of the back-casting studies assume common reduction targets for all sectors and therefore automatically arrive at common reductions without taking into account optimisation of costs. An alternative explanation might be that in the long run the cost effectiveness of GHG reduction in various sectors converge.

The **overall emissions in the EU** in BAU scenarios are expected to increase less than the global emissions and more or less stabilise. The total EU emissions in the vision scenarios are expected to decrease to a greater extent than worldwide emissions but not all vision scenarios achieve a decrease of emissions compared to 1990 levels. Studies achieving a EU wide reduction of 80% compared to 1990 levels are rare. A general consensus is that Europe will be a forerunner in emission reduction.
Transport emissions in the EU are expected to increase less in the BAU scenarios than the world average while reduction scenarios are expected to reduce more than the world average. In the reduction scenarios. Similar to the global emissions, also for the EU most studies assume that transport will have its fair share in these reductions.

Besides the emission trends as such, various studies also present data on transport demand trends, a key driver for GHG emission growth. It was also possible to compare the trends in carbon intensity various studies assumed.

Transport demand is universally expected to increase. The median increase for modes except aviations is around 200%. Aviation is assumed to increase by far more (up to 400%). Some scenarios incorporate demand reduction policies but even then overall demand is expected to increase. Demand reduction instruments tend to be expected (and required) to curb growth, not reduce overall demand.

More than half of the vision scenarios assume that the **carbon intensity** improvements due to technological innovation will outrun demand increase, leading to an overall decrease in emissions relative to the current level. Road transport is expected to continue to dominate in both passenger and freight transport. However most studies exclude international/intercontinental shipping and aviation, two large sources of CO_2 emissions. This omission leads a bias in the reduction potential estimations.

Technical options are expected to have a major share in emission reductions. Three quarters of all studies envisage a leading role for technology in reducing emissions. It should be noted that this may be related to the fact that for these options more data is available than for non-technical options. Most technological options concern road transport and in passenger transportation most innovations are expected. An autonomous improvement of about 20% is expected. The total reduction potentials in the reduction scenarios are generally less than 50%.

Of all technical options biofuels are the most popular, especially in freight transport and aviation. This is mostly due to the lack of other (innovative) solutions in these transport segments. More than half of the studies disregard (or ignore) the current issues regarding the sustainability of biofuels and question of where the fuel comes from and how much is available.

Of the **non technical options** modal shift (or "greater intermodality") is in most scenarios expected to have the highest potential but not more than several percent. Most studies assume that both passenger and freight transport will remain mostly an automotive affair.

With respect to **policy**, all studies agree that to achieve a significant reduction, international cooperation is paramount. Scenarios incorporating global cooperation score best in reduction potential and global cooperation is seen as the obvious course of action. Policy as a means to stimulate innovation and technical development is seen as a necessity for reaching reduction targets. Fuel efficiency targets or CO_2 emission targets can help the industry to reach its full potential but these instruments should be technologically neutral. Emission trading systems or CO_2 taxes can be beneficial if applied fairly and in a way not to restrict economic development.

Finally, most studies emphasize that **immediate action** is required to achieve the more ambitious reductions. If we do not "act now" significant reductions may be not realized or the reduction cost may increase dramatically.

1 Introduction

1.1 Topic of this report

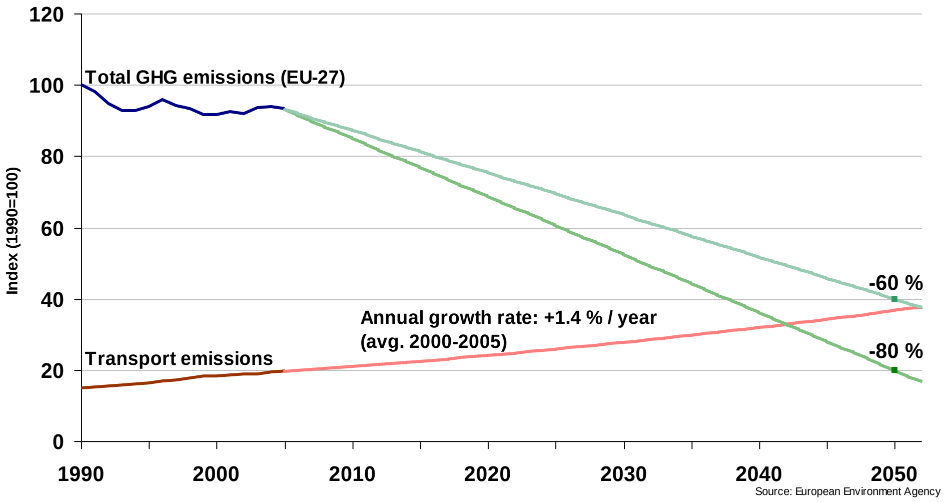
This report is one of the reports drafted under the *EU Transport GHG: Routes to 2050?* It focuses on transport projections and scenarios to 2050.

This report has been presented in draft form to a Technical Focus Group meeting (at which stakeholders were present) in February 2010 after which it has been updated on the basis of the discussion at the meeting and the comments and further evidence that has been received, as far as possible within time constraints.

1.2 The contribution of transport to GHG emissions

The EU-27's greenhouse gas (GHG) emissions from transport have been increasing and are projected to continue to do so. The rate of growth of transport's GHG emissions has the potential to undermine the EU's efforts to meet potential, long-term GHG emission reduction targets if no action is taken to reduce these emissions. This is illustrated in Figure 1 (provided by the EEA), which shows the potential reductions that would be required by the EU if economy-wide emissions reductions targets for 2050 of either 60 or 80% (compared to 1990 levels) were agreed and if GHG emissions from transport continued to increase at their recent rate of growth. The figure is simplistic in that it assumes linear reductions and increases. However it shows that unless action is taken, by 2050 transport GHG emissions alone would exceed an 80% reduction target for all sectors or make up the vast majority of a 60% reduction target. This illustrates the scale of the challenge facing the transport sector given that it is unlikely that GHG emissions from other sectors will be eliminated entirely.

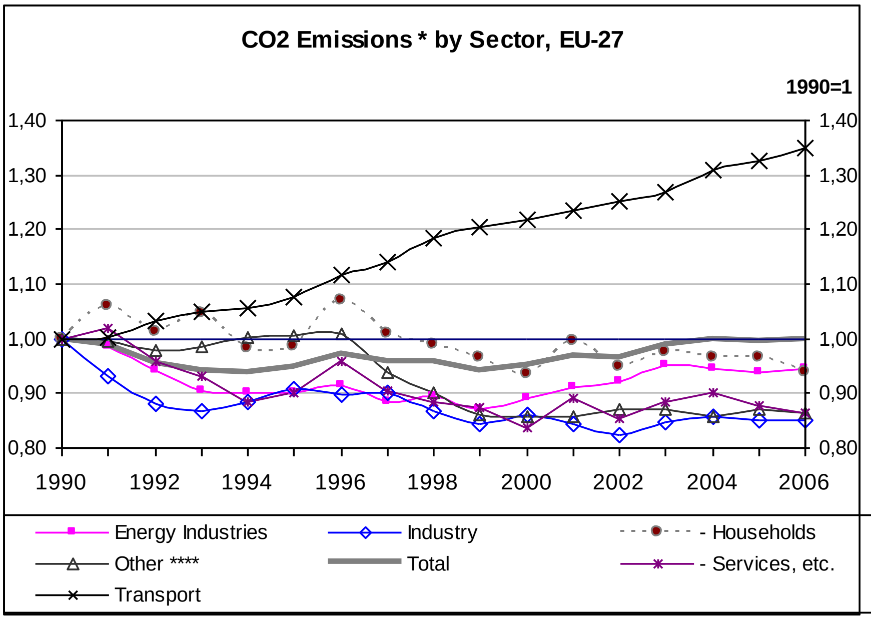
Figure 1 EU overall emissions trajectories against transport emissions (indexed)[1]



The extent of the recent growth in transport emissions is reinforced by Figure 2, which presents a sectoral split of trends in CO_2 emissions over recent years. Whilst the CO_2 emissions from other sectors have levelled out or have begun to decrease, transport's CO_2 emissions have risen steadily since 1990. It should be noted that whilst Figure 2 is presented in terms of CO_2 emissions, very similar trends are evident for GHG emissions (in terms of CO_2 equivalent) since CO_2 emissions represent 98% of transport's GHG emissions.

[1] Graph supplied by Peder Jensen, EEA

Figure 2 Carbon dioxide emissions by sector EU-27 (indexed)[2]



Notes:

i) The figures include international bunker fuels (where relevant), but exclude land use, land use change and forestry

ii) The figures for transport include bunker fuels (international traffic departing from the EU), pipeline activities and ground activities in airports and ports

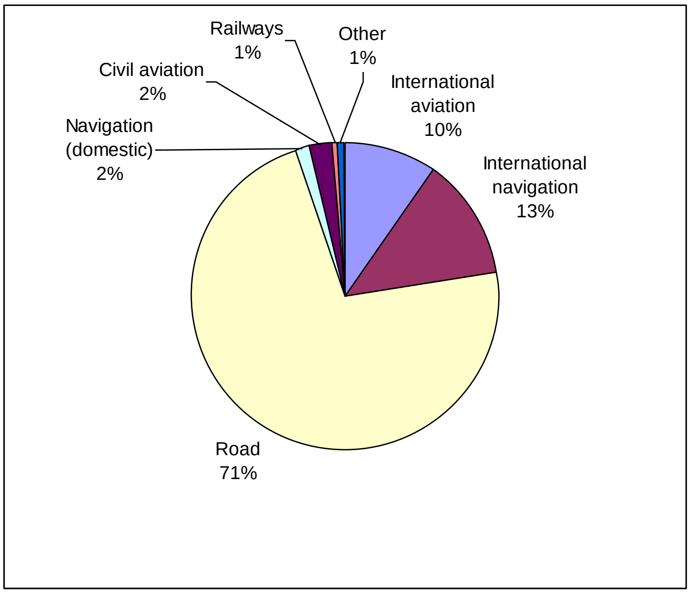
iii) "Other" emissions include solvent use, fugitive emissions, waste and agriculture

The vast majority of European transport's GHG emissions are produced by road transport, as illustrated in Figure 3, while international shipping and international aviation are other significant contributors.

Recent trends in CO_2 emissions from transport are also expected to continue, as can be seen from Table 1 below. Between 2000 and 2050, the JRC (2008) estimates that GHG emissions from domestic transport in the EU-27 will increase by 24%, during which time emissions from road transport are projected to increase by 19% and those from domestic aviation by 45%. It is important to note that these projections do not include emissions from international aviation and maritime transport, which are also expected to increase due to the growth in world trade and tourism.

[2] Graph based on figures in DG TREN (2008) *EU energy and transport in figures 2007-2008: Statistical Pocketbook* Luxembourg, Office for Official Publications of the European Communities.

Figure 3 Greenhouse gases emissions by transport mode (EU-27; 2005)[3]



Note: The figures include international bunker fuels for aviation and navigation (domestic and international)

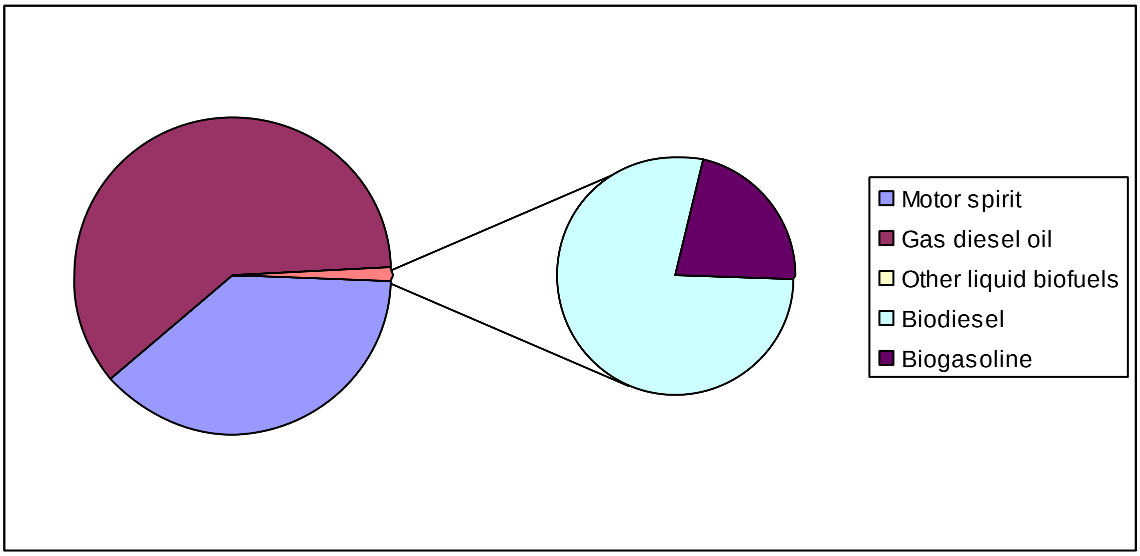
Table 1 CO_2 emissions projection for 2050 by end-users in the EU-27, in Millions tonnes of Carbon[4]

End user Catergory	1990	2000	2010	2020	2030	2050
Road transport	695	825	905	980	1,002	1,018
Rail	29	29	27	27	21	20
Domestic Aviation	86	134	179	206	237	244
Inland navigation	21	16	16	17	17	17
Total	**810**	**988**	**1,110**	**1,213**	**1,260**	**1,299**

Figures from the EEA (2008), illustrate the recent growth in GHG emissions from international aviation, as they estimate that these increased in the EU by 90% (60 Mt CO_2e) between 1990 and 2005; international aviation emissions will thus become an ever more significant contributor to transport's GHG emissions if current trends continue. Furthermore, the IPCC has estimated that the total impact of aviation on climate change is currently at least twice as high as that from CO_2 emissions alone, notably due to aircrafts' emissions of nitrogen oxides (NO_x) and water vapour in their condensation trails. However, it should be noted that there is significant scientific uncertainty with regard to these estimates, and research is ongoing in this area.

[3] Graph based on figures in EEA (2008) *Climate for a transport change – TERM 2007: Indicators tracking transport and environment in the European Union* EEA Report 1/2008, Luxembourg, Office for Official Publications of the European Communities.
[4] Taken from JRC (2008) *Backcasting approach for sustainable mobility* Luxembourg, EUR 23387/ISSN 1018-5593, Office for Official Publications of the European Communities.

Figure 4 Final transport energy consumption by liquid fuels in EU-27 (2005), ktoe5



The principal source of transport's GHG emissions is the combustion of fossil fuels. Currently, petrol (motor spirit), which is mainly used in road transport (e.g. in passenger cars and some light commercial vehicles in some countries), and diesel, which is used by other modes (e.g. heavy duty road vehicles, some railways, inland waterways and maritime vessels) in various forms, are the most common fuels in the transport sector (see Figure 4). Additionally, liquid petroleum gas (LPG) supplies around 2% of the fuels for the European passenger car fuel market (AEGPL, 2009[6]), while the main source of energy for railways in Europe is electricity, neither of which are included in Figure 4. While, alternative fuels are anticipated to play a larger role in providing the transport sector's energy in the future, currently they only contribute 1.1% of the sector's liquid fuel use.

1.3 Background to project and its objectives

The context of the *EU Transport GHG: Routes to 2050* is the Commission's long-term objective for tackling climate change, which entails limiting global warming to 2°C and includes the definition of a strategic target for 2050. The Commission's President Barosso recently underlined the importance of the transport sector in this respect be noting that the next Commission "needs to maintain the momentum towards a low carbon economy, and in particular towards decarbonising our electricity supply and the transport sector"[7]. There are various recent policy measures that are aimed at controlling emissions from the transport sector, but these measures are not part of a broad strategy or overarching goal. Hence, the key objective of this project is to provide guidance and evidence on the broader policy framework for controlling GHG emissions from the transport sector. Hence, the project's objectives are defined as to:

- Begin to consider the long-term transport policy framework in context of need to reduce greenhouse gas (GHG) emissions economy-wide.
- Deal with medium- to longer-term (post 2020; to 2050), i.e. moving beyond recent focus on short-term policy measures.
- Identify what we know about reducing transport's GHG emissions; and what we do not.
- Identify by when we need to take action and what this action should be.

[5] Graph based on figures in DG TREN (2008), page 206
[6] European LPG Association (2009) *Autogas in Europe, The Sustainable Alternative: An LPG Industry Roadmap,* AEGPL, Brussels. See http://www.aegpl.eu/content/default.asp?PageID=78&DocID=994
[7] http://ec.europa.eu/commission_barroso/president/pdf/press_20090903_EN.pdf

Given the timescales being considered, the project will take a qualitative and, where possible, a quantitative approach. The project has three Parts, as follows:

- Part I ('Review of the available information') has collated the relevant evidence for options to reduce transport's GHG emissions, which was presented in a series of Papers (1 to 5), and is in the process of developing four policy papers (Papers 6 to 9) that outline the evidence for these instruments to stimulate the application and up take of the options.
- Part II ('In depth assessment and creation of framework for policy making') involves bringing the work of Part I together to develop a long-term policy framework for reducing transport's GHG emissions.
- Part III ('Ongoing tasks') covers the stakeholder engagement and the development of additional papers on subjects not covered elsewhere in the project.

As noted under Part III, stakeholder engagement is an important element of the project. The following meetings were held:

- A large stakeholder meeting was held in March 2009 at which the project was introduced to stakeholders.
- A series of stakeholder meetings (or Technical Focus Groups) on the technical and non-technical options for reducing transport's GHG emissions. These were held in July 2009.
- A series of Technical Focus Groups on the policy instruments that could be used to stimulate the application of the options for reducing transport's GHG emissions. These were held in September/October 2009.
- Two additional large stakeholder meetings at which the findings of the project were discussed.

As part of the project a number of papers have been produced, all of which can be found on the project's website, as can all of the presentations from the project's meetings.

1.4 Background and purpose of the paper

Within this project high level "illustrative scenarios" of future GHG reductions from transport at the European level are developed. Many other reports have tried to model or develop scenarios with respect to how transport's GHG emissions might be reduced into the future, including the identification of the options that might have to be taken up, and policy instruments that might have to be introduced, in order to achieve this reduction.

The aim of this report is to provide an overview of the main long term scenario studies on the EU transport sector (up to 2030/2050) which include GHG emissions. By summarising and comparing the scenarios developed before some context is provided to this project in general and the illustrative scenarios produced in particular.

1.5 Approach

Many scenario studies exist in the field of transport and GHG emissions. Different types of scenarios have been developed, which differ significantly with respect to their geographical scope, the coverage of economic sectors and within the transport sector the coverage of transport modes. In addition various methodologies are applied for making projections.

In this study, first a selection has been made of available scenarios, based on a set of criteria. In parallel a fact sheet template has been developed for gathering the main results from the scenarios. This approach has been chosen to compare the main assumptions and results of the various scenario studies in a structured way. Based on the fact sheets, this report has been developed.

1.5.1 Selection of scenarios

In this report, we do not pretend to cover all possible scenarios, though we aimed at gathering the most relevant ones. Since there were a large number of different studies available, but finite budget it was necessary to limit the review to a selection of the most relevant to this project. In order to develop a focused list of studies we built a long list of relevant studies for consideration and then selected the studies according to the following criteria. Studies were selected that

- concern itself with the future sustainability of energy use, emissions or energy supply;
- project further than 2020;
- take into account transportation;
- have a geographic scale larger than just one country (we later augmented this and added three national studies for comparison)

A number of additions to a first draft selection were suggested by stakeholders and the resulting list was sent around to check for any obvious omissions. The full list can be found in chapter 4.

1.5.2 Development and analysis of fact sheets

After the selection of studies, factsheets were developed that summarised the principal information relevant to this project. The intention was to make a factsheet containing directly comparable information on each study. However, this proved to be impractical due to the great dissimilarity of the presented information. It was therefore decided to make each factsheet into a miniature summary containing all the relevant data as presented in the study.

We then used the factsheets to aggregate the information from the studies in order to make the results of the analysis more comparable. This aggregated set was analysed and the results are presented in this report. The fact sheets can be found in Annexes B to W.

1.6 Structure of the paper

The report is structured as follows. The next chapter gives an overview of the studies that were analysed and lists their basic characteristics (such as outlook year, geographic scope and projection method).

Chapter 3 analyses the global and European emissions for the transport sector and the total emissions for all sectors. It covers what the scenarios expect in the case of business as usual (BAU) and in the case special effort is put into reducing CO_2 emissions. Henceforth we will call the latter the VISION scenarios.

The reduction potentials of specific transport modes and sectors are discussed in chapter 4. Both technical and non-technical options from the studies are included, as are policy instruments to facilitate their use.

Finally in chapter 5 the conclusions from the other chapters are reviewed and put into context. In the appendix a list of studies used for each graph or table in this rapport can be found. Also included are the factsheet-summaries of all the studies.

2 Overview of studies

2.1 Introduction

In this chapter the studies that have been analyzed are listed and characterized:

- List of studies (section 2.2).
- What types of projections have been used (section 2.3).
- What overall assumptions (e.g. main demographical assumptions) were assumed in the various studies (section 2.4).

2.2 List and scope of selected studies

The table below lists the studies that have been included in the analysis.

Table 2 List of studies

Nr.	Study	Scope	sectors	projection year	projection method
1	Pathways to 2050. WBCSD, 2005	Global	All sectors	2050	Backcasting from concentration
2	Climate Change 2007: Synthesis Report. IPCC, 2007	Global	Not transport specific	2100	Forecasting
3	Back casting approach for sustainable mobility. EC,2008	EU	Transport	2050	Extrapolation of trends to 2050, and backcasting to determine measures
4	European Climate Change Policy Beyond 2012. WEC, 2009	Global/ EU	All sectors	2050	Global emissions: Back casting from concentration, Transport emissions: Extrapolation of trends
5	Foresight for Transport; A Foresight Exercise to Help Forward Thinking in Transport and Sectoral Integration. ICCR et al., 2004	EU	Transport	Not clear	Extrapolation of trends in drivers, forecasting on influence of non-transport factors and policies on mobility and transport.
6	Long-Range Transport Plan – Horizon 2050. CGPC, 2006	France	Transport	2050	Forecasting on the basis of socioeconomic criteria
7	Roads toward a low carbon future: Reducing CO_2 emissions from passenger vehicles in the global road transportation system. McKinsey & Company , 2009	Global	Passenger vehicles	2030	Baseline defined by extrapolation of trends; influence of measures set against baseline.
8	Shell Energy Scenarios to 2050. Shell, 2008	Global	Not transport	2050	Extrapolation and/or forecasting of trends
9	Transport technologies and Policy Scenarios to 2050. WEC, 2007	Global	Transport	2050	Forecasting
10	A sustainable energy	EU	All	2050	Back casting

	system in 2050: promise or possibility? ECN,2007		sectors		
11	Strategic Rail Research Agenda 2020. ERRAC,2007	EU	Rail	2020	Not listed
12	World Energy Technology Outlook – WETO H2. EC, 2007	Global	All	2050	Forecasting with economic model
13	Getting into the Right Lane for 2050. PBL, 2009	EU	All	2050	back casting
14	TRANSvisions Task 2 “Quantitative Scenarios: Mobility scenarios toward a post-carbon society” MCRIT, 2009	EU	Transport	2030-2050	Forecasting with model including socio-economic and logistic models
15	“Very Long Term Energy-Environmental Model. VLEEM Consortium, 2005	Global	All; focus transport	2100	back casting
16	Blueprint Germany, a strategy for a climate safe 2050. WWF, 2009	Germany	All sectors	2030-2050	combination of back casting and forecasting
17	International passenger transport and climate change: A sector analysis in car demand and associated CO_2 emissions from 2000 to 2050. Meyer et al., 2007	Global	Passenger cars	2050	Forecasting with economic model
18	Energy Technology Perspectives. IEA, 2008	Global	All sectors	2050	Back casting from concentration
19	Green4Sure. CE, 2007	Netherlands	All sectors	2030	Back casting from reduction target
20	World Energy Outlook 2009. OECD/IEA, 2009	global & regional	Transport	2030	Extrapolation of trends for reference scenario. Reduction scenario: back casting from concentration.
21	Road Transport Scenario 2030+ ERTRAC, 2009	EU	Road Transport and also aviation & shipping	2030-2050	Analysis of other studies: no specific method used
22	RECIPE, 2009	Global –EU	All sectors	2050-2100	Back casting from concentration

2.3 Types of projections

Three types of projections were seen in the studies

- Back casting from a reduction target
- Forecasting by modeling (economic) development
- Forecasting by projecting current trends

The most common projection method in the reduction scenarios was back casting. The target used differed between studies. Some reduction scenarios were created using the Forecasting by modeling approach. These tend to project less far into the future. For the BAU scenarios both the forecasting methods were used, sometimes together.

2.4 Overall assumptions of the selected studies

The analysis of the scenarios in this report is focused on the CO_2 reduction in transport (see next chapters). In analysing the various studies, also the general assumptions and trends of the various scenarios were compared. From this we conclude that there seems to be consensus about the following:

- The population of the earth will be around 9 billion by 2050.
- Most people will be living in urban environments.
- The population in the EU and VS will consist of a higher fraction of older people.
- The GDP will rise and be decoupled from energy consumption and emissions.
- There will be a shift in GDP distribution with more focus on China and India. The “west” will lose influence.
- The oil price will rise (but the amount is unclear. The range is $ 30 to $ 200 per barrel.

With respect to the other sectors, most studies assume a great deal of power generation can be done without emitting CO_2. Biofuels and Coal with CCS are important technologies. Nuclear energy plays a smaller role but most studies assume that it will grow (i.e. be necessary). Among the sectors Power generation is the most important sector in reducing emissions. On the one hand this is due to the fact that in this sector the most cost efficient reduction methods are thought to exist as well as the possibility of capturing emissions with CCS. On the other hand the demand for electricity is likely to increase with the further electrification of transport.

3 Comparison of trends in total CO_2 emissions

3.1 Introduction

In this chapter we compare the various scenarios with respect to the total CO_2 emissions. We distinguish the trends in CO_2 emissions of the whole economy (section 3.2) and the same trend for the transport sector (section 3.3). Finally, in section 3.4, we draw the main conclusions.

3.2 Emissions for all sectors

3.2.1 Methodology

The studies presenting data on global emissions do so in very different formats. To enable comparison the results have been aggregated and unified. This was not possible for all studies, it should therefore be noted that in the graphs only studies are included for which the presented information could be converted to a comparable format with reasonable certainty.

The data was converted to present the CO_2 emissions relative to 1990 levels. This entailed the following conversion methods:

- From Gt CO_2 to Gt Carbon or visa versa.
- From absolute emissions to relative emissions.
- From relative emissions to a different base year.

Conversion 1 was done based on the molecular weight (CO_2 = 44, Carbon = 12). In some cases the data was reported as weight CO_2 while in fact the unit was weight Carbon or visa versa. Due to the large difference in values it was in some cases possible to correct these obvious errors where needed.

The second and third conversions were based on data from the study at hand if these were available. If not then general figures for the historical emissions were used.

The demand comparison in paragraph 3.3.3 was made using general demand statements from the studies and comparing them with transport emissions. There were few data sources so the comparison combines results from multiple categories (for instance total transport, road transport and aviation).

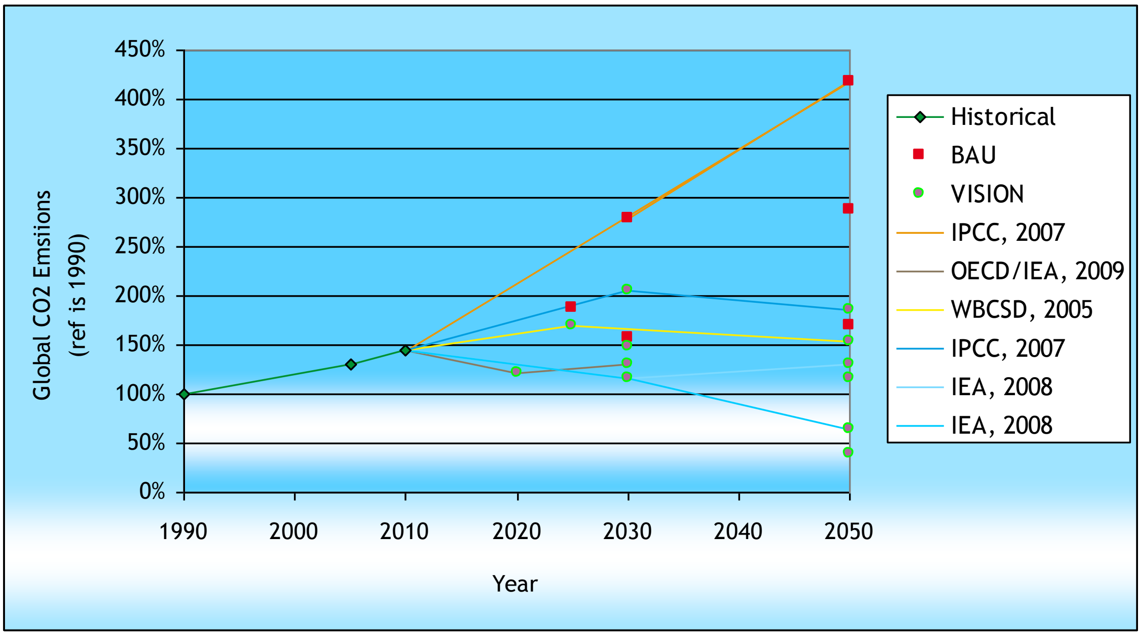
3.2.2 Global emissions

Global emissions from the scenarios are presented in Figure 5. The BAU emissions and the vision scenarios are not always from the same study. They are mixed to give an overall impression of the increase or decrease of emissions.

This graph shows that the BAU global emission trends of the various scenarios differ significantly, ranging from 170% to 420% in 2050 compared to the 1990 level.

The vision scenarios show in most cases lower increase of CO_2 emissions, but in many cases not below 1990 the level. Please note that studies that only present data on energy use, but not on CO_2 emissions could not be included here.

Figure 5 Global CO_2 emissions relative to 1990 levels for all sectors

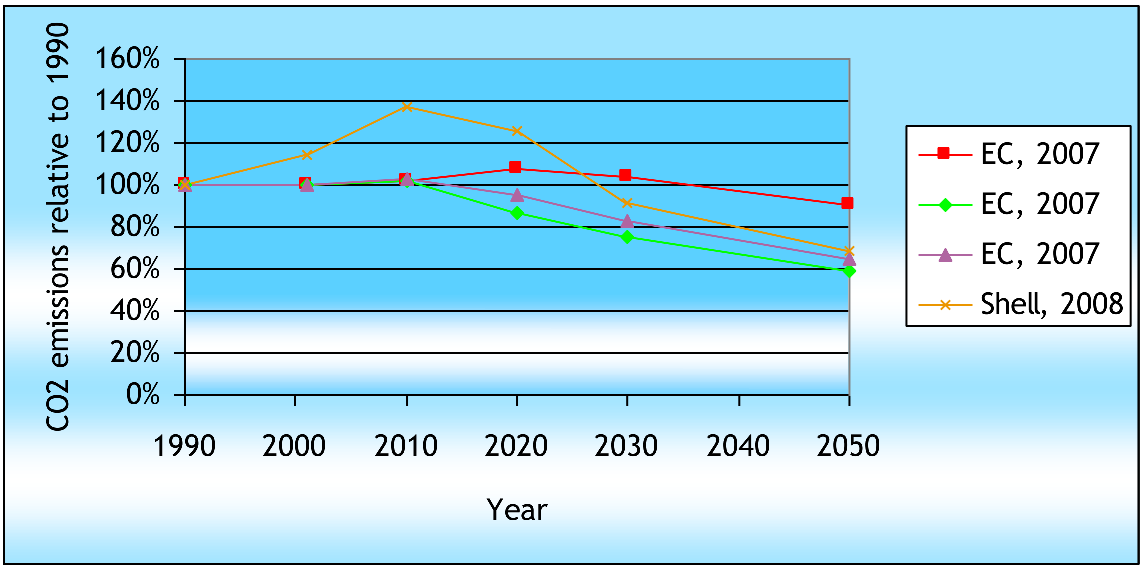


Studies included: WBCSD, 2005; IPCC, 2007; WEC, 2009; Shell, 2008; IEA, 2008; OECD/IEA, 2009; RECIPE, 2009

3.2.3 European emissions

Also for Europe, some of the studies present the CO_2 emission trends for the whole economy. Of the studies included in the analysis, only studies Shell (2008) and EC (2007) presented absolute European emissions for all sectors.

Figure 6 European CO_2 emissions relative to 1990 levels for all sectors



Studies included: Shell, 2008; EC, 2007

The BAU for total CO_2 emissions in Europe do not show the strong increase as we saw for the global trends, but are more or less stable until 2050.

In the vision scenarios, the total CO_2 emissions in Europe decrease in all cases, but as for the global trends not to the long term targets.

The projected CO_2 reduction in Europe is low compared to the BAU scenario, but relatively high compared to the global reductions. This corresponds with a common opinion within the reviewed studies (EC, 2007; WEC, 2009; CGPC, 2006; ECN, 2007; PBL, 2009; RECIPE, 2009) that Europe will play a leading role in emission reduction. Study Shell (2008) is an exception. This study expects the “current policy of supporting investment in the U.S.” to provide breakthroughs that enable a greater change.

The most ambitious reduction in the studies is 60% compared to 1990 levels. This is not in agreement with the current expectation that 80-95% reduction is required by 2050.

3.3 Emissions of the transport sector

Transport is the only sector where the current trend is that emissions increase. This is partly explained by its continual increase in demand and the fact that reducing emissions is eligibly hard or more expensive in transport.

Studies presenting data on more sectors than just transport generally agree with this proposition. The power sector is commonly referred to as the sector where the largest reductions are possible (WBCSD, 2005; ECN, 2007; EC, 2007; IEA, 2008; OECD/IEA, 2009). There are also scenarios that propose that transport can and will realise an equal share in reductions (for instance Shell, 2008; PBL, 2009).

In studies that assume a large share of electric or hydrogen driven cars these two opinions are linked (for instance Shell, 2008). If the power generation sector also provides the power used in the transport sector the advances in power generation propagate into transport emission reductions.

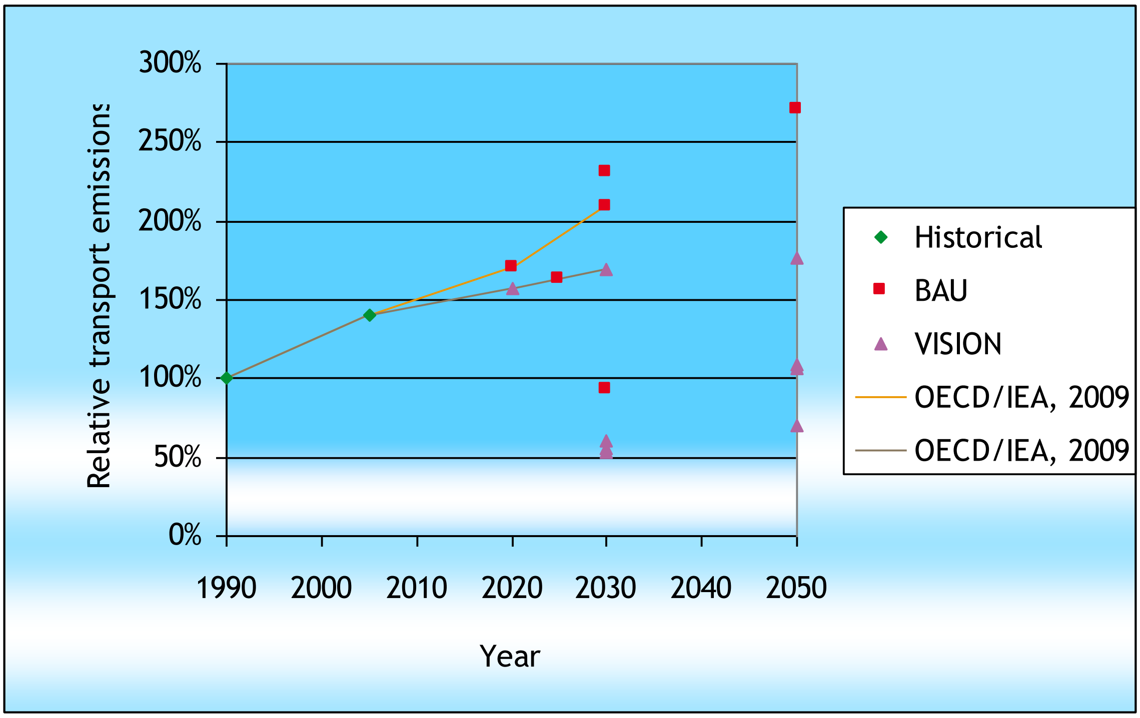
3.3.1 Global transport emissions

Global transport emission projections differ in approach from more regional emission prognosis because they incorporate the expected increase in car ownership in countries such as China and India and the changes in the more developed mobility markets of the EU and northern America.

There are sectors in the world where vehicle fleets are thought to increase 13 fold (Vleem Consortium, 2005) whilst other sectors might see a stabilisation or even reduction of vehicles.

The following figure shows the worldwide transport emissions in the BAU and reduction scenarios (again only for the studies in which these data are included).

Figure 7 Global transport emissions compared to 1990 levels



Studies included: WBCSD, 2005 ;ECN,2007; Meyer et al., 2007; IEA, 2008; IEA, 2008

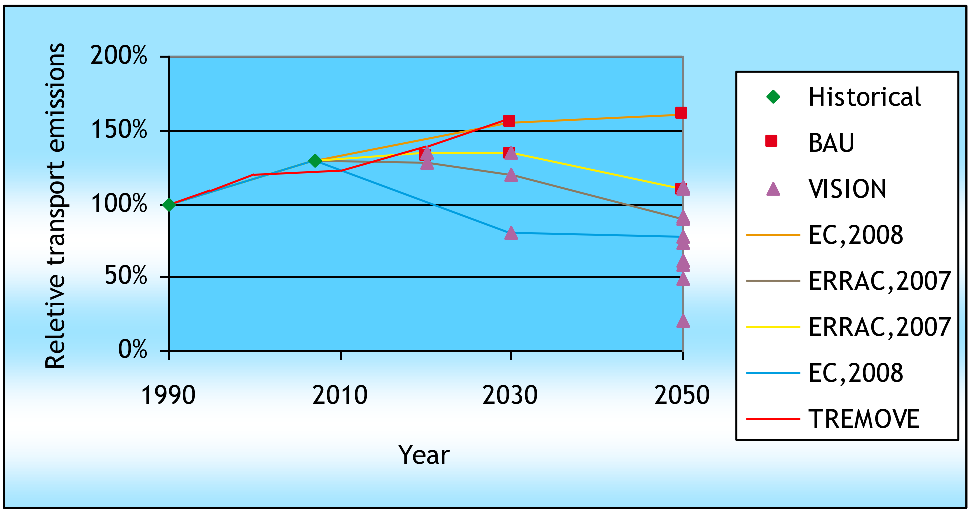
When comparing this figure with Figure 5 there is no great difference in reduction ambition or expectation. The global average of transport emissions is expected to progress in a similar way as the average of the emissions of all sectors. This is in disagreement with the proposition that transport will lag behind in emission reduction.

One reason for the discrepancy is that a large part of the studies reviewed assumed evenly distributed emission reduction targets combined with the back casting method. Studies that used (cost) modelling and optimisation methods tend to agree with the general assumption that reduction in transport is more difficult or costly to achieve and will therefore lag behind.

3.3.2 European transport emissions

In Europe and the US, society is already highly reliant on automotive transport. Although there have been improvements in vehicle efficiency (with particular recent focus on cars), transport emissions are currently still growing, as increase in demand outstrips the rate of fleet efficiency improvements. The projections for the future are shown in Figure 8 for a number of studies. As an additional reference for the BAU case the TREMOVE (EC,2010) data have been added.

Figure 8 European transport CO_2 emissions relative to 1990



Studies included: EC,2008; CGPC, 2006; EC, 2007; PBL, 2009; MCRIT, 2009; EC,2010

Transport emissions in Europe are expected to increase less in the BAU scenarios than the world average and reduction scenarios are expected to reduce more than the world average. This seems to assume a leading role of Europe in (transport) emission reduction.

Reductions in the transport sector are also in the same order of magnitude as reductions for all sectors in the EU for the reduction scenarios. Notably only one study assumes 80% reduction compared to 1990 levels (PBL, 2009).

3.3.3 Transport demand

The general opinion is that transport demand will increase. At the same time volume reductions are presented as an option for reducing emissions. A number of studies provide information on transport demand. This is summarised in the two tables below:

Table 3 Demand increases per transport segment in the BAU scenario

Transport segment	Outlook year	Demand increase
aviation	2050	455%
freight	2020	120%
freight	2030	143%
freight	2050	255%
Passenger	2020	112%
Passenger	2030	135%
passenger	2050	200%

Studies included: EC,2008; PBL, 2009; MCRIT, 2009

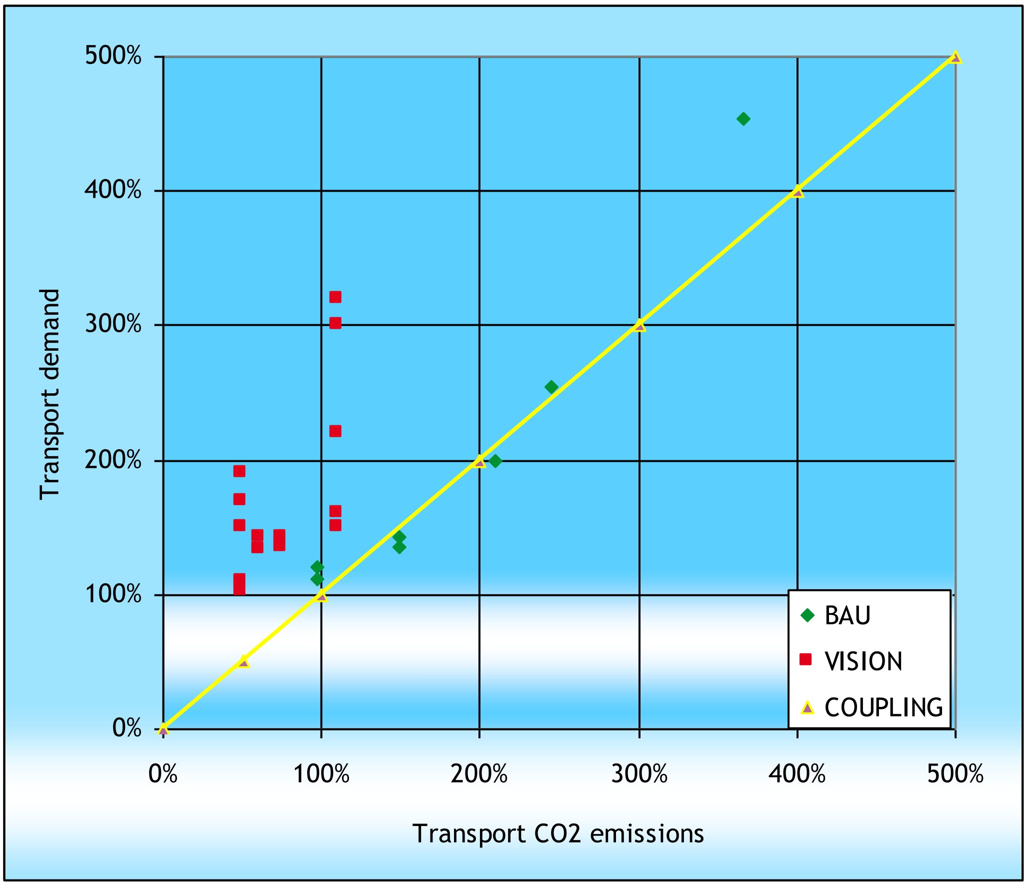
Table 4 Demand increases per transport segment in the VISION scenarios

Transport segment	Outlook year	Demand increase
aviation	2050	300%
aviation	2050	190%
aviation	2050	320%
freight	2020	103%
freight	2020	143%
freight	2030	143%
freight	2050	170%
freight	2050	150%
Passenger	2020	110%
Passenger	2020	134%
Passenger	2030	135%
Passenger	2050	150%
Passenger	2050	160%
Passenger	2050	220%

Studies included: WBCSD, 2005; EC,2008; CGPC, 2006; MCRIT, 2009

An increase of demand does not automatically mean an increase of emission. To explore the general consensus on this matter it is useful to first look at the relation between transport demand and transport emissions. A small number of scenarios provided data on both. Figure 9 shows the relation.

Figure 9 Relation between transport demand and emissions



Studies included: WBCSD, 2005; EC,2008; CGPC, 2006; PBL, 2009; MCRIT, 2009

The transport emission axis states CO_2 emissions relative to 1990 levels and the transport demand axis provides relative demand information, however the base year of these demand values is unclear as most studies are not as accurate in presenting their demand projections as they are in presenting emissions.

The yellow line represents the coupling between demand and emission. It mirrors the case where there is no technological improvement. Most BAU scenarios follow the yellow line. The vision scenarios all lie to the left of the line and above 100%. This means that technology improves (driving efficiency) and demand increases. In all scenarios demand increases even though “demand reduction” is included as a non-technical option (i.e. projected increases in transport demand outweigh measures to mitigate/reduce the demand).

The visions scenarios where technology improves more than demand increases and emissions drop (compared to 1990 levels) slightly outnumber the scenarios with the opposite and thus resulting in an overall increase of transport’s CO_2 emissions.

3.4 Conclusions

With respect to global emissions we can conclude that:

- BAU emissions are expected to increase by at least 150% compared to 1990. Increases of more than 200% seem likely
- There is no clear separation between BAU and reduction scenario emissions. The highest reduction scenario emissions predict emissions that are similar to the lowest (most optimistic) BAU results. This is a result of both the different choices in BAU scenarios (some assume unrestricted

growth while others assume continuation of the trend towards emission reduction policy) and the difference in ambition level of the vision scenarios between studies.
- Very few studies report decreases in emissions compared to 1990 levels. Only one scenario approaches 80%.

Global transport emissions show reductions in the same order of magnitude as global emissions for all sectors (in both BAU and reduction scenarios). This is in contradiction with the more qualitative general assumption that the transport sector will lag behind in reduction because reductions are more difficult or expensive in transport and it is likely that reductions will be achieved first where they are more cost-effective.

For the EU transport emissions, the following can be concluded:
- BAU scenarios indicate an increase around 150%.
- Not all vision scenarios show a reduction compared to 1990 levels.
- Transport emissions in Europe are expected to increase less in the BAU scenarios than the world average and reduction scenarios are expected to achieve more than the world average.
- Reductions in the transport sector are also in the same order of magnitude as reductions for all sectors in the EU for the reduction scenarios. This is possibly the result the fact that many of the reviewed studies use the back casting method with equal reduction targets for all sectors. Cost-optimised studies of the whole energy system show different results.
- Only one study assumes 80% reduction compared to 1990 levels
- Europe is expected to be a forerunner in emission reduction

General conclusions about demand and emissions are:
- Transport demand is projected to increase by up to 200% in total and possibly more (upto a factor 4) for aviation[8]
- If no actions are taken then there will be little decoupling between demand and emissions
- More than half of the vision scenarios assume that technology improves faster than demand increases, resulting a net emission decrease.

[8] This is in agreement with (AEA, 2009) which projects that emissions increase by a factor of around 3 for shipping and 4 for aviation. “

4 Trends in transport carbon intensity and CO_2 reduction potentials

4.1 Introduction

In this chapter we compare the various scenarios with respect to the CO_2 reduction potentials of specific reduction options and policies.

The reduction potential is most often used to represent an allocation of the overall reduction to certain policies or technologies. For technology options it is mainly used to provide insight into the importance of development of a certain technology and of the necessity of early investment. Attribution of emission reductions to policy measures is more difficult and harder to define. Few studies attempt it.

For technological options two sets of information are stated. Reduction potential (as defined above) and application volume (for example: “in 2050 40% of all passenger cars are fuelled by hydrogen”). This volume by itself provides no information on the emission reduction but does give insight into the effort required to reach the reduction potential.

The largest part of the studies only mentions which technologies or policies are important or will be required without attributing the emission reduction to specific measures. This can provide information on the “popularity” of options and in the paragraphs below we attempt to quantify this indicator.

4.2 Trends in carbon intensity for passenger, freight and aviation

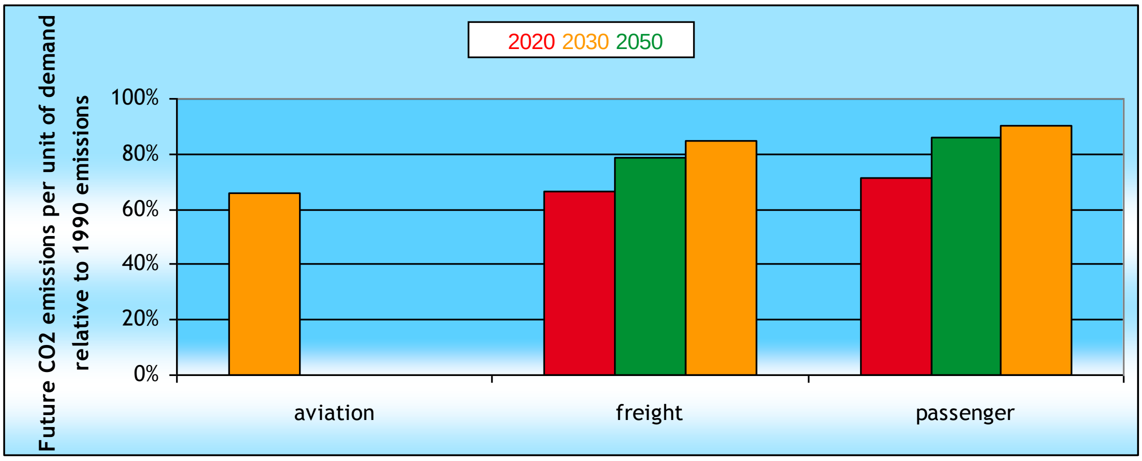
Most scenarios show an improvement of the carbon intensity (gram of CO_2 per tonne-km or passenger-km). In some cases it was possible to calculate the changes in the carbon intensity for a transport category based on reductions and demand predictions. We managed to distinguish:

- Passenger transport
- Freight
- Aviation

Most EU studies include only aviation within the EU and not international aviation. International shipping and aviation are often neglected or excluded in global studies as well. This causes a focus on road modes in most studies.

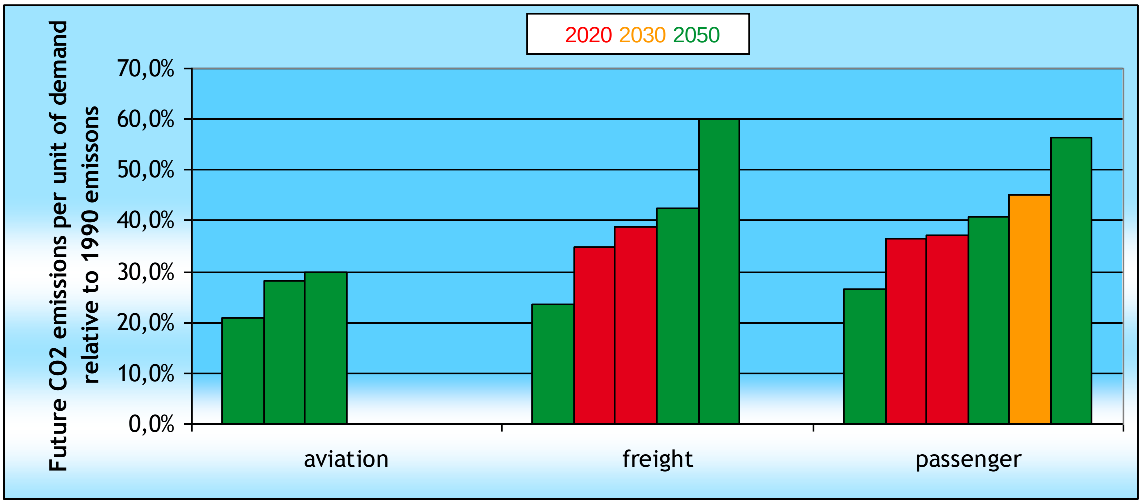
The following figures show the carbon intensity expected by autonomous development (BAU) and the carbon intensity in the vision scenarios. They reflect the total reduction potential per passenger-km or tonne-km.

Figure 10 Autonomous development by 2030-2050



Studies included: WBCSD, 2005; EC,2008; CGPC, 2006; PBL, 2009; MCRIT, 2009

Figure 11 Visions on reduction for 2030 - 2050



Studies included: WBCSD, 2005; EC,2008; CGPC, 2006; PBL, 2009

4.3 Methodology

For each of the studies we scored the potential reduction for technical options, non technical options and policy instruments. The way in which the information on these matters was presented differed greatly between studies. Although we scored as disaggregated as possible we were unable to make meaningful comparisons directly.

Some data was convertible to emissions (per unit of demand such as tonne km) relative to 1990 levels. We distinguished three segments of the transport sector: Aviation, freight and passenger transport. Aviation mostly consists of passenger flights and some studies reporting passenger transport might also include aviation.

Freight and passenger transport often consist mainly of road transport with very little consideration for rail and shipping. Again is was not always clear whether the latter two were included.

Other studies provided reduction potential per unit of demand but without reference or share. These are presented in Figure 12. The emission data was converted in the same format and presented alongside it.

Only a fraction of the studies provided information that was comparable and converted in these figures. To give some insight in the options taken into account by the bulk of the studies we scored the "popularity" of the technical options. Whenever an option was mentioned in a scenario as a major contributor to reduction we incremented its score. The results are presented in paragraph 4.4.3.

For the non technical options and policy instrument such a comparison could not be made. The options and their share and potential are described qualitatively.

4.4 Technical options

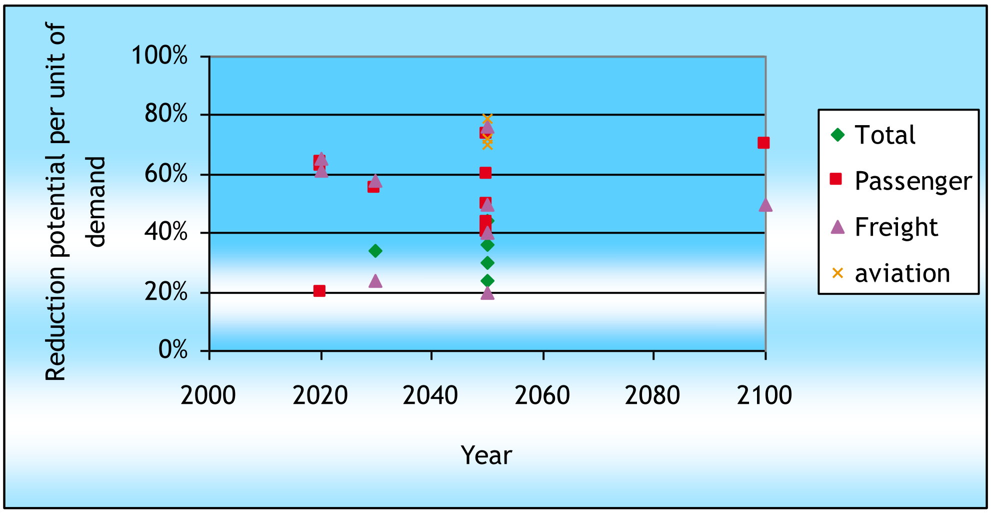
4.4.1 Reduction potential

Occasionally a scenario allocates its total reduction to reduction options itself. These results have been categorised into:

- Passenger potential
- Freight potential
- Total Technical potential

The next figure shows the reduction potential for these categories.

Figure 12 Technical reduction potential in transport



Studies included: WBCSD, 2005; EC,2008; WEC, 2009; CGPC, 2006; McKinsey & Company , 2009; MCRIT, 2009; VLEEM Consortium, 2005; WWF, 2009; Meyer et al., 2007; IEA, 2008; CE, 2007; ERTRAC, 2009

Please note that the percentages in the axis are not identical to most percentages in this study. These are not emissions relative to 1990 levels but reduction potentials (ie. Passenger transport will become 20% more energy/emission efficient)

The studies that provide data on aviation (WBCSD, 2005 and CGPC, 2006) show a reduction potential between 70% and 80%. These reductions are expected to be achieved using biofuels and high efficiency aeroplane technology. Even with these very large reductions overall emissions from aviation are expected to increase due to the explosive growth of demand.

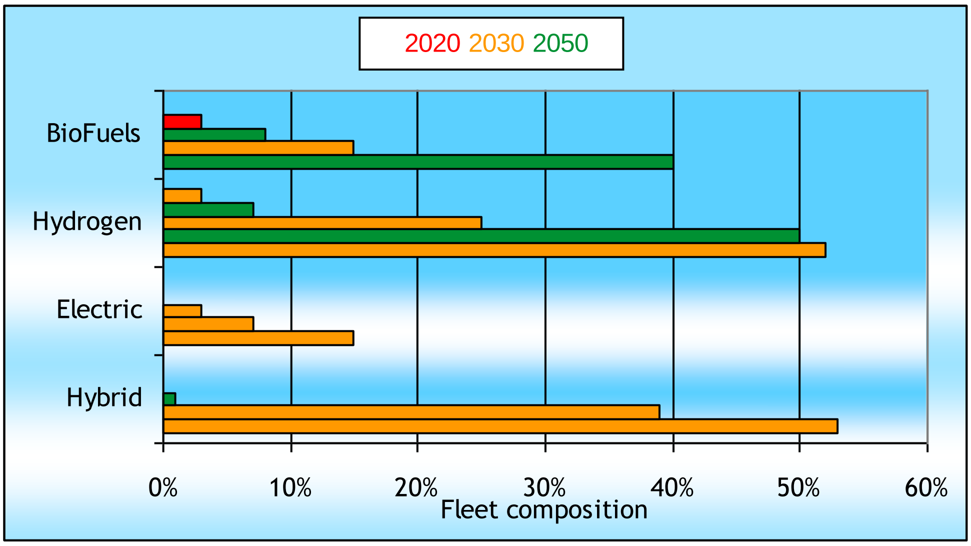
Reduction potentials for passenger and freight show a similar bandwidth (between 20% and 75%) with technical options ranging from hybridisation/electrification and improvements to the internal combustion engine to use of low carbon fuels such as hydrogen and biofuels. Most studies agree that reductions are cheaper and easier to realise in passenger transport than in freight, but the figure does not show any difference between these segments upto 2050. The datapoints for 2100 do show a difference between freight and passenger transport. It is also noteworthy that these very long term projections are not much more ambitious than some of the 2050 or even the higer 2020 potentials.

The large range can be partially explained by differences in presentation of the data. Some studies incorporate emission savings due to biofuels into the technical potential, others only regard technical changes to the vehicles. Some studies may even combine technical and non-technical options (like modal shift) to an overall reduction potential. It is not always clear which options are included and which are not nor to what extend they are applied.

4.4.2 Application volume

The volume of a technology is a good indicator of how integrated into society it is and how well developed it needs to be to make this viable. Sadly too little data was available in a compatible format to give insight into a complete set of technologies. What can be concluded is that there is little agreement between studies. The following figure shows the spread of application volume between three passenger car technologies.

Figure 13 Fleet penetration of car technologies



Studies included: WBCSD, 2005; McKinsey & Company , 2009; ECN,2007; EC, 2007; ERTRAC, 2009

Hybridisation can in some cases be included within technical improvements of the internal combustion engine and within other cases in electrification (e.g. plug in hybrids).

There is a lively debate between hydrogen fuelled cars and electric vehicles (EVs). There are twice as many scenarios that rely on electrification as the low carbon solution of the future (McKinsey, & Company, 2009; Shell, 2008; OECD/IEA, 2009; ERTRAC, 2009) then there are scenarios that envision hydrogen to become dominant (WBCSD, 2005; ECN, 2008). Most studies expect both to make their contributions (EC, 2008; EC, 2007; PBL, 2009; Vleem Consortium, 2005; WWF, 2009; RECIPE, 2009). There are scenarios that specifically say that no breakthrough in EV technology will occur (ECN, 2007). In the most recent analysis by IEA the hydrogen only scenario has been abandoned, mainly due to the failure of hydrogen technology to live up to expectations and the greatly increased development in electric vehicles during the last few years.

4.4.3 Relative importance of options

While not many scenarios give compatible data on the potential of the technological solutions they prescribe many give qualitative indications of which technology will be paramount and which will not be. In an attempt to quantify the myriad of qualitative arguments the following graphs were generated.

We scored how often a technical measure was mentioned as having a significant share in the overall solution. We then categorised the measures as follows:

- **Technology solutions**
- **Fuel efficiency**
    - Improved ICE
    - Weight reduction
    - Aerodynamics improvements
    - Energy efficient air-conditioning etc
    - Hybridisation
- **Low carbon fuels**
    - Hydrogen
    - Biofuels
    - Gaseous fuels
    - electrification
    - Coal liquefaction
- **Mobility management (its)**
- **Soft Measures**
    - Vehicle maintenance
    - Driver support/coaching
    - Infra/information
    - Logistics/business model

Where the bold categories presented totals of the other categories. Figure 14 and Figure 15 show the results in percentage of studies that mention the measures.

Figure 14 Popularity of general technical measures

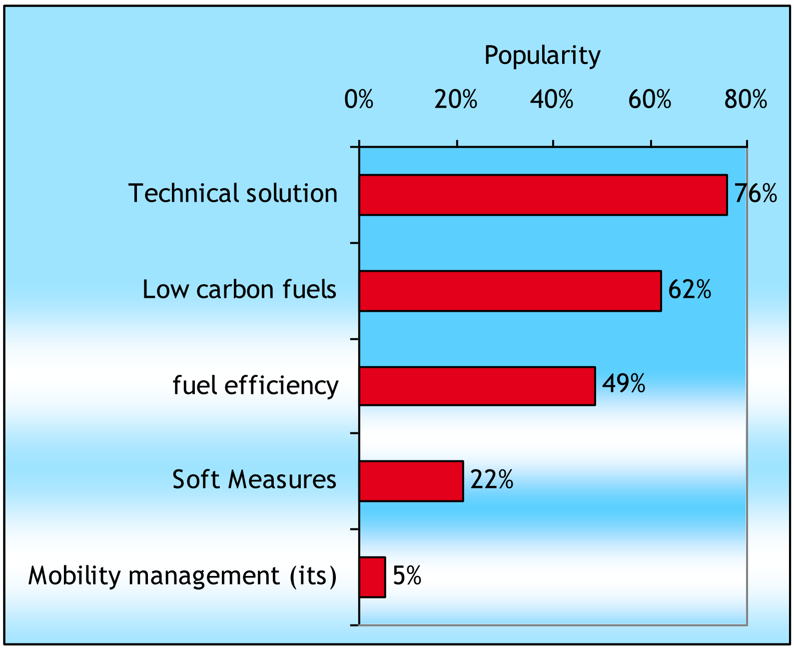
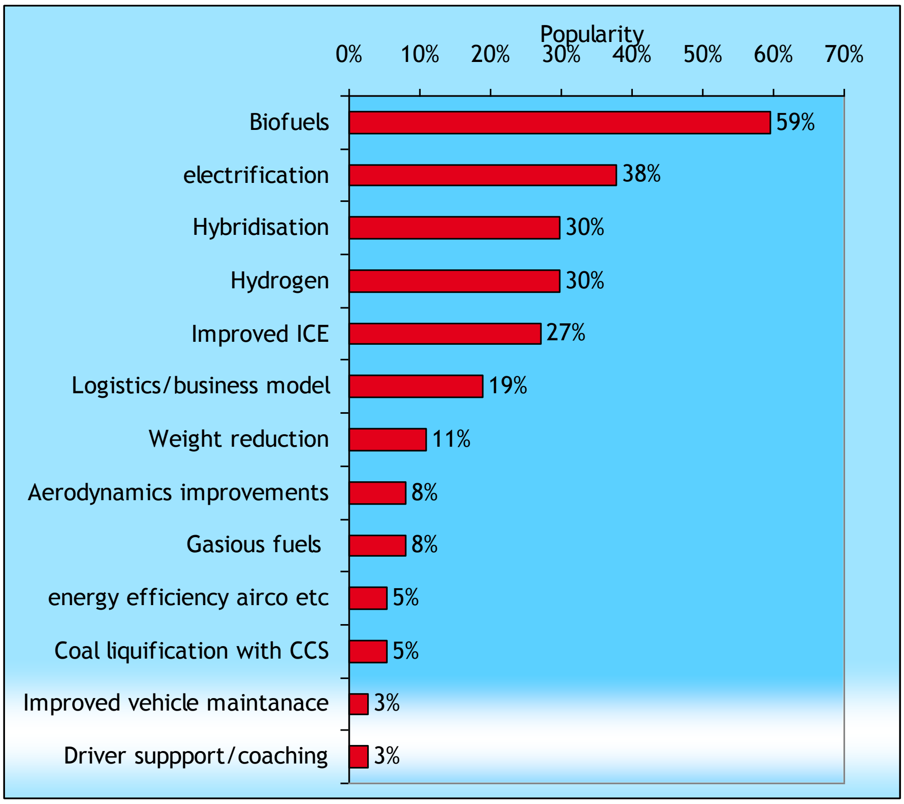


Figure 15 Popularity of specific measures



4.4.4 Qualitative observations

Many of the studies focus their discussions about technical options on road transport (EC, 2008; WEC, 2009; McKinsey & Company, 2009; EC, 2007; WWF, 2009; Meyer et al., 2007; OECD/IEA, 2009; ERTRAC, 2009). Some of these distinguish the results for other modes (for instance EC (2008) and WWF (2009)), but not all. Studies with a more detailed distinction (PBL, 2009; Vleem Consortium, 2005; IEA, 2008) tend to describe the most innovative options for passenger road transport. This is also valid for studies with less quantitative descriptions of potential. The reductions in passenger road transport are most often attributed to innovation while the reductions in freight are more often due to the use of biofuels (bio-diesel) in conventional vehicles.

The production of biofuels is often not discussed. Many studies imply that the biofuels used are sustainable biofuels, but production methods or competition with food and biodiversity are often not mentioned. The studies that have performed optimisations and modelling of more than just the transport sector and discuss availability of recourses tend to be more careful in deploying biofuels and also tend to provide more details on sustainable agriculture.

Not all studies report whether tailpipe emissions are used in the projections and calculations of reduction potential or whether the emissions from the production chain are also attributed to the vehicle (well to wheel). Studies that cover more sectors than just transportation also generally either use well to wheel emissions for transport or at least report what happens with the production emissions of the fuels. Not all studies dealing with only the transport sector are equally clear. Most state or imply that production emissions are included. We have assumed that if not stated otherwise well to wheel emissions were presented.

Possibilities for innovation in freight are universally expected to be less than for passenger transport. Technical options for non-road modes are rare and only ERRAC (2007) describes them in a detail level comparable to that of passenger road transport.

The general opinion seems to be that there is more room for improvement (ie. reduction) in the passenger segment than in freight. This opinion is not in agreement with the quantitative analysis in paragraph 4.4.1. Again this might be a result of the back casting method combined with equal reduction targets.

Reduction for rail and shipping (excepting modal shift) seems to be expected to be lower than from road (EC, 2008; ERRAC, 2007; IEA, 2008; OECD/IEA, 2009; ERTRAC, 2009). Only 13 expects reductions for non road modes to be at par with road transport. Technical improvements (like high speed rail and improved comfort for passenger transport and improved intermodality for freight) are expected to cause modal shift from road or aviation. The emission reductions from this move are sometimes added to the road reductions. Data on the scale of these reductions is limited. PBL, 2009 reports that modal shift and demand reduction together contribute 15% of the overall reduction. Modal shift potential in freight is generally limited (in the order of several percent of the overall reduction). Modal shift in passenger transport can range from increased use of public transport (also in the order of a few percent) and shift to self propelled modes (1,5%).

Shift from aviation to high speed rail is reported to have a greater effect by two studies (WWF, 2009 and IEA,2008). In the latter 25% of all air travel under 750km is shifted to high speed rail. This is assumed to be 5% of all air travel. In total about 3% of the baseline emissions can be saved by model shift towards high speed rail.

4.4.5 Conclusions

Based on the analysis in the previous paragraphs the following conclusions can be stated:

- Both passenger and freight are expected to show an autonomous improvement of 20% (reduce carbon intensities to 80% of 1990 levels)).
- The majority of reduction potentials stated in the scenario studies are less that 50%.
- Qualitatively most studies agree that passenger transport is expected to be able to reduce its emissions more than freight transport. The quantitative analysis in this report shows equal potential.
- There is little agreement on the future application volume of technologies.
- Three quarters of all studies assume a leading role for technology in achieving emission reductions.
- Most technical options that are modelled or reported in detail concern the road modes and most innovations are expected in passenger road transport
- Most studies assume a significant share in the CO_2 reductions for biofuels sustainable and non-food-competitive biofuels

4.5 Non-technical options

Not all available options depend exclusively on technology. The studies that provide more detailed and comparable data on reduction potentials are more focussed on technology (EC, 2008; EC, 2007; IEA, 2008; OECD/IEA, 2009). In these studies the non technical options are generally less developed than the technical options or completely omitted. The studies that do go into non-technical options provide less quantitative details. As a result, reduction potentials for non-technical options are rarely presented in quantitative comparable form. The non technical options are often described qualitatively along with the policy instruments with which they are to be achieved.

In general we can distinguish six non-technical options that are often mentioned:

- Improvement of spatial planning.
- Improved logistics.
- Change in travel behaviour.
- Fuel efficient driving.
- Modal shift.
- Demand reductions.

Some of these options are closely linked and may overlap. For example improvements of spatial planning can be a requirement of improvements in logistics or cause a change in travel behaviour and model shift. In fact the option "change in travel behaviour" can in most cases be seen as a derivative of Modal shift, Demand reductions and (less frequently) Fuel efficient driving.

A common assumption (for instance EC, 2008; ERTRAC, 2009) is that in the future a greater portion of the population will live in urban area's (up to 80% of the population of the world, study ERTRAC (2009)) and closer to urban centres of activity. This in turn is assumed to improve logistics in freight transport and cause modal shift (EC, 2008; WBCSD, 2005; CGPC, 2006; Vleem Consortium, 2005) to public transport and self propelled modes (more cycling and walking) in passenger transport.

Fuel efficient driving is mentioned qualitatively by (EC, 2008; McKinsey & Company, 2009) and is expected to have only a small impact (1-2,5% reduction). Other studies include fuel efficient driving in the increase in efficiency of the internal combustion engine.

Modal shift is commonly discussed separately for passenger and freight transport. For freight transport, rail and shipping are popular options but almost all studies agree that road transport will continue to dominate. Greater intermodality in freight transport is also described as an improvement in logistics (PBL, 2009; OECD/IEA, 2009; ERTRAC, 2009). Study Vleem Consortium (2005) distinguishes modal shift (road share of freight transport) for each of the world regions and observes that there are great differences in the share between regions (33-96%).

For passenger transport a shift to public transport and self propelled modes is often expected (EC, 2008; WBCSD, 2005; CGPC, 2006; PBL, 2009; Vleem Consortium, 2005) but the majority of studies ignore public transport and assume short range transportation to remain an automotive affair. Modal shift from aviation to High speed rail is most commonly described in the European studies, while demand for air travel is expected to increase by all (except WWF, 2009)

On the whole transport demand is expected to increase as is evident from Figure 9. Demand reduction as a method of reducing emissions, especially in passenger transport is not uncommon (PBL, 2009; MCRIT, 2009; WWF, 2009; RECIPE, 2009). In WWF, 2009 the cause of the reduction is the aging population of Germany. Others envision a more policy driven reduction. The scale of the reduction is not often presented. PBL, 2009 is an exception. In the vision scenario modal shift and volume reduction together are assumed to be responsible for 15% of the overall reduction. A more general opinion is that demand reduction policies do not reduce demand in the absolute but curb growth.

4.6 Policy instruments

Three different types of policy information are presented in the studies:

- Specific policies (support production of 4 million hydrogen fuelled cars by 2020)
- General policies (stimulate the introduction of low carbon technologies
- Advice on how to make policies (instigate technology neutral stimulation policies)

There were few studies that provided specific policies, the general policies and advising statements were more common and often used in conjunction.

The single most commonly stated general policy was that of international cooperation. Almost all studies assumed it as a necessity for significant reductions. In studies with more than one reduction scenario the vision with strong international cooperation uniformly showed the greatest reduction. No study provides clear advice on how this international cooperation is to be obtained.

Support (in the form of investments or subsidies) for research and development and the stimulation of the introduction of low carbon technologies that are not initially cost effective are the next two popular general policies. These are mentioned by about half the studies and often together. Many studies advice that these stimulations should be technology neutral (among others WEC, 2007; ECN, 2007; ERTRAC, 2009; RECIPE, 2009) to allow the market to choose the most appropriate technology.

An other popular approach for stimulating technology is the formulation of fuel consumption standards or CO_2 emissions standards for vehicles (EC, 2008; WEC, 2007; WWF, 2009; IEA, 2008; CE, 2007; OECD/IEA, 2009; ERTRAC, 2009; RECIPE, 2009). The general consensus is that these regulations should be stable in the long term so that private investors can anticipate and the market can choose the "winning" technology (for instance ECN, 2007; IEA, 2008; RECIPE, 2009).

As a general policy many studies advocate some form of additional internisation of the cost of emissions with a (global) emission trading system (WEC, 2009; Shell, 2008; MCRIT, 2009; OECD/IEA, 2009; RECIPE, 2009) or CO_2 tax (WWF, 2009; IEA, 2008; OECD/IEA, 2009; RECIPE, 2009). These systems can help achieve reduction goals and assure that reductions take place in the most cost efficient way. But they should be fair and not economically restrictive.

Three studies contain scenarios with demand reduction policies (PBL, 2009; MCRIT, 2009; RECIPE, 2009) but the overall demand is expected to increase regardless.

Finally, many studies stress the need for swift action if the more ambitious reductions are to be achieved (WBCSD, 2005; WEC, 2009; ECN, 2007; PBL, 2009; MCRIT, 2009; WWF, 2009; IEA, 2008; OECD/IEA, 2009; RECIPE, 2009). All studies convey some sense of urgency, but this may be a property of scenario studies in general.

4.6.1 Conclusions

From the previous paragraph the following aggregation of common themes in the analysed studies can be made:

- To achieve a significant reduction international cooperation is paramount. Scenarios incorporating global cooperation score best in reduction potential and global cooperation is seen as the obvious course of action.
- Immediate action is required to achieve the more ambitious reductions. If we don't respond quickly we might not realize a significant reduction or the reduction will cost a lot more to achieve
- Stimulation of research and support for developing technologies can force breakthroughs that are necessary for reaching reduction targets
- Fuel efficiency or CO_2 emission targets can help the industry to reach its full potential but these instruments should be technologically neutral
- Emission trading systems or CO_2 taxes can be beneficial if applied fairly and in a way not to restrict economic development
- Transport demand will increase regardless of demand reduction policies.

5 Conclusions

5.1 Expectations

What can be expected to be the result of an overview such as this? In the best case there is a good deal of agreement between studies and the results can be combined into one big study that presents a vision of the future and the measures to be undertaken to achieve that future.

Another possible outcome is a playing field where there is some agreement but strong disagreement on a few topics. This can give further insight into the nature of the argument and force an outcome or facilitate further research.

Or the results can be as diverse as the assessed studies numerous. In this case very little can be concluded about the future, but more can be said about the difficulty of fore (back) casting and the diversity of viewpoints of the issues at hand.

The assessment in this paper seems to place itself somewhere between the latter two possibilities. In the next paragraphs we will attempt to draw conclusions on the aggregated results from the assessed studies.

5.2 Conclusions on the trends and reduction potentials

If no action is taken the total global emissions for all sectors are expected to increase by at least 150% compared to 1990 levels. Increases of 200% or more seem likely. Even if we do act, only a few reduction scenarios achieve a decrease in emissions compared to 1990 levels and only one scenario approaches 80% reduction. Global transport emissions show reductions of the same order of magnitude as the total of all sectors.

For the EU the reductions of the transport sector are also in the same order of magnitude as the reductions in total emissions. And although the BAU emissions in the EU are expected to increase less than the global emissions and the emissions in the vision scenarios are expected to decrease more than worldwide emissions, not all vision scenarios achieve a decrease of emissions compared to 1990 levels. Only one scenario achieves 80% reduction (and that is a back casting study[9]). On the whole Europe is expected to be a forerunner in emission reduction.

Transport demand is expected to increase by up to 200% and more for aviation (up to 400%). If no action is taken there will be little decoupling between demand and emissions. More than half of the vision scenarios assume that technological carbon intensity improvements will outrun demand increase, leading to an overall decrease in emissions relative to the current level. Some scenarios incorporate demand reduction policies but even then overall demand is expected to increase. Road transport is expected to continue to dominate in both passenger and freight transport. However most studies exclude international/intercontinental shipping and aviation, two large sources of CO_2 emissions. This omission leads a bias in the reduction potential estimations.

Technical options are expected to have a major share in emission reductions. Three quarters of all studies envisage a leading role for technology in reducing emissions (though in some cases stimulated by policy). Most technological options concern road transport and in passenger transportation most innovations are expected. An autonomous improvement of about 20% is expected. The total reduction potentials in the reduction scenarios are generally less than 50% . Of all technical options biofuels are the most popular, especially in freight transport and aviation. This is mostly due to the lack of other (innovative) solutions in these transport segments.

[9] PBL, 2009

Of the non technical options modal shift (or “greater intermodality”) is in most scenarios expected to have the highest potential but not more that several percent. Most studies assume that both passenger and freight transport will remain mostly an automotive affair.

With respect to policy, all studies agree that to achieve a significant reduction, international cooperation is paramount. Scenarios incorporating global cooperation score best in reduction potential and global cooperation is seen as the obvious course of action. Policy as a means to stimulate innovation and technical development is seen as a necessity for reaching reduction targets. Fuel efficiency targets or CO_2 emission targets can help the industry to reach its full potential but these instruments should be technologically neutral. Emission trading systems or CO_2 taxes can be beneficial if applied fairly and in a way not to restrict economic development.

Some demand reduction policies are mentioned but demand is expected to increase regardless. Most studies emphasize that immediate action is required to achieve the more ambitious reductions. If not, significant reductions may be not realized or the reduction cost will increase dramatically.

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A Studies Included in the Figures

A.1 Figure 5 Global CO_2 emissions relative to 1990 levels for all sectors

WBCSD, 2005
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OECD/IEA, 2009
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A.2 Figure 6 European CO_2 emissions relative to 1990 levels for all sectors

Shell, 2008
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A.3 Figure 7 Global transport emissions compared to 1990 levels

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A.4

EC,2008
CGPC, 2006
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A.5 Figure 9 Relation between transport demand and emissions

WBCSD, 2005
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A.6 Figure 10 Autonomous development by 2030-2050

WBCSD, 2005
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A.7 Figure 11 Visions on reduction for 2030 - 2050

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A.8 Figure 12 Technical reduction potential in transport

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A.9 Figure 13 Fleet penetration of car technologies

WBCSD, 2005
McKinsey & Company , 2009
ECN,2007
EC, 2007
ERTRAC, 2009

A.10 Figure 14Popularity of general technical measures

ALL

A.11 Figure 15Popularity of specific measures

ALL

A.12 Table 3 Demand increases per transport segment in the BAU scenario

EC,2008
PBL, 2009
MCRIT, 2009

A.13 Table 4 Demand increases per transport segment in the VISION scenarios

WBCSD, 2005
EC,2008
CGPC, 2006
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B Strategic Rail Research Agenda 2020

ERRAC,2007
Strategic Rail Research Agenda 2020
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B.1 Scenario Summary

The background of the research is to improve the railways in all respects for the benefit of its citizens and wider society. The analysis shapes a vision for the future of railways, taking into account a long-term framework for the 2020 horizon. The priority areas suggested are technological advances (Intelligent mobility) energy and environment, personal security, infrastructure development, strategy and economics.

B.2 Context

The context behind the preparation of the Strategic Rail Agenda is that the environmental benefits of rail in a European transport environment driven by carbon trading will raise political expectations that rail shall take a much increased share of passenger and freight transportation than at present. Hence, the European railways must be prepared for eventualities such as global warming and the need to assume a greater role in the transportation of people and goods, and have developed strategies for dealing with these issues on a continental scale.

B.3 Scope

The analysis provides the indication of priority research areas to 2020, without the indication of scenarios or quantitative evaluations of the potential gains in terms of carbon emissions.

The priority areas are the following:

- Enhanced environmental advantages of the rail mode: Reducing emissions, including electromagnetic emissions. Adapting noise attenuation techniques to differing networks ahead of emerging standards.
- Improved performance of rolling stock: Developing new and advanced vehicles concepts using innovative materials and production processes and benefiting from economies of scale
- Improved performance of infrastructure: Developing innovative solutions to significantly reduce the life cycle costs of high value infrastructure assets.
- Enhanced competitiveness: Increasing the performance of products, improving production processes and reducing life cycle costs with the aim to improve the economic attractiveness of the rail transport mode.
- Exploring IT technologies to develop sufficiently high-quality services and implementing overall intelligent mobility concepts

The analysis is carried out by the European Rail Research Advisory Council (ERRAC), an advisory body to the EU Commission representing Member States and all stakeholders in the sector ranging from operators to infrastructure managers.

B.4 Wider assumptions

The assumption behind the Agenda is that the overall transport demand would grow by 40 per cent for passengers and 70 per cent for freight by 2020 compared with 2000.

Projected Modal Split 2020 (per cent, EU 25):

Freight	Road	Rail	Inland Waterway	Short Sea Shipping	Pipeline
Total	42	14	3	39	2
Passenger	Road	Rail(incl. Metro/Light Rail)	Air	Bus	
Total	72 5	11	9	7,5	

*Projected Volume 2020 (pkm/tkm*109):*

Freight	Road	Rail	Inland Waterway	Short Sea Shipping	Pipeline
Total	2520	840	180	2340	120
Passenger	Road	Rail(incl. Metro/Light Rail)	Air	Bus	
Total	5510	836	684	570	

B.5 Results

No results have been provided.

B.6 Other remarks

Strengths:

The Agenda benefits of the involvement of the relevant rail stakeholders

Weaknesses:

Short-term 2020 scenario horizon. No quantitative assessment of potential gains from the Agenda has been provided

C Long-Range Transport Plan - Horizon 2050 : Strategic considerations

CGPC, 2006
Long-Range Transport Plan - Horizon 2050 : Strategic considerations
S.l. : Ministère des Transports, de l'Équipement, du Tourisme et de la Mer, Conseil Général des Ponts et Chaussées (CGPC), 2006

C.1 Scenario Summary

The background of the research is the Conseil Général des Ponts et Chaussées (CGPC) Committee activity, which has been assigned responsibility for evaluating and preparing future public policy regarding infrastructure, land planning and regional development.

The CGPC organization comprises an "Economics and Transportation" Directorate, which often gets asked to provide consultative input on projects with very long-term planning horizons. Such has been the case for the audit commissioned on large-scale infrastructure programs that took place between September 2002 and February 2003, in collaboration with national financial authorities. In such a context, the Long Range Transport Plan has been devised.

C.2 Context

The Conseil Général des Ponts et Chaussées "Economics and Transportation" unit decided at the end of 2003 to undertake along-term planning study on the transportation system out to 2050 in France. The vision set forth four potential views of the transportation system in the year 2050, in the form of four exploratory scenarios established from socioeconomic criteria.

By concentrating specifically on transportation and the provision of transportation services, this exercise has provided some of the initial framing elements for examining the problems and issues inherent when defining goals and priorities surrounding long-term transportation policies, Namely:

upcoming trends in transportation flows;

- potential for developing alternative and complementary modes to roads;
- infrastructure needs, beyond the completion of projects already earmarked at the December 2003 Inter-ministerial planning committee meeting;
- the prospect for achieving significant reductions in CO_2 emissions (provided the promulgation of appropriate economic regulations and the development of "accessible" technologies, i.e. rechargeable hybrid vehicles and biomass based fuels) within an overall context of promoting sustainable development.

C.3 Scope

The scenarios set forth four potential views of the transportation system in the year 2050 in France, in the form of four exploratory scenarios established from socioeconomic criteria. The scenario building step includes a number of elements from the worldwide and European context that appear as determinant to shaping a long-term view; these would include:

- demographics, with a dual emphasis: aging of the population, and population migration patterns (increasing vs. decreasing concentrations within certain zones?);
- energy available over the upcoming decades, and the interrelationships existing between
- transportation and the greenhouse effect;
- the economic context (how will globalization play out? what kind of GDP growth rates can be expected?) likely to influence evolution;

- technological progress, especially that relative to enhanced vehicle engines and cleaner fuels.

The scenarios involve passenger and freight transport. All mode of transport. A brief description follows:

- **Scenario 1 - "Worldwide governance and environment-friendly industry**" is characterized both by worldwide cooperation for enhanced control over energy-production technologies, which allows for enhanced mitigation of the adverse effects due to greenhouse gases and by a pan- European policy favouring industrial development, especially through extensive R&D support;
- **Scenario 2 - "European isolationism and decline**", with the world's major blocks engaging in a ferocious economic competition against a backdrop of energy supply crises; each European nation manages and protects its resources, and both demographic and economic growth rates remain low;
- **Scenario 3 - "A tightly-integrated, enlarged Europe**" is founded by virtue of the successful economic integration of the Mediterranean Region and Russia into the European Union, to ensure providing for their development and European security at the same time. This scenario reflects strong economic growth;
- **Scenario 4 - "Inward-looking European governance and regionalization"** lies within a context of worldwide energy crisis, as characterized by a decisive increase in the price of oil paid on the world market. In order to preserve security and employment, Europe pursues a more endogenous growth formula, with considerable emphasis on integration, yet only a limited opening onto the other world blocks.

The above visions are underpinned by the following **policy scenarios**

Scenario 1: strong world governance and strong European governance on climate issues, open trade and international relations;
Scenario 2: absence of either world or European governance; a rather protectionist stance;
Scenario 3: no world governance; moderate European governance; opening onto the world;
Scenario 4: no world governance; strong European governance; protectionism.

C.4 Wider assumptions

The following table summarises the assumption beyond the scenarios:

	Retrospective	2002	Horizon 2050 scenarios			
			Scenario 1 Worldwide governance and environment-friendly industry	**Scenario 2** European isolationism and decline	**Scenario 3** A tightly-integrated enlarged Europe	**Scenario 4** Inward-looking European governance and regionalization
Demographics (in millions of population)	46,5 (1962)	59	67	58	67	70
GDP (annual growth)	-	2 %	1,5 %	1 %	2 %	1,5 %
Price of a barrel of oil *including the carbon tax*	-	28 $	90 $ *60 $*	60 $ *0*	90 $ *30 $*	180 $ *60 $*
After-tax fuel price (average value per liter)	-	0,87 €	1,85 €	1,33 €	1,76 €	2,43 €
Land-based passengers (0-1,000 km distances)	49 (1975)	100	150	118	164	158
Airline passengers (airport traffic)	46 (1986)	100 (2004)	191	185	318	168
Freight volumes (domestic traffic)	54 (1965)	100	167	94 à 117	146 à 182	150

C.5 Results

In the **Scenario 1 - "Worldwide governance and environment-friendly industry**" the local mobility flows (trips of up to 50 km), which had risen by nearly 90% between 1975 and 2002, will only gain another 30% over the period 2002-2050. While the private automobile will continue as the main mode, the share of public transit, which had fallen from 12% to 8% of all motorized trips between 1975 and 2002, will climb back to the 10% mark. Between 2002 and 2050, long-distance mobility (50-1,000 km trips) will double, while more local mobility will only rise by a third. Airport traffic within metropolitan France will reach a figure of 238 million passengers (less than a twofold increase through 2050, i.e. 1.4% annual expansion). The freight growth scenario lies within the continuum of current trends (with a 1% annual increase in flows between 2002 and 2050, a figure sharply lower than over the past several decades). Worldwide cooperation on energy prices, particularly via heavy carbon taxation ($140 per ton of CO_2, equivalent to $60 a barrel of oil), will engender technological leaps: at 2050 a heavy decrease in per-vehicle consumption rates and emphasis on developing synthetic fuels (according to our scenario, biomass-derived fuels will constitute half of all liquid fuels consumed). A moderate demographic and economic growth (GDP rising by 1.5% a year) will underpin the scenario
In the **Scenario 2 - "European isolationism and decline"** is characterised by a weak demographic and economic growth (1% a year). Passenger flows over short and medium distances (land-based) will be reduced, with automobile traffic out to 2050 rising by just 10% and public transit by 25%. Long distance will be more heavily affected, with a slow growth over the 2004-2050 period (+1.4%) for the air sector. the dual effect of reduced economic growth and the absence of worldwide and European regulation will not enable the widespread development of alternative energies to replace petroleum and fossil fuels. Consequently, bio fuels will account for the smallest share (8%) of all four scenarios and will consist of agricultural by products (ethanol and ester from vegetable oil).
The **Scenario 3 - "A tightly-integrated, enlarged Europe**" assumes moderate demographic evolution and strong economic growth (2% a year). The level of mobility for trips exceeding 50 km will double by 2050. Airline traffic offers the most substantial rise in the demand for airline transportation, i.e. on the order of +2.5% a year over the period 2004-2050, which works out to a 350% increase through 2050. The strong economic growth will lead to an increased freight traffic volume (with a 1% annual increase in flows between 2002 and 2050). The energy assessment relative to this scenario is the least favourable of the four. The major gains experienced in transportation flows will be associated with an **1**1% jump in total liquid fuel consumption for transportation uses.
The **Scenario 4 - "Inward-looking European governance and regionalization"** is characterised by a strong demographic evolution and a moderate economic growth (by 1.5% a year), intensive development of trade within the European zone and high energy costs. The passenger flows over short and medium distances will slow considerably. Given the rise in automobile operating costs coupled with a drop in travel speeds, the modal share attributed to public transit will edge up from 8 to 10%. The long-distance flows will double by 2050, despite the extremely high jump in energy prices. A significant rise in airline ticket prices (in direct correlation with oil prices - $120 to 180 a barrel, including the carbon tax) will determine the smallest annual growth in airline traffic (+1.1% over the study period), at 2050. With Europe's industrial base moving towards regional specialization favouring economic development at the local level, this scenario will foster employment while limiting growth.

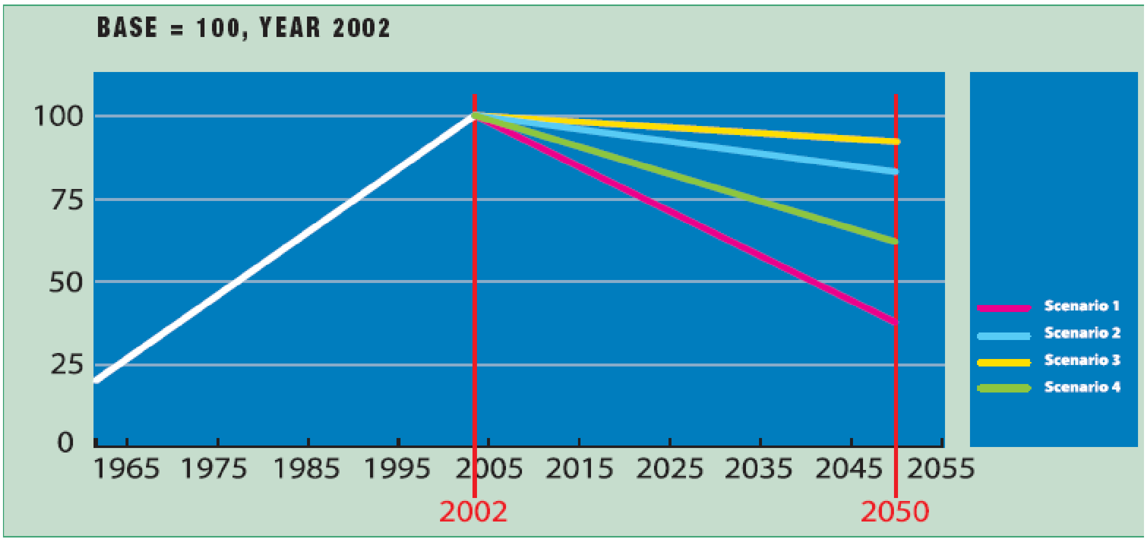
In comparison with Scenarios 1 and 3, national transportation volumes will experience stronger growth, even though total flow will remain within a moderate range. Given the high price of oil ($180 a barrel, with the carbon tax) and poorer energy performance than in Scenario 1, the per-km cost of running a vehicle will increase by more than 50%**.** The long-term view associated with this set of input data will resemble that of the first scenario, with a total consumption of liquid fuels used in the transportation sector dropping slightly (to 47 million eto vs. 52 at present) and a market share of 30% for biofuel.

In terms of carbon emissions, Greenhouse gas emissions amounted to 163 million tons of CO_2 in 2002 (including international bunkers, as opposed to 24 million in 1960, of which 14 million were accounted for in non-road modes: coal- and diesel-powered locomotives, etc.).
Scenarios 1 and 4 exhibit greater energy efficiency, albeit with highly-divergent energy prices, which reflects discrepancies in the extent to which alternative energies have been developed. Scenarios 2 and 3 will lead to very minimal drops in CO_2 emissions, due to a lack of "clean" alternative energies available (continued heavy reliance upon coal), which in Scenario 3 gets worsened as a result of the strong expansion in traffic volumes.

Reversing the trend (as visualized by a peak on the graph) corresponds to a plateau that may last a good ten years, with small variations in emissions. Higher CO_2 emissions will have already started to subside for the previous several years, with the rise in traffic volumes being lower and partially compensated by annual per-vehicle consumption savings.

The figure below summarises the above conclusions.

SUMMARY IN THE EVOLUTION OF CO_2 EMISSIONS



C.6 Other remarks

Strengths:

Interesting analysis of the key socio-economic transport drivers and their impacts on demand.

Weaknesses:

The scenarios are national-based (France)

D Roads toward a low carbon future: Reducing CO2 emissions from passenger vehicles in the global road transportation system

McKinsey & Company , 2009
Roads toward a low carbon future: Reducing CO_2 emissions from passenger vehicles in the global road transportation system
New York City : McKinsey & Company, 2009

D.1 Scenario Summary

The background of the study is the increasing focus on carbon dioxide emissions from passenger vehicles, due to the fact that these vehicles are a highly visible source of greenhouse gases and are projected to grow up to 2030 and forward.

D.2 Context

The objective of the study is to address the following questions:

- Will the reduction of CO_2 emissions from the sector force the produces to scale back production, closing factories and loss jobs ?
- Will the consumers be forced to drive smaller vehicles or even sacrifice the use of personal automotive transportation ?
- Or, on the other hand, it will be possible to curb emissions and to supply new fuel-efficient vehicles and new products, spurring new development ?

The report, produced by the Automotive & Assembly Practice and Climate Change Special Initiative of the McKinsey Company, addresses these issues providing facts base to measure abatement potential and incremental resource costs (cost abatement curves) of a series of key measures (25) to reduce CO_2 emissions. It is worthwhile to note that resource costs reflect the incremental costs of an abatement measure compared to the no-action baseline. Resource costs include investment and operating costs (no transaction, communication and information costs are included), while benefits include savings from the measure.

The abatement scenarios envisaged have been analysed with reference to two reference points: projected future automotive sector emissions (assuming no action is taken to reduce emissions) and 2006 emissions figures.

D.3 Scope

Serving this propose, three types of scenarios have been designed:

1. Hybrid and electric technologies
2. Mixture of hybrid, electric and internal combustion technologies
3. Internal combustion technologies

The scenarios provide abatement cost curves for four regions, North America, Europe (including Russia), China and Japan.

The vehicles involved are passenger vehicles, i.e. cars and light-duty vehicles up to 3.5 metric tons.

The above scenarios share the same assumptions for abatement, with reference to the following measures: bio-fuel, traffic flow, a shift to public transportation and eco-driving, but they differ in the rate and time over which particular technologies penetrate the global vehicle fleet, leading to different penetration level in 2030.

D.4 Wider assumptions

The wider assumptions behind the scenarios are the following:

- Optimized Internal combustion technology scenario (ICE): this scenarios assumes no internal (significant) global penetration of electric or hybrid vehicles
- Mixed technology scenario: this scenario assumes a more balanced mix of technological solutions, including optimized internal combustion engines and electric vehicles.
- Hybrid and electric technology: this scenario represents a relatively aggressive scenario, assuming a rapid transition toward a world of electricity-based propulsion systems. The remaining internal combustion powered vehicles are optimized for grater carbon efficiency. This scenario relies on the availability of low carbon sources of electricity

The prospect at 2030 of fleet composition (shares of new vehicles by fuel type) in the three scenarios is the following:

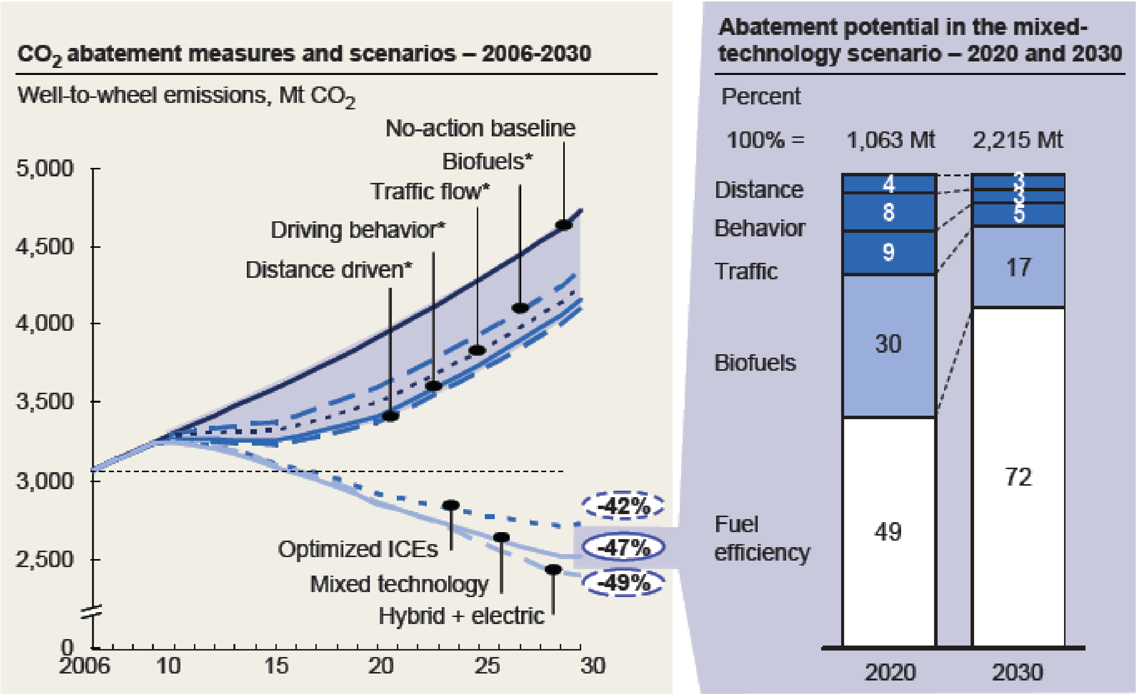
Scenarios	2010	2020	2030
Optimized Internal combustion technologies (ICE)			
-Optimized ICE	100	99	99
- Hybrid		1	1
-Plug-in-hybrid			
-Electric			
Mixed technologies			
-Optimized ICE	100	84	58
- Hybrid		10	23
-Plug-in-hybrid		5	16
-Electric			3
Hybrid + electric			
-Optimized ICE	100	75	40
- Hybrid		18	28
-Plug-in-hybrid		2	24
-Electric			8

D.5 Technical details

It is important to stress that the electrification of the vehicle fleet will pay an increasing role in reducing carbon emissions in the medium and long term. In the most aggressive case, the hypothetical electrification of the global fleet by 2030 would likely to reduce well-to-wheel carbon emissions by 81% to the no-action baseline. This scenario assumes the carbon intensity of electricity generation in 2030 would be 250 tonnes per gigawatt-hour: a challenging but feasible scenario Furthermore, a technical breakthrough reducing battery system costs and development of an infrastructure that supports vehicle charging on a mass scale would likely to occur.

D.6 Results

The following figures summarises the results for the above scenarios



* Emissions reductions for biofuels, traffic flow, driving behavior and distance driven based on mixed-technology scenario.
Source: McKinsey analysis

The following results can be stressed:

Optimized Internal combustion technology scenario (ICE)

- 42% reduction relative to the baseline, 11% reduction relative to 2006.
- Average well to wheel emissions drop to 170grams in 2030.
- Assumes automakers optimize fuel efficiency of vehicles powered by ICE, with little meaningful penetration of hybrid or electric vehicles

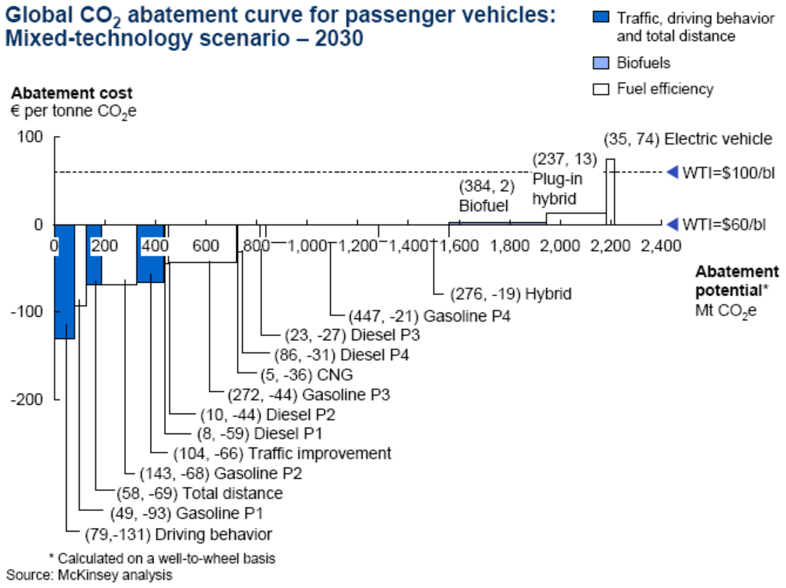
Mixed technologies

- 47% reduction relative to the baseline, 18% reduction relative to 2006.
- Well to wheel emissions decline of 150grams in 2030.
- A more mixed balance of vehicles powered by ICE, hybrids and electric vehicles is assumed.

Hybrid + electric scenario

- A 49% reduction in emissions relative to baseline, 22% reduction relative to 2006.
- Well to wheel emissions decline from 270grams in 2006 to 130grams in 2030 per kilometer travelled.
- Almost 60% of the abatement costs depends on the emissions reduction dependent on low carbon sources of electricity

In terms of the most efficient abatement cost curves, the measures relate to the mixed-technologies scenario (the most likely ones, according to the authors), show that second-generation bio fuels, driving behaviour and traffic flow measures would be highly cost effective, as showed in the figure below.



D.7 Other remarks

Strengths:

Highly relevant for addressing CO_2 emissions strategies: being focussed on passenger vehicle

Weaknesses:

The time reference scenarios stops at 2030. Lack of information in the assumptions differentiating the outcome by regional areas and the assessment of benefit

E Shell Energy Scenarios to 2050

Shell, 2008
Shell Energy Scenarios to 2050
The Hague : Shell International BV, 2008

E.1 Scenario Summary

The background of the assessment is the recognition that the global energy system stands at the nexus of some of the deepest dilemmas of our times: the development dilemma – prosperity versus poverty; the trust dilemma – globalisation versus security; and the industrialisation dilemma – growth versus the environment. Two scenarios have been designed against this background, addressing the future of energy supply and demand, to describe alternative ways it may develop.

E.2 Context

The context behind the two scenarios concerns with the future of energy supply and demand, developing two scenarios that describe alternative ways it may develop. In the first scenario – called **Scramble** – policymakers pay little attention to more efficient energy use until supplies are tight. Likewise, greenhouse gas emissions are not seriously addressed until there are major climate shocks. In the second scenario – **Blueprints** – growing local actions begin to address the challenges of economic development, energy security and environmental pollution. A price is applied to a critical mass of emissions giving a huge stimulus to the development of clean energy technologies, such as carbon dioxide capture and storage, and energy efficiency measures. The result is far lower carbon dioxide emissions.

E.3 Scope

The scenarios have been developed at world level by the Royal Dutch Shell Company staff, with the help of external experts. The scenarios show the carbon emissions (Blueprint scenario) for the following regions:

- Sub Sub-Saharan Africa
- Middle East & N. Africa
- Latin America
- Asia & Oceania - Developing
- Asia & Oceania - Developed
- North America
- Europe

Other results include the final energy consumption by sector and the primary energy supply by source to 2050.

E.4 Wider assumptions

The authors stresses that the two scenarios are both challenging outlooks. Neither are ideal worlds, yet both are feasible and though prices and technology will drive some of these transitions, political and social choices will be critical. An overview of trends and characteristics of the main drivers in the two scenarios is provided in the following table.

	Drivers	Scramble scenario	Blueprints scenario
	Choice	Mandates	Market driven but with incentives

Demand	Prices	Externalities not included	Externalities included
	Efficiency technology	Mandates	Economic incentives & standards
	Efficiency behaviour	Necessity	Designed in
Resources	Oil & Gas	Constrained growth	Long plateau
	Coal	Flight into coal	Coal not wanted unless clean
	Nuclear	Modest uptake	Continued growth
	Electric renewables	Sequential-wind, solar	Incentivise early stage technologies
	Biomass	Strong growth	Complements alternative fuel mix
Technology	Innovation	Strongly guarded	Extensively shared
	Implementation	National docking points	International flipping points
	Mobility	Hybrids & downsizing	Hybrids & electrification
	Power	Efficiency	Carbon capture & storage
	IT	Supply optimization	Demand load management systems
Environment	Land Use	Energy vs food principle	Sustainable principle
	Pollution	Important locally	Important
	Climate/Biodiversity	Background global concern	Prominent local & global concern
	Water	Energy production & climate change impact	Factored into development frameworks

E.5 Technical details

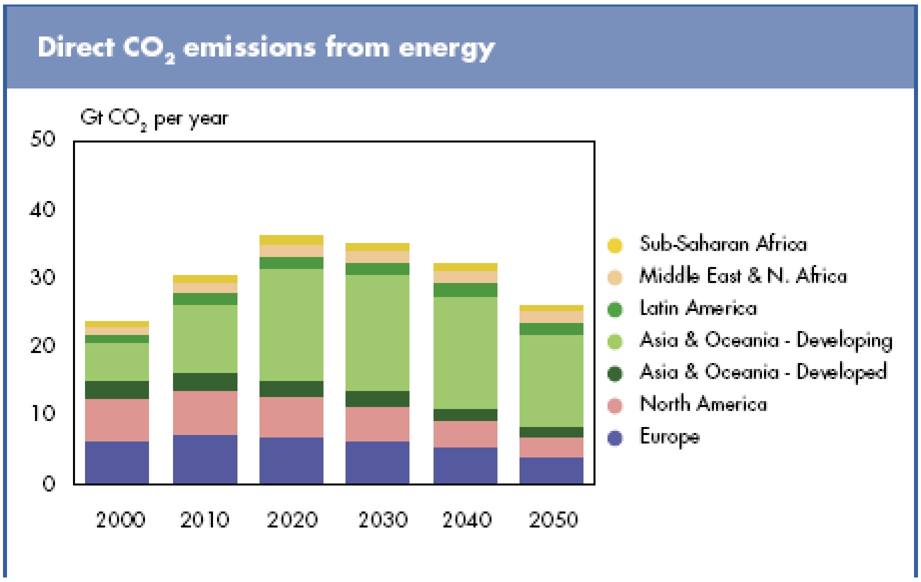
World population growth is one the most important background driver. World population has more than doubled since 1950 and is set to increase by 40% by 2050. History has shown that as people become richer they use more energy. Population and GDP will grow strongly in non-OECD countries and China and India are just starting their journey on the energy ladder.

In the **Scramble scenario** political and market forces favour the development of **c**oal as a widely available, low-cost energy option. Partly in response to public pressures for “energy independence,” and partly because coal provides a local source of employment, government policies in several of the largest economies encourage this indigenous resource. Between 2000 and 2025, the global coal industry doubles in size, and by 2050 it is two and a half times at large. Biomass represents around 15% of primary energy by 2050. Biofuels become a significant part of this, in particular helping to diversify the supply of transport fuel. But with accelerating demand, fossil fuels remain an important part of the energy mix.

In the **Blueprints scenario**, one of the key revolutionary transitions is that economic growth no longer mainly relies on an increase in the use of fossil fuels. By 2050, over 60% of electricity is generated by non-fossil sources. It is increasingly a world of electrons rather than molecules. Electric vehicles are becoming the norm in the transport sector because of their attractiveness to consumers and cost-effectiveness once governments have supported the build-up to mass production. Power generation from renewable energy sources is growing rapidly, while utilities that still rely on coal and gas are required to implement strict carbon abatement technologies. In the developed world, almost 90% of all coal-fired and gas-fired power stations in the OECD and 50% in the non-OECD world have been equipped with carbon dioxide capture and storage technologies by 2050.

E.6 Results

The following graph shows the results of the CO_2 emissions arising from the Blueprint scenario. It is the resulting outcome of a strong commitment after the Kyoto Protocol expires in 2012. Consistent U.S. policy support for technology investment and deployment pays dividends in providing tangible breakthroughs for effective change. More reliable energy statistics and better informed market analysis allow carbon-trading futures markets to reflect clearer long-term price signals. Because of these frameworks, markets can anticipate tightness in CO_2 emission allocations and plan for them.



E.7 Other remarks

Strengths:

Convincing storyline of the two scenarios

Weaknesses:

No BAU scenario is provided. The impacts of the transport sector have not been examined in details.

F Backcasting approach for sustainable mobility

EC, 2008
Apollonia Miola (JRC)
Backcasting approach for sustainable mobility
Luxembourg: Office for Official Publications of the European Communities, 2008

F.1 Scenario Summary

This report summarises the results of an exploratory research on "Back casting approach for sustainability planning in the transport sector". The aim of this research is the identification of main elements of a methodology to develop back casting scenarios for policy of sustainable mobility. The report consists of two sections.
The first part analyses the most common future methods. It examines the applications of back casting approach in a sustainability context and identifies main steps of a back casting exercise to achieve a sustainable transport system.
In the second section, a back casting exercise to define an EU sustainable transport system is developed to give a practical example of this method and to define some policy packages to achieve an EU sustainable mobility.

F.2 Context

This vision applies through a literature review a back casting approach finalized to achieve a sustainable mobility toward a relevant cutting of CO_2 emissions from EU transport sector by 2050. The study is carried out by The Joint Research Centre, Institute for Environment and Sustainability. Following the OECD EST guidelines (OECD, 2002a) the main steps of this exercise will consist of:

- Definition of a long term vision of a desirable transport future that is sustainable for the environment (in our analysis abatement of CO_2 emissions) and that provides benefits of access and mobility;
- Assessment of long term-trends considering all aspects of transport activity;
- Identification of packages of measures and instruments for reaching the targets.

Following this approach, the main transport drivers have been analysed to identify their main trends to 2050 and to define the space of efficient transport policy measures. Finally, the back casting scenarios to 2050 are developed and policy strategies are designed.
The main drivers of transport demand considered are the following: Demographic trends; Economic trends (i.e. GDP and sectorial production trends; World oil prices, the tourism sector); Technology progress, for which the main trends at 2030 have been identified.

Three scenarios have been designed:

- The Baseline to 2050
- The technological vision (back casting)
- The behavioural vision (back casting)

F.3 Scope

The scenarios are at EU 27 level (no country assessment is provided). Time horizon is up to 2050. Transport modes considered are road, rail and aviation (domestic).

F.4 Wider assumptions

- Demographic trends is one of the factors that influences transport demand in terms of its composition by person types, with considerable variation in trip making and trip distances between persons by age, sex, economic position, car availability and income.
- The main trends of passenger and freight transport highlight the positive relationship between transport, on one hand, and economic activity, employment and welfare on the other. That emphasizes the “derived nature” of travel demand that implies that increase in economic growth leads to greater demand for transport services.
- Concerning oil prices, transport is the one sector of the economy where substitution with other fuels has been negligible. Consumer responses to changes in fuel prices are often measured through elasticity. According with OECD the price elasticity of fuel demand is fairly low, meaning that prices have no big impact on demand.
- According to OECD estimations, tourism contributes up to 5.3% of global anthropogenic greenhouse gas emissions**,** with transport accounting for 90% of this. Travel for tourism purpose is expected to grow significantly to 2030 with international tourism growing by over 4% per year accompanied by increasing environmental pressures. The OECD has recently explored the relationship between tourism and transport. Most tourism travel is made by car. However, tourism travel is driven by the growth in availability of inexpensive air transport.
- Concerning the fuel option to 2050, the IPCC in the 4th Assessment Report on climate change policies has estimated a potential for bio fuels from agricultural crops and wastes to replace 5% to 10% of road transport fuel by 2030 being competitive with oil.
- On the technological side, the promising options are the following: light weight material, whereby OECD estimate that a weight reduction is technically possible, but only 5 to 10 % may be practical by 2015 and 11-16% by 2025 at reasonable costs. Technologies to reduce the energy requirements of on board equipment such as air conditioners. For these technologies has been estimated a maximum potentiality of conventional technology of 3 to 5 % by 2025. Improvements in internal combustion engine technologies, including engine technology potential in the short term (by 2015) with regard to 2-steo valve lift; continuous valve lift; Gasoline direct Injection, Friction reduction. Cam-less valve actuation are estimated very promising in term of technology potential in mid term (by 2030).

To 2050, the **baseline scenario** assumes as reference the Baseline Reference Scenario performed by European Commission to estimate Energy and transport trends to 2030. This Baseline Reference scenario presents a projection on how it would be like in 2030 if currently existing policies were maintained and target achieved (namely, the legislation in place up to 2006 and implemented in the Member States or likely to be implemented before 2010. The volume of transportation of passengers is projected to increase at a rate of 1.4% per years between 2005 and 2030 while the volume of freight transport is projected to increase by 1.7% per year during the same period. At the same time it is estimated a gradual decoupling of transportation activity from GDP growth. Road transport continue dominating passenger and freight transport even if the share of road transportation of passengers is projected to decline (79.7% of total activity in 2030 down from 84% in 2005) and road freight transport activity is projected to increase (+1.8% pa in 2005-2030).

The **technological vision** to 2050 relies on high expectation on new technology to deliver the solution to meet long-term CO_2 targets. In short term, although technology could theoretically provide the required reduction in CO_2, this would be a difficult and expensive. The technological vision is based on the assumption of a full development of technologies which exist today and are likely to become commercially available in the years to achieve the CO_2 reduction target. The full penetration of new fuel options and more efficient energy technology are supported by the assumption of high GDP growth in presence of high oil price. No assumption on decreasing travel demand and on change in transport users behaviour (car ownership, shift to public transport, et cetera) have been done. Policy interventions are to support technology. Key policy instruments are the fuel
economy standards, which stimulate the use of technology to improve fuel economy, and regulation of fuel mix. Additionally, a central role have policy support to research and development and using taxation to enable the switch to fuels with low carbon content.

The **behavioural vision** is based on the assumption that a reduction in greenhouse gas emissions is considered equivalent to wealth generation and compensates the loss of wealth related to a travel behaviour change. The policy strategies coherent with this vision pay particular attention to the complexity of travel behaviour which involves, at the same time, the location of activities and housing, several social practices and relations and transport network and supply. In this scenario the behavioural change is supported by demand side policies (by economic tools and soft measures such as information program) and integrated sustainable land use and transport plans. The technology change gives a marginal contribution to meet the target with vehicle categories and fuel options having the lowest unit impact. This is supported by a taxation policy and pricing incentives to use cleaner technologies. Taxation and pricing scheme are also preferable tools to influence land use plans to locations that generate multi modal solutions.

The table below shows other assumptions behind the two visions:

	Technological vision	**Behavioral vision**
Population change	**9%**	**9%**
Economic growth (GDP)	**3.5%**	**2%**
World oil Price	**160$ a barrel**	**200$ a barrel**

Furthermore, a common assumption of both visions is the elimination of the unsustainable subsidies that are pervasive in transport sector6

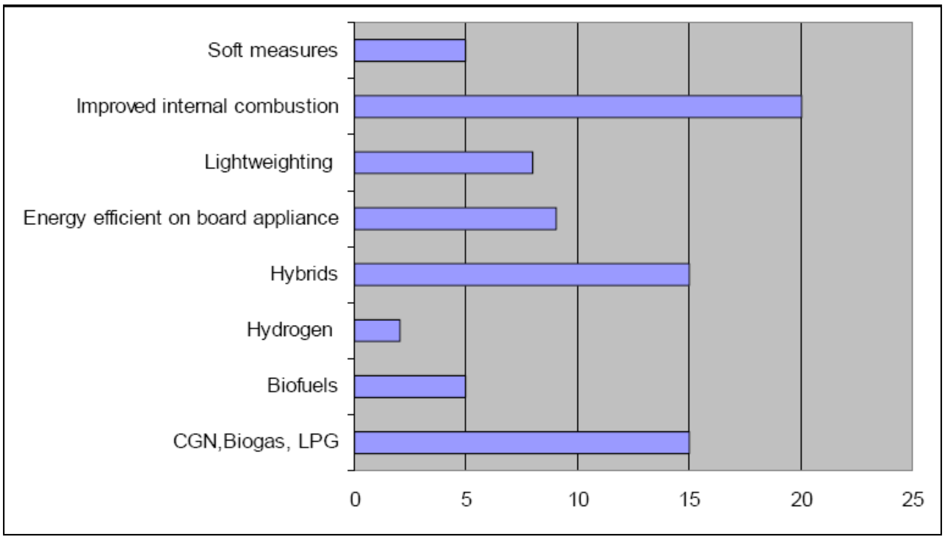
F.5 Results

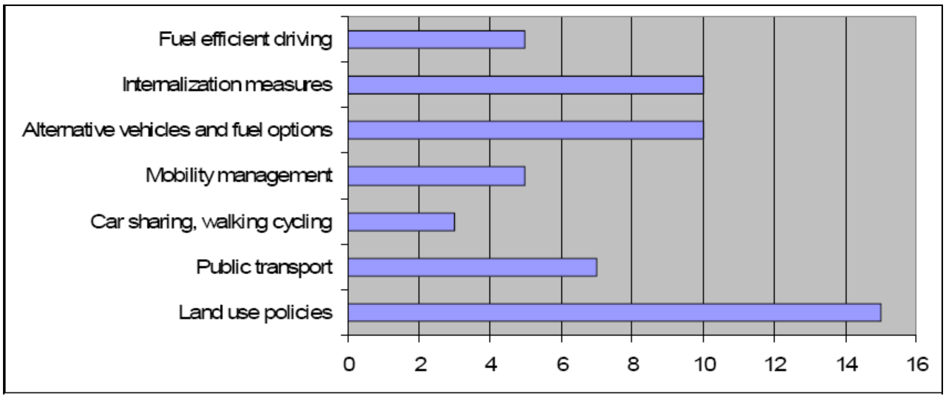
In terms of CO_2 emissions (Million tonnes of Carbon (MtC), the baseline reference to 2050 is the following:

End user Category	**1990**	**2000**	**2010**	**2020**	**2030**	**2050**
Road transport	695	825	905	980	1002	1018
Rail	29	29	27	27	21	20
Domestic Aviation	86	134	179	206	237	244
Inland navigation	21	16	16	17	17	17
Total	**810**	**988**	**1110**	**1213**	**1260**	**1299**

The table shows that road transport continue dominating transport emissions.

Concerning the back-casting visions, the share of the contribution of the measures to meet the target of cutting CO_2 emissions by 50% in 2050 (in the transport sector) is showed in the next figures:





According to the technological vision, the improved internal combustion measures and new fuels provide about 50% of the contribution. Concerning the behavioural vision, land use policies provide the most important contribution.

F.6 Other remarks

Strengths:

The back casting approach provides usful insights in terms of the assessment of policy packages

Weaknesses:

Transport modes do not include maritime and international aviation, sectors that are projected to increase emissions in the long-term

G Climate Change 2007: Synthesis Report

IPCC, 2007
Pachauri, R.K. and Reisinger, A. (Eds.)
Climate Change 2007: Synthesis Report : Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change
Geneva : Intergovernmental Panel on Climate Change (IPCC), 2007

G.1 Scenario Summary

The study is based on the assessment carried out by the three Working Groups (WGs) of the Intergovernmental Panel on Climate Change (IPCC). It provides an integrated view of climate change as the final part of the IPCC's Fourth Assessment Report (AR4).

The topics of the study are the following: Topic 1 summarises observed changes in climate and their effects on natural and human systems, regardless of their causes. Topic 2 assesses the causes of the observed changes. Topic 3 presents projections of future climate change and related impacts under different scenarios, while Topic 4 discusses adaptation and mitigation options over the next few decades and their interactions with sustainable development. Topic 5 assesses the relationship between adaptation and mitigation on a more conceptual basis and takes a longer-term perspective. Topic 6 summarises the major robust findings and remaining key uncertainties in this assessment.

G.2 Context

In such a context, six illustrative SRES scenarios have been designed. The SRES scenarios are grouped into four scenario families (A1, A2, B1 and B2) that explore alternative development pathways, covering a wide range of demographic, economic and technological driving forces and resulting GHG emissions.

The main characteristics of the scenarios are the following:

The A1 storyline and scenario family describes a future world of very rapid economic growth, low population growth, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building, and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. The A1 scenario family develops into four groups that describe alternative directions of technological change in the energy system.
The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in high population growth. Economic development is primarily regionally oriented and per capita economic growth and technological change are more fragmented and slower than in other storylines. A1 is divided into three groups that describe alternative directions of technological change: fossil intensive (A1FI), non-fossil energy resources (A1T) and a balance across all sources (A1B).
The B1 storyline and scenario family describes a convergent world with the same low population growth as in the A1 storyline, but with rapid changes in economic structures toward a service and information economy, with reductions in material intensity, and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to economic, social, and environmental sustainability, including improved equity, but without additional climate initiatives.
The B2 storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social, and environmental sustainability. It is a world with moderate population growth, intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines. While the scenario is also oriented toward environmental protection and social equity, it focuses on local and regional levels.

The SRES scenarios do not include additional climate policies above current ones. The emissions projections are widely used in the assessments of future climate change, and their underlying assumptions with respect to socio-economic, demographic and technological change serve as inputs to many recent climate change vulnerability and impact assessments.

G.3 Scope

The scenarios are world wide. Time horizon is up to 2100. Specific emissions from transport activities have not been included.

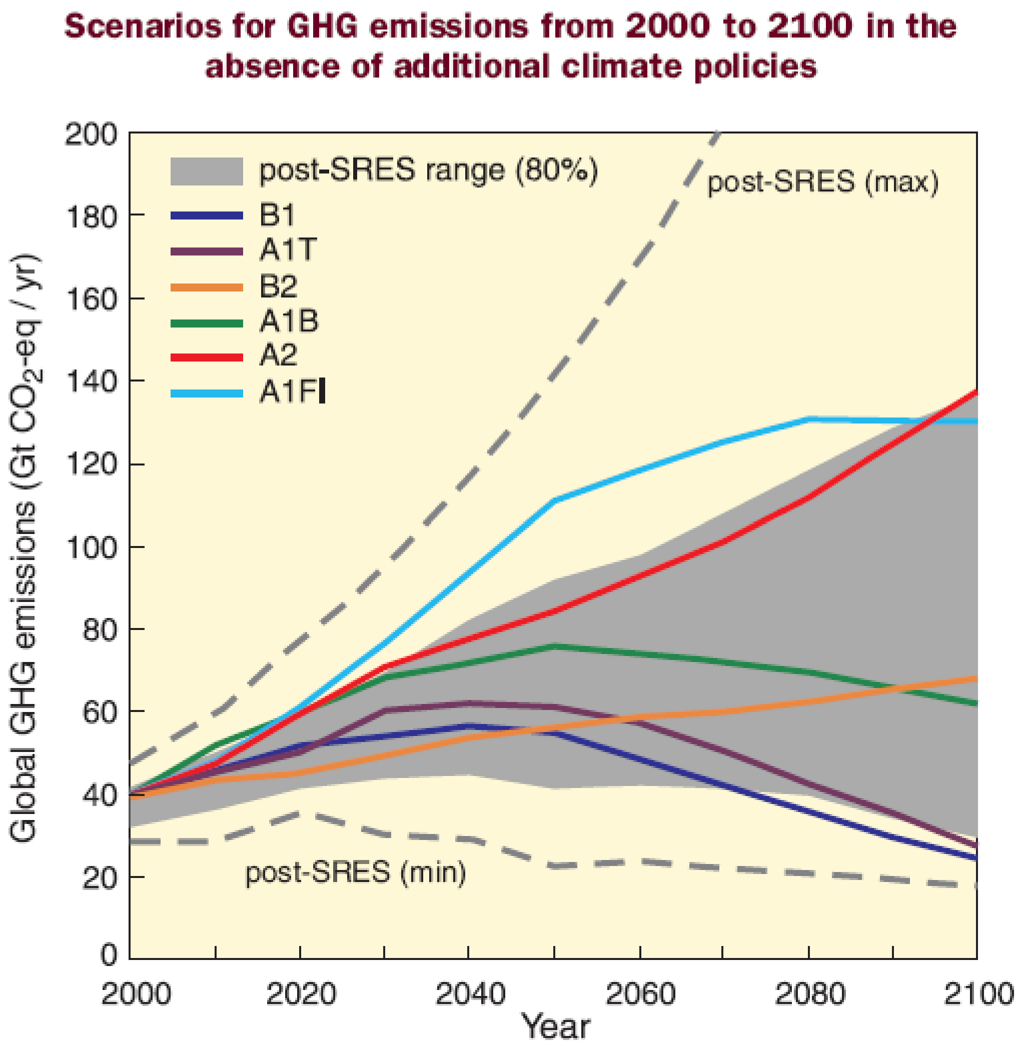
G.4 Wider assumptions

The following table summarises the assumptions beyond the SRES scenarios:

Set	SRES						
Family	A1				A2	B1	B2
Scenario Group	**A1C**	**A1G**	**A1B**	**A1T**	**A2**	**B1**	**B2**
Population growth	low	low	low	low	high	low	medium
GDP growth	very high	very high	very high	very high	medium	high	medium
Energy use	very high	very high	very high	high	high	low	medium
Land- use changes	low-medium	low-medium	low	low	medium/high	high	medium
Resource availability[d]	high	high	medium	medium	low	low	medium
Pace and direction of technological	rapid	rapid	rapid	rapid	slow	medium	medium
change favoring	coal	oil & gas	balanced	non-fossils	regional	efficiency & dematerialization	"dynamics as usual"

G.5 Results

The impacts in terms of GHG emissions are the following



The SRES scenarios project an increase of baseline global GHG emissions by a range of 9.7 to 36.7 $GtCO_2$ eq (25 to 90%) between 2000 and 2030. In these scenarios, fossil fuels are projected to maintain their dominant position in the global energy mix to 2030 and beyond. CO_2 emissions from energy use between 2000 and 2030 are projected to grow 40 to 110% over that period. The authors note that studies published since SRES (i.e. post-SRES scenarios) have used lower values for some drivers for emissions, notably population projections. However, for those studies incorporating these new population projections, changes in other drivers, such as economic growth, result in little change in overall emission levels. The authors claim that economic growth projections for Africa, Latin America and the Middle East to 2030 in post-SRES baseline scenarios are lower than in SRES, but this has had only minor effects on global economic growth and overall emissions

G.6 Other remarks

Strengths:

The assessment is carried out according to up-to-date scientific evidences, gathering international experts in the fields

Weaknesses:

No BAU scenario is provided. The contribution of transport emissions to the overall trends is not analysed

H Foresight for Transport: A foresight exercise to help forward thinking in transport and sectoral policy integration

ICCR et al., 2004
ICCR Wien ; Alamo Online ; University of Cardiff ; INRETS Paris
Foresight for Transport: A foresight exercise to help forward thinking in transport and sectoral policy integration
Wien : ICCR, 2004

H.1 Scenario Summary

The FORESIGHT for TRANSPORT project was launched in 2001 under the 'Competitive and Sustainable Growth Programme' (1998-2000) of the European Community with the main objective to organise and run a strategic dialogue in the form of a foresight exercise on the influence of non-transport factors and policy on mobility and transport.

The implementation of the project entailed the organisation of thematic expert panel consultations on the topics of enlargement, environment and energy, information and communication technologies, multilevel governance and time dynamics, a Delphi survey involving 165 experts around Europe as well as the establishment of a meta-database system with information on indicators that can be used to monitor developments in fields of relevance for transport and mobility.

The scenarios for the future were elaborated in five thematic expert panel consultations and validated through a Delphi survey. The strategic dialogue also provided the material for the elaboration of the transport impact pathways. The latter were also submitted to validation through the Delphi survey. A second (smaller) round of expert consultations refined these impact pathways using the feedback of the Delphi survey.

H.2 Context

The FORESIGHT for TRANSPORT project had three strategic objectives:

1. To set up and run a strategic dialogue with the participation of experts from different disciplines as well as representatives of business and industry, policy-makers and interest organisations that identifies the critical external factors that influence mobility and transport policy and specifies the contextual scenario conditions within which these developments take place.
2. To use the input from the strategic dialogue to specify the impact of external developments and associated trends on mobility and the transport system and elaborate the concept of the transport impact pathway.
3. To develop a procedure for monitoring external developments and their impact on transport in the future.

The study has been carried out by ICCR (A), Adelphi Research (DE), University of Cardiff (UK), NESTEAR (F) and Alamo (ES)

H.3 Scope

Scenarios represent visions / images of the future and courses of development organised in a systematic and consistent way.

There are different types of scenarios depending on the objectives and perspective of the scenario writer(s) and their use. In summarising the relevant literature Ling (2000) draws a useful distinction between the 'precautionary model', the 'visionary model' and the 'learning model' of scenario writing.

Scenarios developed under the 'precautionary model' approach have as a goal to envisage a negative future state resulting from a certain course of events in order to demonstrate or make explicit the negative consequences of present actions and elaborate ways to counteract these. Under the 'visionary model', a preferred future is outlined and then strategies for reaching this future are outlined using the so-called back-casting approach (cf. Banister and Stead, 2001). Both the 'precautionary' and 'visionary' models of scenario writing are normative in orientation. In consultation and/or assessment exercises further insights can be gained by comparing different normative scenarios arrived at by different stakeholders or institutions.
Scenarios developed under the 'learning model' follow the extrapolative approach whereby between two and four desirable and/or plausible futures are described based on a systematic analysis of current trends.
The FORESIGHT for TRANSPORT project relied primarily on the 'learning model' approach of scenario-writing. Participants were provided with a summary of the issues produced through brainstorming in their respective sessions and asked to select those that would in their opinion be most suitable for describing (a) the present situation and (b) possible futures.

Respondents were presented with the statement and then asked to estimate separately for the short-term (2004-2009), medium-term (2010-2019) and long-term (2020+) whether they thought the trend would persist in the same way or be higher or lower.

The geographical scope is the European area, without further specification.

H.4 Wider assumptions

The global reference scenario was specified with reference to the thematic scenarios elaborated by the experts of the first consultation round and validated through the FORESIGHT Delphi survey. Respondents to the Delphi survey were asked to assess these thematic scenarios in terms of likelihood and desirability. The reference scenario represents the cluster of those thematic scenarios corresponding to specific policy domains which were assessed as most likely.

Demography	Ageing of population
Attitudes	Individualism prevails
Social developments	Laissez-faire social policy, increase of inequality
Institutional arrangements	Re-assertion of nation state (variable geometry) or Federal State Europe
Technology	Low level of innovation; incremental changes
Political	Elite closure and technocracy under federalism
Environment	Weak sustainability (technology / economy)
Economy	Stabilisation at a fairly low level of growth
Transport	Increasing transport demand and motorisation; weak internalization of external costs; congestion and environmental problems persist.

H.5 Technical details

In FORESIGHT for TRANSPORT trend extrapolation was used for indicators selected as important for monitoring future developments with regard to either transport or external developments.

H.6 Results

Eight dimensions have been interested by the experts forecasts:

1. Demographics
2. Attitudes
3. Social developments
4. Institutional arrangements
5. Science and technology
6. Politics
7. Environment
8. Economy

Concerning the environment, the anticipated development of CO^2 emission transport share A trend-break with regard to the share of transport in CO2 emissions is anticipated after 2020, while NOx emissions (figure 27) will continue to decrease as in the recent past. These assessments hold true for both the EU-15 and the New Members States.

H.7 Other remarks

Strengths:

Interesting insights toward pros and cons of the use of Delphi surveys with experts for forecasting exercises

Weaknesses:

The scenarios are qualitative. No calculation has been carried out

I Mobility scenarios toward a post-carbon society

MCRIT, 2009
Mobility scenarios toward a post-carbon society : TRANSvisions Task 2 "Quantitative Scenarios
Barcelona : MCRIT, 2009

I.1 Scenario Summary

The background of the study is to provide technical support to a debate on transport scenarios with a 20- and 40- year horizon, to be reached, inter alia, by collecting and analysing information on transport long-term scenario forecasting, by developing long-term transport scenarios including modelling work and case studies, and by suggesting long-term objectives for the European transport policies.

I.2 Context

The key objective of the TRANSvisions study is to provide a foresight exercise based on the following uncertainties for the future of European transport from now until 2050:

- Will the strong correlation which has been observed between passenger and freight transport on one side, and GDP and GDP per capita growth on the other side, continue? (For which segments of the market? In which regions of Europe?)
- Will transport growth be decoupled from environmental impacts? (By which modes, or trip purposes? Using which technologies?)
- Which transport policies could be the most effective in reducing CO2 emissions generated by transport activities, facilitating a sustainable and more stable economic development?

I.3 Scope

Serving this propose, three types of scenarios have been designed:

1. Predictive scenarios, i.e. 'what will happen' up to 2030, using the TRANS-TOOLS output[10]. These scenarios include the following:
   - Baseline (continuation of existing trends) to 2030.
   - High growth and stable population.
   - Low growth and declining population.
2. Exploratory scenarios, i.e. 'what could happen' up to 2050, calibrated with TRANS - TOOLS results for 2005, 2020 and 2030 for three scenarios (Baseline, High Growth and Low Growth) and validated against other forecast studies for 2020 and 2050. In this context, the following exploring scenarios have been considered:
   The organisational path ("Moving Together" or Decoupled Mobility scenario);
   The behavioural path ("Moving Less" or Reduced Mobility scenario);
   The technological path ("Moving Alone" or Induced Mobility scenario);
   The mandatory path ("Stop Moving" or Constrained Mobility scenario).

3. Normative scenarios, showing how can 2020 and 2050 CO2 emission reduction targets be reached according to the following characteristics.
   - The organisational path backwards: increasing the utilisation of the vehicles in the transport system, and making citizens take more responsibility for climate change and environment: 2050 - 2020
   - The technological path backwards: implying that a considerable effort is done in the RTD field, leading to a fast technological development.2050 - 2020

[10] TRANS-TOOLS is a transport model including socio-economic and logistic models developed and updated to 2005 by DTU in the context of the TEN CONNECT study, issued by DG TREN (2009)

- The baseline backwards: most effective policy packages (e.g. speed limits, land use, pricing measures, road investments) 2050 ‑ 2020

As a general rule, all the above scenarios relate to EU 27 inter and intra NUTS 3 (road, passenger cars and trucks, and rail passenger) and NUTS 2 (freight) level. Neighbouring countries include Eastern European countries. Northern Africa is not included.

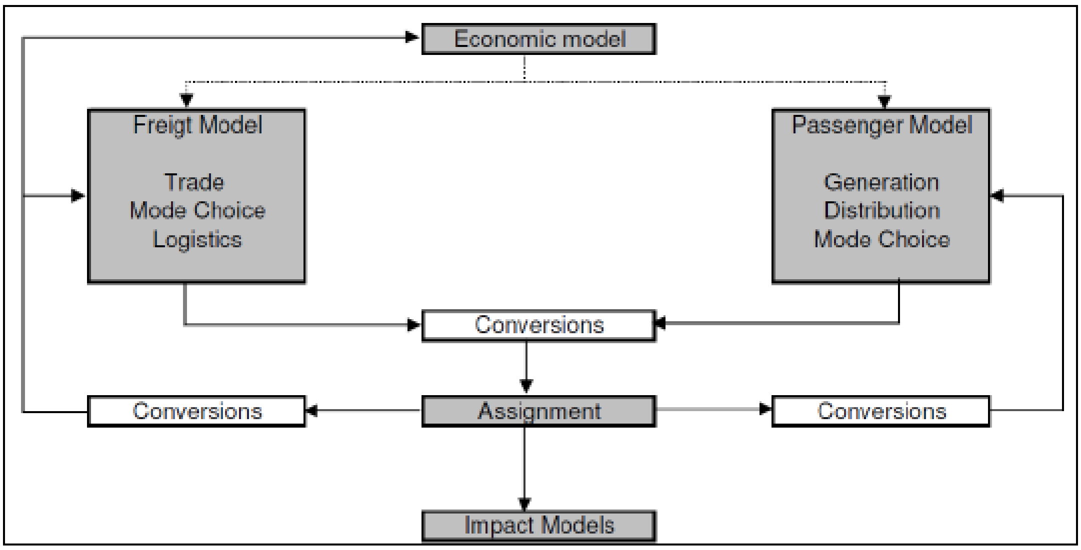
- In the case of aviation and maritime, trips with origin or destination outside the EU ‑ 27 are not modelled (EU ‑ 27 trip segments included, in non ‑ direct flights).
- Freight trips with origin or destination outside the EU ‑ 27 are included as if they had their origin or destination in a European port (except for neighbouring countries).
- Air freight is not included.
- No explicit modelling of ferries when used as road and rail links.

I.4 Wider assumptions

The baseline predicting and exploratory assumptions are essentially a prolongation of existing trends. The assumptions can be subdivided into socio ‑ economic trends, transport cost assumptions and network assumptions. The socio ‑ economic trends depict the expected development in a number of basic parameters like population, employment, income growth, etc. These are based as much as possible on available sources like EUROSTAT population projections and economic development data from DG ECFIN, and other sources. The transport cost assumptions cover both ongoing policy initiatives as well as possible development paths for variables in the TRANS-TOOLS model reflecting the scenario assumptions. The network assumptions address the infrastructural development.

I.5 Technical details

The type of models used are basically the TRANS ‑ TOOLS model and the Metamodel approach, calibrating each other in order to obtain consistent results. The former is the state ‑ of ‑ the ‑ practice, transport ‑ oriented ‑ step forecast model available at EU level, which includes specific socioeconomic modules based on complementary modelling paradigms, as showed in the figure below.



The latter, is a software application based on Microsoft Excel and Microsoft Access, following a simple mathematic structure. Transport demand is in fact generated for passengers and freight from socio ‑ demographic and macroeconomic indicators aggregated at European level, then, transport demand is distributed by local, regional and long‐distance and by macro‐zones (North and Centre, East and South), and overseas, by trip purposes and modal division. The resulting passenger transport demand is adjusted considering a fixed income per person allocated to transport, and the freight transport demand in relation to economic growth. Through occupancy and load factor ratios in all modes the demand in terms of vehicles, trains, used by vehicle fleets is taken into account. Emission factors of each technology influence the final result of directly and indirectly generated emissions, according to the mix of energy sources defined in each scenario. This main formulation is complemented by independent modules dealing with passenger and freight traffic, in order to further regionalise transport demand according to different types of trips (such as short‐distance, cross‐border, between capital cities, etc.). In such a way, the level of CO2 emissions in the 2050 scenario are forecasted, and trace back the path combining trends and policies leading to this result.

I.6 Results

The following table summarises the results in the baseline and the TRANSvisions exploratory scenarios (2005-2050):

	2005	Baseline	Decoupled mobility	Reduced mobility	Induced mobility	Constrained mobility
Total population	491,999,371	486,218,917	545,598,557	431,090,794	545,740,798	488,212,797
Annual population growth	-	-0.03%	0.23%	-0.29%	0.23%	-0.02%
Total GDP B€[13]	9,853,475	24,359,922	29,051,343	17,091,935	31,717,532	17,868,710
Annual GDP growth	-	2.0%	2.4%	1.2%	2.6%	1.3%
EU-27 intra-NUTS3 passenger traffic						
Road passenger 1000Mpax-km	3,433	5,048	5,185	3,863	9,888	5,411
Rail passenger 1000Mpax-km	215	318	1,164	423	303	596
EU-27 inter-NUTS3 traffic						
Road passenger 1000Mpax-km	1,491	1,921	2,200	1,921	3,460	1,945
Rail passenger 1000Mpax-km	161	526	864	449	858	696
Air passenger 1000Mpax-km	320	315	345	295	1,262	633
Extra-EU-27 passenger traffic						
Air passenger in EU airspace 1000Mpax-km	68	151	148	63	170	62
Air passenger outside EU airspace 1000Mpax-km	651	1,664	1,777	634	2,207	617
EU-27 intra-NUTS2 freight traffic						
Road freight 1000M/ton-km	395	465	494	264	872	340
EU-27 inter-NUTS2 traffic						
Road freight 1000M/ton-km	1,316	2,347	2,599	1,290	5,843	2,189
Rail freight 1000M/ton-km	447	1,222	1,471	698	1,868	780
Maritime freight traffic						
Sea freight EU-27 and NCT 1000M/ton-km[14]	1,525	2,949	3,476	1,861	4,733	1,485
Sea freight outside EU-27 and NCT 1000M/ton-km	52,022	129,104	154,835	91,121	168,837	94,520
Annual EU-27 intra-NUTS3 passenger traffic variation						
Road passenger	-	0.9%	0.9%	0.3%	2.4%	1.0%
Rail passenger	-	0.9%	3.8%	1.5%	0.8%	2.3%
Annual EU-27 inter-NUTS3 traffic variation						
Road passenger	-	0.6%	0.9%	0.6%	1.9%	0.6%
Rail passenger	-	2.7%	3.8%	2.3%	3.8%	3.3%
Air passenger	-	0.0%	0.2%	-0.2%	3.1%	1.5%
Annual Extra-EU-27 passenger traffic variation						
Extra-EU-27 air passenger	-	2.1%	2.2%	-0.1%	2.7%	-0.1%
Annual EU-27 intra-NUTS2 freight traffic variation						
Road freight	-	0.4%	0.5%	-0.9%	1.8%	-0.3%
Annual EU-27 inter-NUTS2 traffic variation						
Road freight	-	1.3%	1.5%	0.0%	3.4%	1.1%
Rail freight	-	2.3%	2.7%	1.0%	3.2%	1.2%
Annual Maritime freight traffic variation						
Sea freight EU-27 and NCT	-	1.5%	1.8%	0.4%	2.5%	-0.1%

	2005	Baseline	Decoupled mobility	Reduced mobility	Induced mobility	Constrained mobility
Sea freight outside EU-27 and NCT	-	2.0%	2.5%	1.3%	2.7%	1.3%
EU-27 traffic						
Passenger 1000Mpax-km	5,619	8,129	9,759	6,950	15,771	9,281
Freight 1000M/ton-km	3,683	6,983	8,039	4,114	13,316	4,794
Annual EU-27 traffic variation						
Passenger	-	0.8%	1.2%	0.5%	2.3%	1.1%
Freight	-	1.4%	1.7%	0.2%	2.9%	0.6%
Passenger Rail share for long distance inland traffic	9.7%	21.5%	28.2%	18.9%	19.9%	26.3%
Freight Rail share for long distance inland traffic	25.3%	34.2%	36.1%	35.1%	24.2%	26.3%
Energy consumed by road oil-based transport inMToe	362	291	130	182	99	246
Average taxes on oil in €/litre	0.61	1.40	1.60	1.80	1.20	2.00
Taxes on oil by transport in M€	184,216	338,933	173,406	273,525	98,612	409,789
% Renewable in primary electricity generation	15	25	40	20	35	40
% Nuclear in primary electricity generation	35	40	35	35	50	40
Car CO_2 emission ratio in gCO_2/km	196	119	98	137	59	129
Truck CO_2 emission ratio in gCO_2/km	966	889	483	676	290	638
% non-fossil fuel vehicles	0%	21.8%	54.5%	35.0%	70.0%	31.0%
Energy consumption reduction per km in rails	-	40%	46%	33%	51%	34%
Energy consumption reduction per km in ships	-	49%	57%	40%	62%	42%
Energy consumption reduction per km in airplanes	-	62%	71%	50%	78%	53%
Car occupancy in urban trips pax/veh	1.40	1.50	1.60	2.10	1.10	1.60
Car occupancy in interurban trips pax/veh	2.0	2.10	2.50	2.50	1.50	2.00
Truck load in ton/veh	7.0	7.78	8.75	10.00	8.24	7,78
Direct CO_2 emission variation 2005-2020	-	-23%	-61%	-61%	-56%	-36%
Indirect CO_2 emission variation 2005-2020	-	77%	206%	95%	369%	94%
Total CO_2 emission variation 2005-2020	-	-21%	-55%	-57%	-46%	-33%
Direct cumulative CO_2 emissions 2005-2020	-	44,892	34,213	32,007	36,805	46,677
Indirect cumulative CO_2 emissions 2005-2020	-	1,714	2,372	1,893	2,719	2,132
Total cumulative CO_2 emissions 2005-2020	-	46,606	36,585	33,900	39,524	48,809

I.7 Other remarks

Strengths:

The exercise is based on the development of TRANS-TOOLS, a common standard model in the recent EC transport policy evaluation.

Weaknesses:

The prolongation to 2050 from the 2030 forecasts (Metamodel approach) is based on a purely statistical calibration of parameters. A more consistent validation would have required several runs of TRANS-TOOLS

J VLEEM 2 : final report

VLEEM Consortium, 2005
ENERDATA -- ECN --VERBUNDPLAN -- IPP -- STE Juelich -- Universiteit Utrecht
VLEEM (Very Long Term Energy-Environment Model) 2 ; final report
Brussels : European Commissions, Directorate-General for Research, 2005

J.1 Scenario Summary

The background of the scenarios is represented by the understanding The 21th century will have to face tremendous challenges related to the climate change, the depletion of fossil fuel resources and the management of nuclear wastes. The development of the technologies necessary to face these challenges and the long reinvestment cycles especially for buildings, power generation and energy intensive manufacturing, require to consider all these issues over the whole century, in the broad context of sustainability.

J.2 Context

The VLEEM project has been designed to address these challenges, combining two methodological innovations which are imposed by the very long time-frame:

- an innovative approach of the very long term future, particularly suitable for RTD strategies elaboration in the context of sustainability: the back-casting approach;
- a re-foundation of the energy-environment modelling structures, in order to properly assess very long term modification of social and cultural preferences and technology evolution dynamics in relation to them.

The study has been carried out by a consortium of ENERDATA, ECN, Max-Planck-Institut, Univesiteit Utrecht, STE Juelich, Verbundplan.

J.3 Scope

Three “visions” have been elaborated:

1.HiPop with high demography in 2100 with near 12 billion people, corresponds to a very slow demographic transition process towards a low fertility rate in developing countries where religious and cultural determinism remain very strong and change only very slowly: south Asia, conservative Muslim countries, sub-Saharan Africa. It corresponds also to a relative success of nativity policies in the industrialised countries where the demographic transition is now completed.
2. MidPop as middle storyline with a stabilization of the world population around 8 billion people (UN projection for 2050), which means that the demographic transition will be completed in most parts of the world by 2050, and that governments succeed in convincing educated women to get slightly more than two children in their life. This scenario also means that the transition to universal education and democracy has also been achieved everywhere, and that collective values, inspired by regional value systems, are stronger than the development of individualism.
3. LowPop storyline with little growth, same or less population than today (+/- 6 billion). The demographic transition will be completed by 2050, with a peak population around 8 billions at that time. After that, the trend towards a decreasing fertility rate continues in developing countries, and nativity policies, if any, fail to convince women to get more children almost everywhere. This scenario means that individual values take the lead over collective values.

The above scenarios are developed at world level, distinguishing the following regions:

- Europe (EU 25)

- CIS (Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyz Rep., Moldova, Russia, Tajikistan, Turkmenistan, Ukraine, Uzbekistan)
- North America (USA and Canada)
- Latin America (Central America (including Mexico), South America and Caribbean
- Japan, Pacific (Japan, Australia, New Zealand, Papua New Guinea, Fiji, Kiribati, Samoa (Western), Solomon Islands, Tonga, Vanuatu)
- Africa, Middle West
- Asia (China, South Asia, Other Asia)

Time horizon of the scenarios is 2100, compared to 2000.

The transport sector is taken into account as an aggregated, estimating the energy services in MJ/per cap necessary for passenger, freight and socio-cultural functions for the Mid-pop scenario.

J.4 Wider assumptions

Passenger mobility: In the Mid-Pop scenario, the model simulates a convergence of the mobility around the world in a range 12 000-20 000 km/cap per year because of the average speed increase. North America remains apart of the other regions with a very high mobility pattern: 29 000 km/cap per year. Household equipment in private vehicles is assumed to come soon to saturation in the industrialised countries of today, and to reach saturation before the turn of the century in most developing countries of today, because of the growth in affluence. The share of private vehicles in persons mobility is calculated to decrease in industrialised countries of today, down to 41% in the USA and 69% in Europe (75% in 2000)**.** In the developing world of today, it is calculated to increase first (up to 85% in Latine America in 2100, 69% in 2000 for example) and, for some more advanced regions to start decreasing before the turn of the century.
Freight mobility. In the Mid-Pop scenario, there is a clear distinction among three groups of regions:

- A first group corresponding to regions with only one country of a very big size (USA, CIS, China), where the geographical dimension drives the freight mobility to high levels when the economic production develop (12 000 to 19 000 ton-km/cap per year in 2100)
- A second group corresponding to regions either with one big dominant country or highly economically integrated, for which the model calculates a convergence around 8 000 ton-km/cap per year (South Asia, Europe, Latine America)
- A third group with the other countries, where the freight mobility is calculated to remain close or below 5 000 ton-km/cap per year.

The share of road in freight mobility ranges from 10% to 91% among the world regions in 2000: this reflects huge differences in the historical development of the infrastructures, from countries like the USA, the CIS or China, where rail infrastructures have been widely developed to cope with the transportation of natural resources over long distances, and countries with almost no rail infrastructures, where everything has to be moved by road. In 2100, the model calculates a much reduced gap between the different world regions (33% to 96%), in particular because of the development of fast modes imposed by the speed constraint.
Concerning the end-use energy efficiencies, for the period 2000 to 2100, it is projected that energy efficiency can be increased by up to two thirds for passenger transport by car and by air, by up to somewhat more than half for public transportation on roads and by 15-35% for passenger transport by rail (different values for high speed, medium speed and local rail). For freight, energy efficiency can be increased by somewhat more than half for freight transportation by road, by 10-25% for rail and by around one third for freight transport via waterways and overseas.
The largest fuel efficiency gains will be achieved by speeding up the transition either to fuel cells or to electric vehicles. In both cases the well-to-wheel fuel efficiency in primary energy terms will depend on the efficiency of producing the combustible fuels (e.g. hydrogen). Development and progress in the field of fuel cell systems indicate that there are a couple of unresolved technical problems, making it rather unlikely that fuel cells will be introduced to the market on a broad scale in the next 15 to 20 years. Concerning hydrogen, the report assumes the path to the hydrogen development in Europe as sketched out by the European Commission DG Research in 2003 “Hydrogen Energy and Fuel Cells A vision of our future” in which by 2040 fuel cells become the dominant technology in transport, in distributed power generation, and in micro-applications and by 2050 there is the H2 use in aviation.

J.5 Technical details

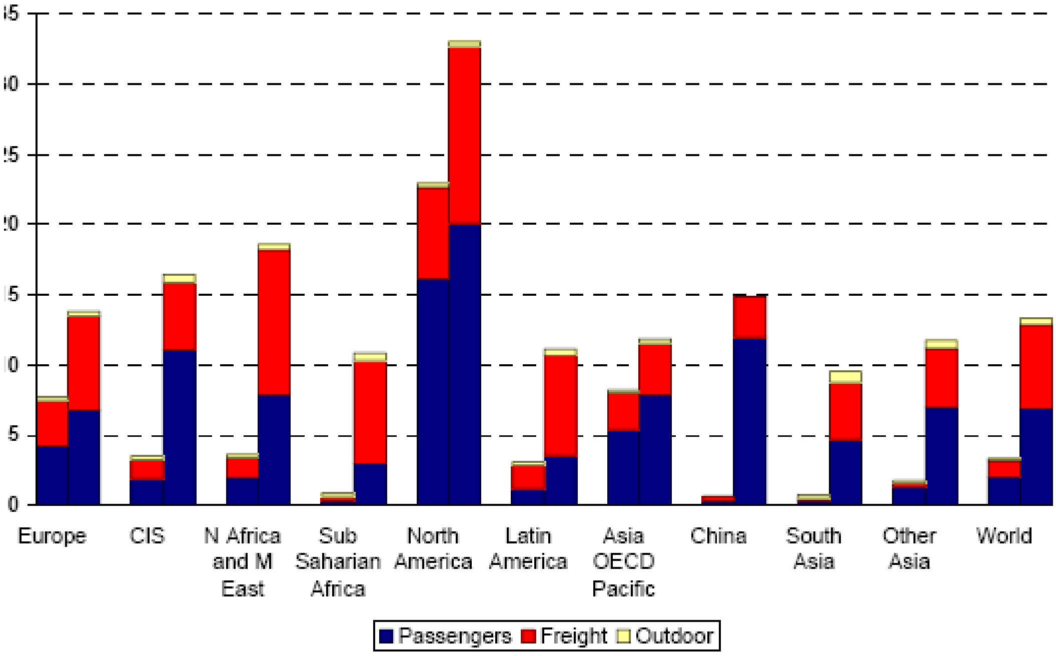
The back-casting approach is strongly connected with the concept of sustainable development or more generally with a concept of a desirable future. The whole task is to find trajectories able to convert the existing system into a desired future system.
In general terms, a back-casting approach involve three steps:

- first, design the desired future, in our case the sustainable energy systems according to
- the criteria reviewed above
- second, identify and assess the necessary changes as compared to the current situation
- to reach the desired future
- third, assess the problems and conditions to implement the change.

In VLEEM, only the technology and the organisation of the energy system (including endues of energy) are supposed to enter in the field of the debates and decisions about sustainability, not the population growth or the peoples life styles and behaviours. Therefore, back casting is only strictly applied to the whole chain from the primary energy carriers down to the energy services, the later being taken for granted. The needs of energy services are still assessed with a forecasting philosophy, through general but simple causal relations with demography, wealth and life styles.

J.6 Results

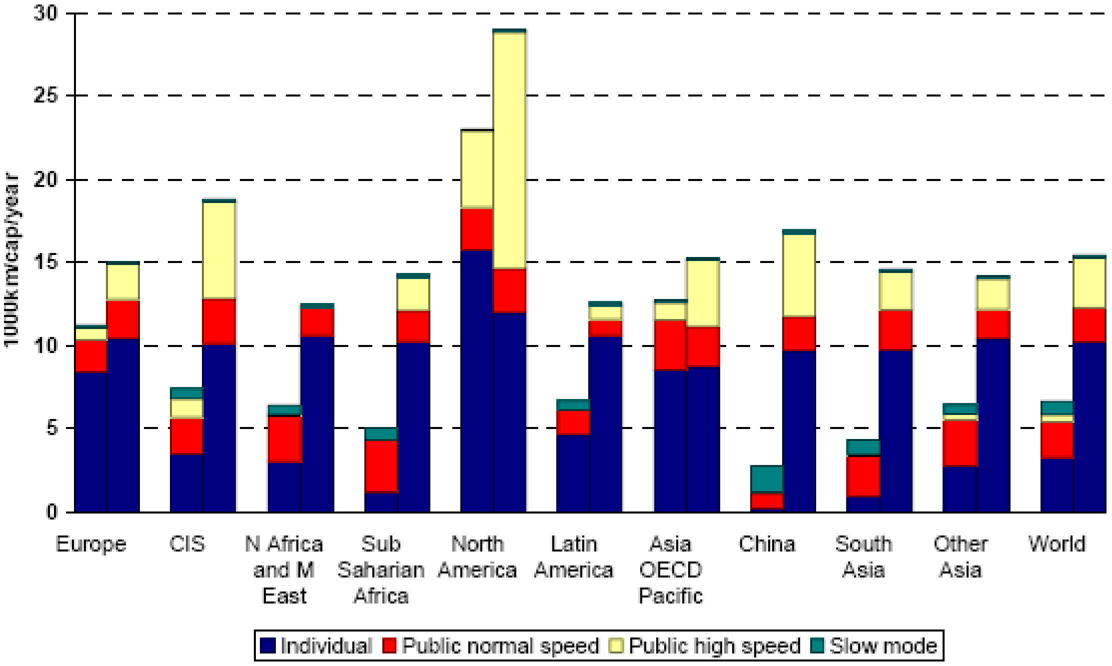
The following table summarises the results of the scenario (Mid-Pop) in terms of energy services for transport (in MJ/per cap):



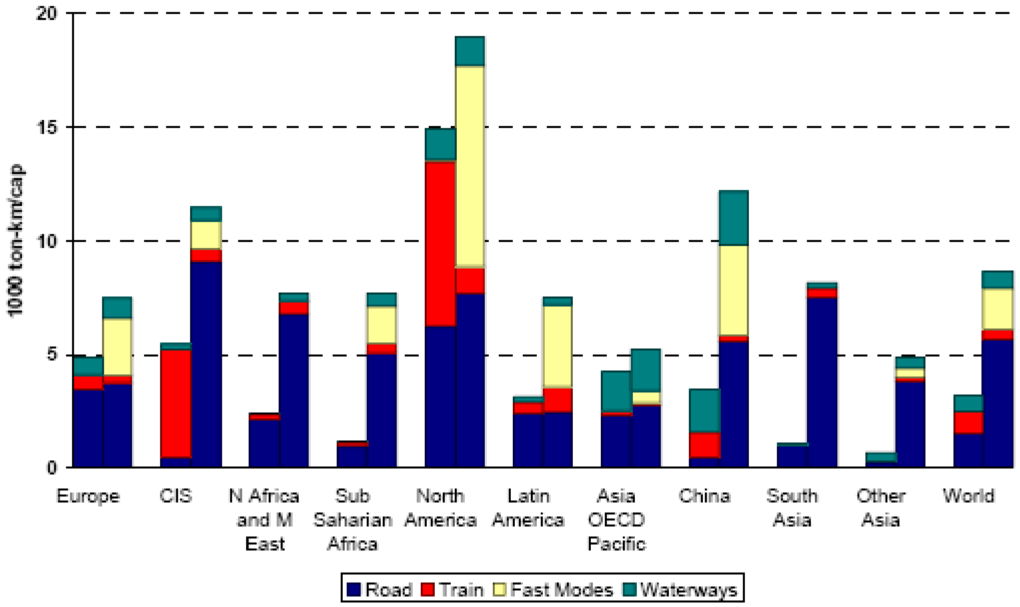
Summing up, transportation services (passenger and freight) are projected to more than quintuple from 2000 to 2100. Most of the growth will occur in developing countries which a projected increase of transportation services by a factor of 13 while transportation in industrialized countries is expected to increase by 2 between 2000 and 2100.

The following graphs show the long term transport demand for passenger and freight transport.

Passenger



Freight



J.7 Other remarks

Strengths:

Long term vision of transport energy need.

Weaknesses:

CO_2 emissions are not calculated. Assumptions behind the scenario and their relationship with results are not developed.

K European Climate Change Policy Beyond 2012

WEC, 2009
European Climate Change Policy Beyond 2012
London : World Energy Council (WEC), 2009

K.1 Scenario Summary

The background of the study is the increasing scientific consensus that human activities do trigger climate changes. Actual forecasts predict temperature increases that are likely to be beyond the adaptation potential of ecosystems. In order to improve the knowledge of effectiveness of policies and measures to curd carbon emissions, the study provides some general background and statistical material about the GHG emissions, particularly CO2 emissions. The political framework is also described described, briefly examining the different levels: global, regional and national. Some important abatement technologies and their technical and economic potential are analysed.

K.2 Context

The WEC report "European Climate Change Policy Beyond 2012" provides an overview of the EU climate and energy policy package and, more specifically, the further developments of its emissions trading scheme (EU-ETS). Whereas EU policy covering the period to 2020 has well developed milestones and legislation, the future beyond 2020 is rather nebulous.

K.3 Scope

Serving this propose, several types of scenarios have been analysed:

1. Global Climate Change scenarios, including the IEA's World Energy Outlook 2008 forecasts on the impacts of no climate regulation to the GHG emissions at 2030
2. Climate Friendly Technology scenarios, comparing and evaluating the effectiveness of technologies and practices in terms of climate change mitigation, as in the BLUE Map scenario 2005-2050 from the IEA's ETP Energy Technology Perspective 2008
3. The role of transport in the roadmap to sustainability has been considered in the World Business Council for Sustainable Development to 2050

Time horizons range between 2020-2050, depending on the type of scenario considered. Generally, the geographical scale is aggregated: world or European level. No country disaggregation is available.

K.4 Wider assumptions

Scenarios of global carbon emissions. As stated in the IEA's World Energy Outlook 2008, global energy-related carbon emissions will continue to grow until at least 2030.The Reference Scenario assumes no change to current climate regulations. In addition, the IEA considered two climate-policy scenarios corresponding to long-term stabilisation of GHG concentrations at 550 and 450 parts per million of CO2-equivalent. The 550 Policy Scenarios equates to an increase in global temperature of approximately 3°C, the 450 Policy Scenario to a rise of around 2°C. Unlike the Reference Scenario above, these scenarios assume additional climate protection efforts.
Impacts of technologies. Several technologies have been considered in their reaching a Blue Map scenario on the supply side (half the CO2 emissions of 2005 by the year 2050): Carbon Capture and Storage, Nuclear, Renewables, improving of efficiency of power generation and end use electricity, end use fuel efficiency.
The **role of transport in sustainability scenarios** have been provided by the World Business Council for Sustainable Development to 2050. In particular, projections of CO2 emissions according to

different regulatory regimes have been estimated, with three scenarios for the average emissions of new passenger cars :

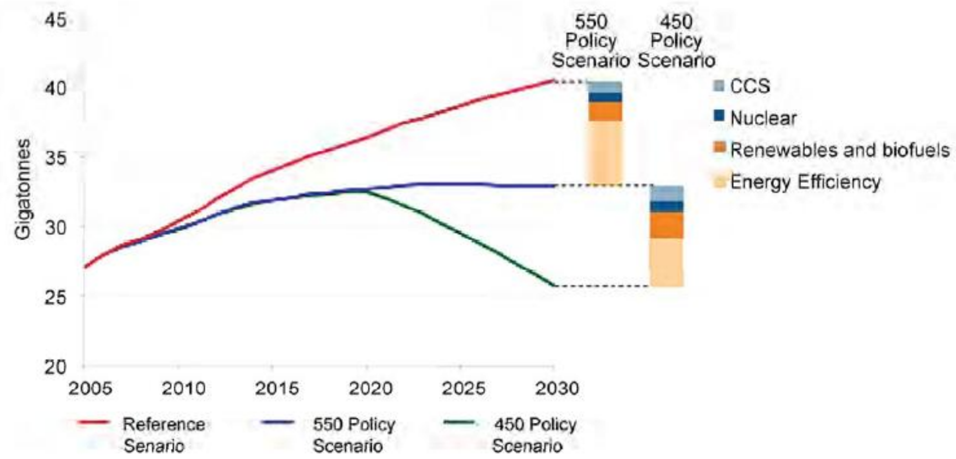
1. Business as usual (as projected by the WBCSD in 2005).
2. Uniform reduction in average emissions at the same rate as 2000-2010.
3. Assuming 95 g/km average in 2020 (EU regulation) and constant percentage reductions in each time period equivalent to that between 2000 and 2020.

K.5 Technical details

Not provided

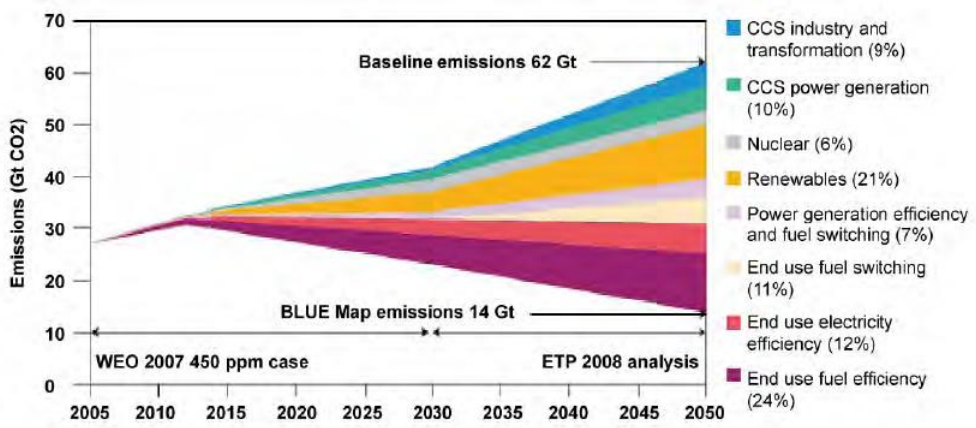
K.6 Results

Scenarios of global carbon emissions (world level)



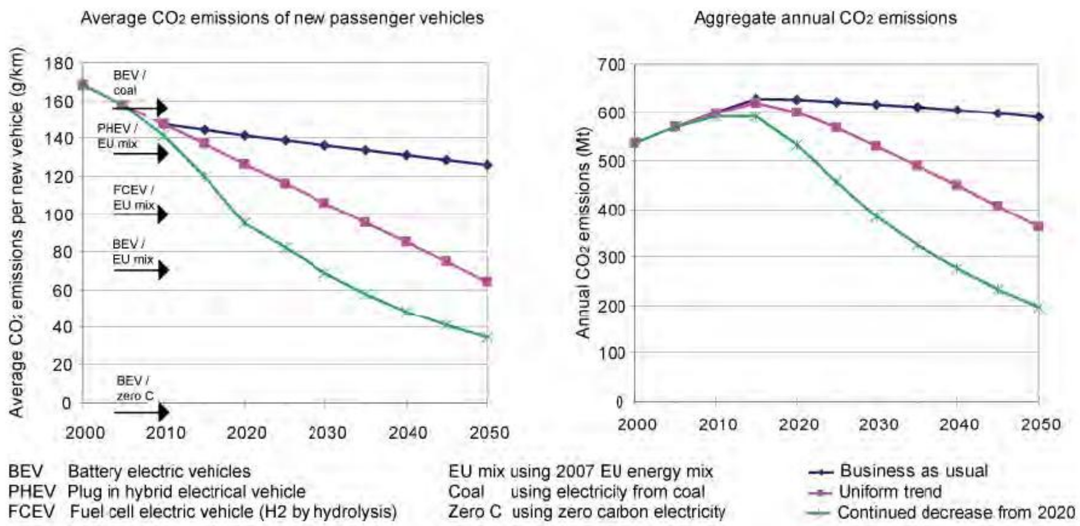
The 550 Policy Scenario involves a flattening of GHG emissions by 2020 and reductions soon after. The 450 Policy Scenario involves much more substantial reductions after 2020 . Even then, emissions overshoot the trajectory needed to meet the 450 ppm CO2-eq target. To reach either of these outcomes, hundreds of millions of households and businesses will need to achieve substantial emissions reductions after 2020. In both scenarios, total emissions are significantly lower in 2030 than in the reference scenario, requiring a drastic change in how we consume energy. This will require innovative policies, an appropriate regulatory framework, the rapid development of a global carbon market and increased investment in energy research, development and demonstration, as stated by the IEA.

Impacts of technologies (world level)



The result shows that there is no one magic bullet technology available to fight climate change; rather, a large portfolio of techniques must be implemented to effectively address the greenhouse effect

The **role of transport in sustainability scenarios**



The results demonstrate that with regulatory ambition equivalent to that in the first 20 years of the century (green line), a substantial penetration of advanced technology vehicles (plug in hybrids, fuel cell, and battery electric) would be necessary by 2030. For the less ambitious reduction scenario (pink line), this penetration is still required by 2040.
The graph also demonstrates that substantial advances in the carbon content of electricity production are needed in order for fuel cell or electric vehicles to reach their CO2 reducing potential.

Aggregate EU CO2 emissions (right hand graph) demonstrate that substantial reductions (over 50% by 2050) are possible in the most ambitious scenario. Again, this result is based on a significant penetration of the market by electric or fuel cell vehicles, with more modest reductions possible with a later introduction of these technologies. It can be concluded that only with substantial progress in advanced technology vehicles can ambitious goals be met.

K.7 Other remarks

Strengths:

Exhaustive comparison of transport and energy scenarios, relevant technologies and policies

Weaknesses:

The study is basically a collection of existing scenarios. No original calculations have been provided.

L World Energy Technology Outlook - 2050 : WETO H2

EC, 2007
World Energy Technology Outlook - 2050 : WETO H2
Luxembourg: Office for Official Publications of the European Communities, 2007

L.1 Scenario Summary

The background of the scenarios is represented by the understanding that the age of cheap energy resources comes to its end, and then a strong political commitment is needed to preserve European competitiveness and to combat climate change. The WETO-H2 report (World Energy Technology Outlook-2050) tries to place the European energy system in a global context. Europe represents today 10% of the world population, 25% of the world GDP and 20% of world energy consumption. Considering the demographic changes and the techno-economic progress made by developing countries, by 2050 these figures will be less than 7%, 15% and 12% respectively.

L.2 Context

The WETO-H2 study has developed a Reference projection of the world energy system to test different scenarios for technology and climate policies in the next half-century; it has a particular focus on the diffusion of hydrogen as a fuel. This Reference projection adopts exogenous forecasts for population and economic growth in the different world regions and it makes consistent assumptions for the availability of fossil energy resources and for the costs and performances of future technologies. It uses a world energy sector simulation model – the POLES model – to describe the development to 2050 of the national and regional energy systems and of their interactions through international energy markets, under constraints on resources and from climate policy.

The research has been carried out by a consortium included the following organisations: Enerdata, the Coordinator, LEPII-EPECNRS (France), the Federal Planning Bureau (Belgium), IPTS (Institute for Prospective Technology Studies, JRC), ECN (Energy research Centre of the Netherlands), University of Sussex (SPRU Energy Research Group, UK) and MEERI (Mineral and Energy Economy Research Institute of Polish Academy and Science).

L.3 Scope

Serving this propose, three types of scenarios have been designed:

4. The Reference projection describes a continuation of existing economic and technological trends, including short-term constraints on the development of oil and gas production and moderate climate policies for which it is assumed that Europe keeps the lead.
5. The Carbon Constraint case reflects a state of the world with moderately ambitious climate targets, aiming at an emission profile that is compatible in the long-term with concentration levels below 550 ppmv for CO_2.
6. The Hydrogen scenario is derived from the carbon constraint case, but also assumes a series of technology breakthroughs that significantly increase the cost-effectiveness of hydrogen technologies, in particular in end-use. The assumptions made on progress for the key hydrogen technologies are deliberately very optimistic.

The above scenarios are developed at world level, distinguishing the following regions:

- Europe (EU 25)
- CIS (Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyz Rep., Moldova, Russia, Tajikistan, Turkmenistan, Ukraine, Uzbekistan)
- North America (USA and Canada)
- Latin America (Central America (including Mexico), South America and Caribbean

- Japan, Pacific (Japan, Australia, New Zealand, Papua New Guinea, Fiji, Kiribati, Samoa (Western), Solomon Islands, Tonga, Vanuatu)
- Africa, Middle West
- Asia

Time horizon of the scenarios is 1990-2001-2010-2020-2030-2050.

The transport sector is taken into account as an aggregated (together Industry and Household, Service and Agriculture), without disaggregation by vehicle type.

L.4 Wider assumptions

The **Baseline scenario** assumptions are the following: the total energy consumption in the world is expected to increase to 22 Gtoe per year in 2050, from the current 10 Gtoe per year. Fossil fuels provide 70% of this total (coal and oil 26% each, natural gas 18%) and non-fossil sources 30%; the non-fossil share is divided almost equally between renewable and nuclear energy. The size of the world economy in 2050 is four times as large as now, but world energy consumption only increases by a factor of 2.2. Conventional oil production levels off after 2025 at around 100 Mbl/d. Non-conventional oils provide the increase in total liquids, to about 125 Mbl/d in 2050. Natural gas shows a similar pattern, with a delay of almost ten years. In Europe, the reference energy consumption trend increases only a little from 1.9 Gtoe / year today to 2.6 Gtoe / year in 2050. In 2050 non-fossil energy sources, nuclear and renewable provide 40% of the primary energy consumption, much above the present 20%.
The **Carbon constraint** scenario assumes that three quarters of power generation is based on nuclear and renewable sources and half of thermal power generation is in plants with CO_2 capture and storage**.** Hydrogen delivers a quantity of energy equivalent to 15% of that delivered by electricity. By 2050**,** half of the total building stock is composed of low energy buildings and a quarter of very low energy buildings. More than half of vehicles are low emission or very low emission vehicles (e.g. electricity or hydrogen powered cars).
The **Hydrogen scenario** assumes in Europe that nuclear energy provides a third of the total energy demand in Europe. Oil, natural gas and renewables each provides roughly 20% and coal 6%. The share of fossil fuels in power generation decreases steadily and significantly. The use of CO_2 capture and storage systems develops strongly; by 2050, more than 50% of thermal electricity production is from plants with CO2 capture and storage. The production of hydrogen increases rapidly after 2030 to reach 120 Mtoe by 2050, or 12% of world production. Hydrogen provides 7% of final energy consumption in Europe, against 3% in the Reference case.
A summary of the socio economic assumptions in Europe is provided in the following table.

	1990	2001	2010	2020	2030	2050	Annual % change 1990/10	2010/30	2030/50
Key Indicators									
Population (Millions)	564	588	599	605	606	586	0.3%	0.1%	-0.2%
GDP (G$95)	8373	10312	12660	15900	19079	25194	2.1%	2.1%	1.4%
Per capita GDP ($95/cap)	14849	17533	21124	26260	31496	43005	1.8%	2.0%	1.6%

L.5 Technical details

All the projections to 2050 have been made with a world energy sector simulation model – the POLES model – that describes the development of the national and regional energy systems, and their interactions through international energy markets, under constraints on resources and climate policies. POLES is a modelling system that provides a tool for the simulation and economic analysis of world energy scenarios under environmental constraints. It is not a General Equilibrium, but a Partial Equilibrium Model, with a dynamic recursive simulation process. From the identification of the drivers and constraints in the energy system, the model allows to describe the pathways for energy development, fuel supply, greenhouse gas emissions, international and end-user prices, from today to 2050.
The approach combines a high degree of detail in the key components of the energy systems and a strong economic consistency, as all changes in these key components are largely determined by relative price changes at sectoral level. The model identifies 46 regions of the world, with 22 energy

demand sectors and about 40 energy technologies – now including generic “very low energy” end-use technologies. Therefore, each scenario can be described as the set of economically consistent transformations of the initial Reference case that is induced by the introduction of policy constraints.
A principal feature of the POLES model is that it estimates international prices for oil, gas and coal, based on an explicit description of the fundamentals of each international market and a detailed representation of the reserve and resource constraints.
The model calculates a single world price; the oil market is described as “one great pool”. It depends in the short-term on variations in the rate of utilisation of capacity in the Gulf
countries and, more importantly, in the medium and long-term on the average Reserve-to-
Production ratio across the world. The price of gas is calculated for each regional market; the price depends on the demand, domestic production and supply capacity in each market. There is some linkage to oil prices in the short-term, but in the long-term, the main driver of price is the variation in the average
Reserve-to-Production ratio of the core suppliers of each main regional market. As this ratio decreases for natural gas as well as for oil, gas prices follow an upward trend that is similar in the long-term to that of oil.
The price of coal is also estimated for each regional market as the average price of the key suppliers on each market, weighted by their market shares. The average price of the key suppliers is derived from variations in mining and operating costs (that are a function of the increase in per capita GDP and of a productivity trend) and from the capital and transport costs (both depending on the simulated production increases, as compared to a "normal" expansion rate of production capacity).

L.6 Results

The following table summarises the results of the scenarios in terms of carbon emissions in Europe:

Baseline

	1990	2001	2010	2020	2030	2050	Annual % change 1990/10	2010/30	2030/50
CO2 Emissions (MtCO2), *of which :*	**4360**	**4367**	**4463**	**4712**	**4534**	**3963**	0.1%	0.1%	-0.7%
Electricity generation	1608	1519	1585	1755	1623	1454	-0.1%	0.1%	-0.5%
Industry	961	765	742	738	716	596	-1.3%	-0.2%	-0.9%
Transport	826	1122	1093	1122	1104	900	1.4%	0.0%	-1.0%
Household, Service, Agriculture	828	800	805	862	868	811	-0.1%	0.4%	-0.3%
CO2 Sequestration (Mt CO2)	0	0	0	9	200	529			5.0%

Carbon constraints

	1990	2001	2010	2020	2030	2050	Annual % change 1990/10	2010/30	2030/50
CO2 Emissions (MtCO2), *of which :*	**4360**	**4367**	**4445**	**3760**	**3278**	**2566**	0.1%	-1.5%	-1.2%
Electricity generation	1608	1519	1586	1100	804	582	-0.1%	-3.3%	-1.6%
Industry	961	765	742	609	552	407	-1.3%	-1.5%	-1.5%
Transport	826	1122	1086	1055	988	742	1.4%	-0.5%	-1.4%
Household, Service, Agriculture	828	800	792	777	731	664	-0.2%	-0.4%	-0.5%
CO2 Sequestration (Mt CO2)	0	0	0	353	609	595			-0.1%

Hydrogen

	1990	2001	2010	2020	2030	2050	Annual % change 1990/10	2010/30	2030/50

CO2 Emissions (MtCO2), *of which :*	**4360**	**4367**	**4475**	**4170**	**3612**	**2841**	0.1%	-1.1%	-1.2%
Electricity generation	1608	1519	1617	1315	856	548	0.0%	-3.1%	-2.2%
Industry	961	765	738	654	580	428	-1.3%	-1.2%	-1.5%
Transport	826	1078	1065	1117	1122	914	1.3%	0.3%	-1.0%
Household, Service, Agriculture	828	800	821	852	826	755	0.0%	0.0%	-0.4%
CO2 Sequestration (Mt CO2)	0	0	0	177	412	498			0.9%

L.7 Other remarks

Strengths:

Overall forecasts of energy consumption, energy supply, electricity generation and carbon emissions (CO_2) at world level and by regions

Weaknesses:

The transport sector is taken into account as an aggregated (together Industry and Household, Service and Agriculture), without disaggregation by vehicle type.

M A sustainable energy system in 2050 : promise or possibility

ECN,2007
M.A. Uyterlinde, J.R.Ybema, R.W. van den Brink, H. Rösler,F.J. Blom
A sustainable energy system in 2050 : Promise or possibility?
Petten : ECN, 2007

M.1 Scenario Summary

In view of the increasing dependence on imports of oil and natural gas by industrialised countries and the prospects of global warming it is imperative to act. In this study a vision is presented for a more sustainable energy system in the year 2050 with the intention of inspiring and guiding research in both the private and public sectors.

M.2 Context

The study was independently produced by the ECN/NRG energy transition think tank. The objective is to inspire and guide European businesses and governments towards a sustainable energy system. It contains a vision on a sustainable energy system for 2050 and a description of the measures needed to achieve it.

M.3 Scope

The study covers European energy use in the sectors: Built environment, Transport, Industry and Electricity generation. Global energy issues are included but the vision only deals with the European situation. segregation of the results is made per country. The outlook year of the vision is 2050. The level of detail differs. On one side the modelling and presented results are very detailed (for instance the fuel distribution of passenger cars) and on others more general (policy options)

M.4 Wider assumptions

For the BAU scenario:
Not a great deal of data is presented for the reference case. The price for CO2 (CO2 tax) is assumed to be €10/tCO2. The following fuel prices were used:

$\$_{2005}$ / barrel (equivalent)	2000	2030	2050
Oil	27	36	39
Gas	17	29	33
Coal	9	11	11

For the VISION scenario:
Part of the results of the vision are in fact assumptions due to the back casting method. Only assumptions that do not directly cover CO2 or energy reductions are stated here.
The annual rate of energy savings is assumed to be 1.5%. Oil production peaks in 2015 and prices increase. The fuel prices used are:

$\$_{2005}$ / barrel (equivalent)	2000	2030	2050

Oil	27	61	97
Gas	19	49	73
Coal	10	18	23

CO2 tax starts at €10 per tonne and rises to €85 per tonne in 2050.

M.5 Technical details

Projection method is backcasting from a vision. The modeling is done with Markal. The database was developed as par of EU project CASCADE MINTS Part 1.

M.6 Results

M.6.1 Business as usual

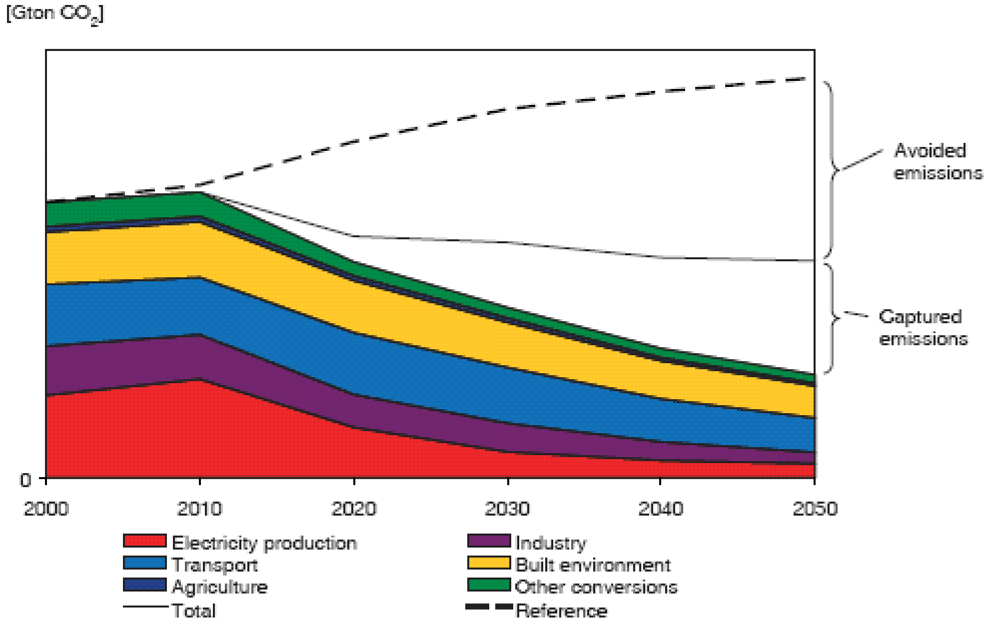
No results of the BAU scenario are reported separate from those of the sustainable energy vision.

M.6.2 Sustainable energy vision

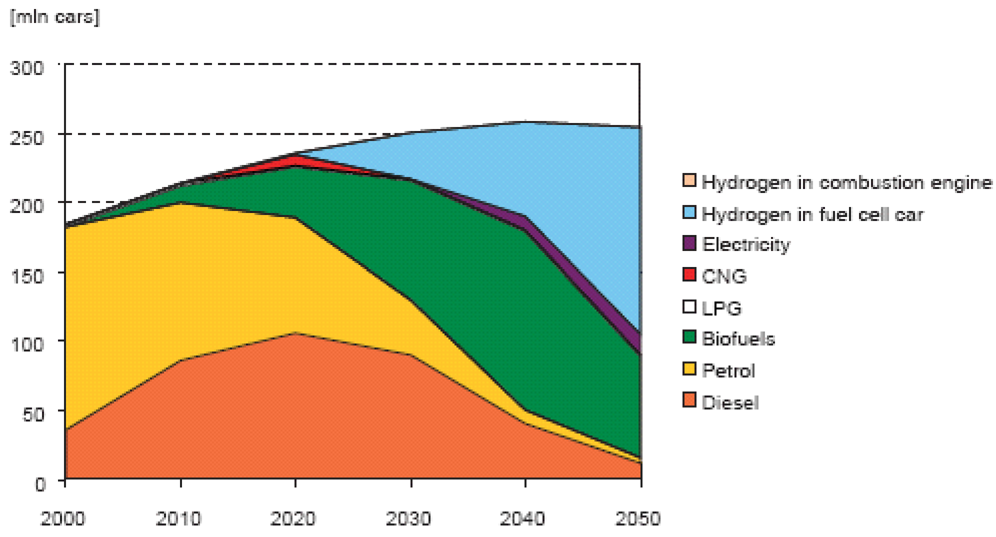
All sectors:
A CO2 reduction of 60% compared to 1990 levels, lies at the basis of the vision scenario. This reduction is distributed between sectors but all sectors achieve at least a 30% reduction by 2050 and a 20% reduction by 2020. In 2050 35% of all energy is renewable (mostly biomass, wind and solar).

Transport sector:
In passenger transport, more use is made of public transport due to road charging and improvement of the public transport systems. No breakthrough in electric vehicles is expected due to difficulties with battery technology but by 2050 50% of all passenger cars are hydrogen powered. The hydrogen needed is mostly produced from coal with CCS (Carbon Capture and Storage)
Freight mostly uses bio-diesel (Fisher Tropsh). Only 30% of all diesel is made from mineral oil. Sea freight and inland water ways shipping also use bio-diesel. Aviation has mainly witched to bio-kerosien.

The following figure shows the CO2 emission reductions of the BAU and the Vision scenario.



The next graph shows the distribution of fuel types in the passenger transport car market.



One concrete policy mentioned is that of getting 100.000 hydrogen vehicles on the road by 2020. Other policies are more general and include:

- Long term CO2 reduction objectives approved and supported by all stakeholders and harmonised with other areas of policy
- Consistent set of policy instruments to help technologies through their development phases without distorting the market
- Strict greenhouse gas emission ceilings and energy consumption standards
- Cooperation between government, businesses and the public
- International cooperation

M.7 Other remarks

Strenghts

- The scenario covers all sectors
- Detailed passenger car fuel segregation

Weaknesses:

- Little details are presented as to a BAU scenario
- Few concrete policies

N Pathways to 2050

WBCSD, 2005
Pathways to 2050 : Energy & climate change
S.l. : World Business Council for Sustainable Development (WBCSD) , 2005

N.1 Scenario Summary

The study shows pathways towards a more sustainable future for all energy sectors. It shows the scale and complexity of the change needed and indicates the level of progress that has to be made by 2050. It also provides a checkpoint (2025) to verify progress and contribute to the sense of urgency

N.2 Context

Composed by the World business council for sustainable development in 2005. It is intended to stimulate dialogue and enhance mutual understanding of the issues of sustainable development. To show the trends and to indicate when changes are needed and give a indication of the potential of certain measures.

N.3 Scope

The study covers all energy sectors and is Global in scale. It projects towards 2050 with an intermediate outlook to 2025. The modelling is general and intended as an indication and to show the scope and scale of the issues presented. detailed and the results are indicative. It does not go into policy instruments.

N.4 Wider assumptions

General assumptions for 2050:

- The population of the earth has stabilised at 9 billion people
- The average GDP in the order of $20.000 per capita

N.5 Technical details

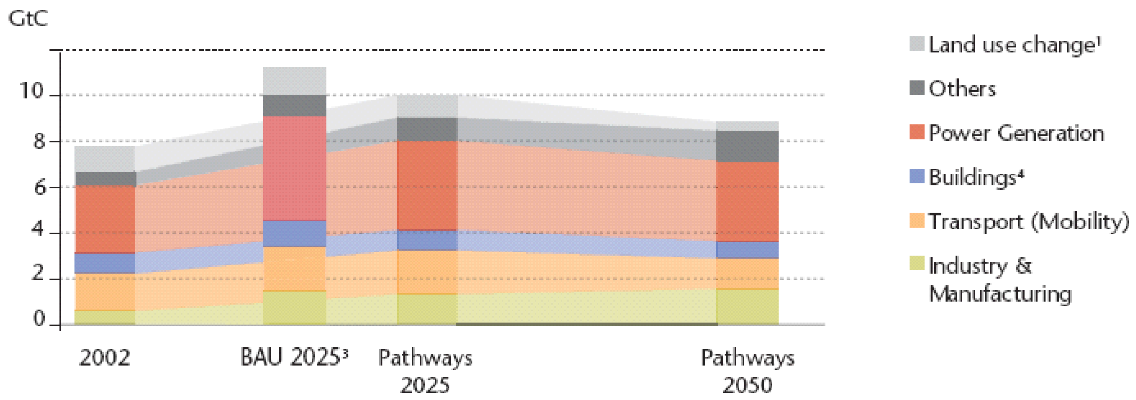
The modelling of the scenario is done by back casting and assessing what needs to be achieved to stabilize the CO2 concentration in the atmosphere at around 550 ppm, which relates to total global emissions of 9 GT (from Facts and trends WBCSD 2004)

N.6 Results

N.6.1 Business as usual

Data is taken form WBCSD 2004 Facts and trends to 2050: energy and climate change. BAU scenarios are taken from IEA World Energy Outlook (IEA 2004) and only contain projections up to 2025

The following figure shows the CO2 emissions in the BAU scenario. No modes are distinguished.



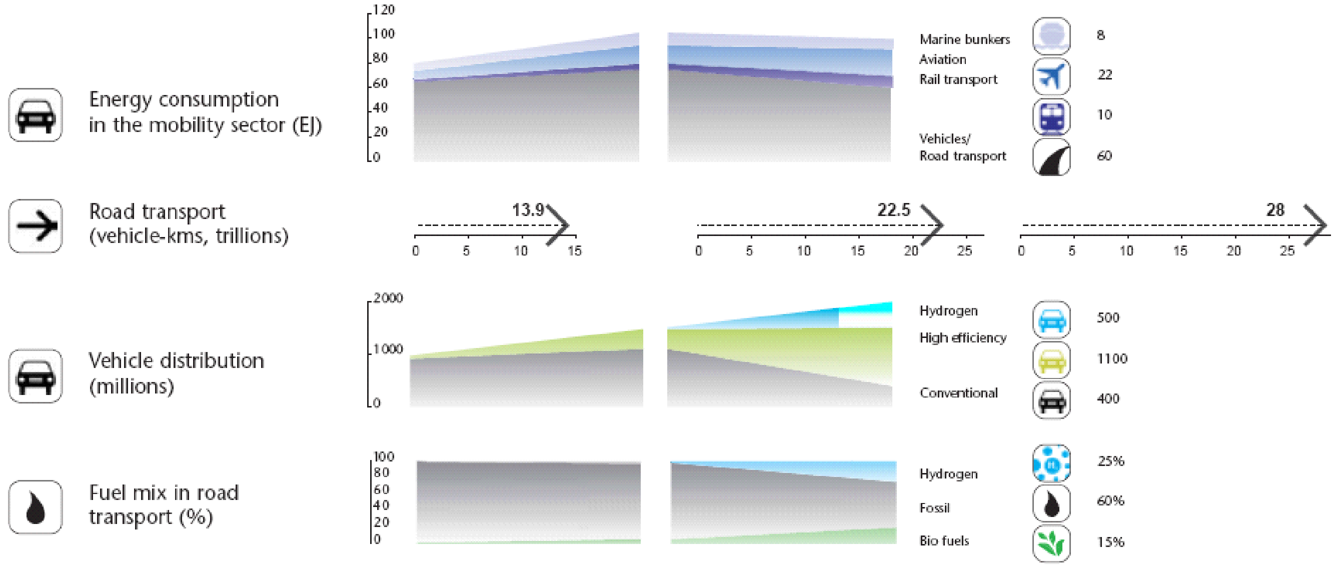
N.6.2 GHG reduction scenarios

By 2025 change is underway. 4 million hydrogen vehicles are on the road in North America and Europe and globally 5% of all fuel used in transport is advanced bio fuel.

By 2050 overall CO2 emissions from the transport sectors are expected to be 10% lower in 2050 than in 2002 (1,29 GtCO2). Emissions for road transport are reduced even more but vehicle kilometres have more than doubled. There is an increasing number of highly efficient hydrogen vehicles. In freight there is a modal shift towards rail transport and bio-fuels are used.

Emissions from aviation increase by a factor of 3 even with the introduction of high efficiency planes

The emissions for the transport sector are compared with the emissions of the other sectors in the figure in the previous paragraph. The following figure presents some further details.



N.7 Other remarks

Strengths

- The study covers all sectors

Weaknesses

- The study is not intended as a scenario but more as an overview to facilitate discussions
- No policy measures are included

O Transport technologies and policy scenarios to 2050

WEC, 2007
Transport technologies and Policy Scenarios to 2050
London : World Energy Council (WEC), 2007

O.1 Scenario Summary

Transport is one of the main global consumers of energy and it is a sector that is particularly dependent on mobile fuels such as gasoline and diesel. The study addresses the need to move to a more sustainable transport system. It covers current technologies, technologies that require a breakthrough before being viable and policy options to stimulate technical and non-technical measures.

O.2 Context

The sustainability of fossil fuels in transport till 2050 has been questioned by scientists, policymakers and other stakeholders. In this study the World Energy council presents a roadmap to a more sustainable future.
The BAU scenario was based on another study (WBCSD Mobility 2030); The scenarios were defined by the effects of certain measures separately (one scenario per option) and “what ifs”. Scenarios look at one change at a time and the calculate effects. No scenarios covered the total of effects by multiple options

O.3 Scope

The study covers the Global transport sector. All modes are discussed and distinguished. It projects up to 2050. It contains a large number (13) of scenarios that cover one possible set of solutions for sustainability. For each of the scenarios the viability is discussed qualitatively and the effects are calculated. In addition a number of “what-if”scenarios are presented that deal with technologies that require a breakthrough to become viable. The likelihood, benefits and barriers of these scenarios are assessed.

O.4 Wider assumptions

The reference (BAU) scenario is based on WBCSD Mobility 2030. No details reported.

O.5 Technical details

The qualitative assessments of the scenarios is done based on the three A’s:

- Accessibility
- Availability
- Acceptability

The options are scored on each of these factors. The quantitative assessment is performed in accordance with WBCSD Mobility 2030 for each of the scenarios. The What-if scenarios are evaluated as qualitatively or quantitatively as availability of data allows.

O.6 Results

O.6.1 Business as usual

Little details are presented on the BAU scenario. The study refers to WBCSD Mobility 2030.

O.6.2 GHG reduction scenarios

The scenarios are too numerous to describe all of them, nor is it possible to chose a “most likely” scenario as it is not the objective of the study to present complete future scenarios. The following figures and tables give an indication of the scenarios and results.

Technology (@ global penetration)	2050 fossil energy change 2050 vs. business as usual		Main barriers to high penetration
	Absolute	Percentage	
BTL 50%	-36.0 EJ	-22.4%	Total yield, variable cost, initial investment
Cellulosic ethanol (CellEtOH) 50%	-34.7 EJ	-21.6%	Total yield, initial investment, vehicle range, vehicle compatibility
Diesel 50%	-4.1 EJ	-2.5%	Variable cost
Hybrid 50%	-8.1 EJ	-5.0%	Variable cost
F.C.V. 50% on the road	-19.0 EJ	-11.7%	Variable cost, vehicle investment, infrastructure investment
B.E.V. 50% on the road	-20.27 EJ	-12.5%	Variable cost, vehicle investment, vehicle range, infrastructure investment
P.H.E.V. 50% on the road	-7.0 EJ	-10.8%	Variable cost, vehicle investment
CTL 50%	-39.2 EJ	-24.5%	CO_2, investment

#	Fuel status by 2050	Vehicle: status by 2050	Global WTW mobility energy change (% and absolute)						Global WTW mobility fossil energy change 2050 (% and absolute)					
			Energy change (%)			Energy change (EJ)			Energy change (%)			Energy change (EJ)		
			2020	2035	2050	2020	2035	2050	2020	2035	2050	2020	2035	2050
0	-	BAU	-	-	-	-	-	-	-	-	-	-	-	-
1a	BTL 25%	BAU	4.1%	7.1%	10.1%	+4.5	+9.5	16.8	-4.5%	-7.9%	-11.2%	-4.8	-10.2	-18.0
1b	-	OECD diesel 50%	-0.82%	-1.35%	-1.69%	-0.9	-1.8	-2.8	-0.79%	-1.29%	-1.62%	-0.9	-1.7	-2.6
1c	BTL 25%	OECD diesel 50%	4.1%	7.4%	11.0%	4.5	9.9	18.2	-4.8%	-9.0%	-13.2%	-5.1	-11.7	-21.2
1d	-	Non-OECD diesel 50%*	-0.65%	-1.21%	-2.09%	-0.7	-1.6	-3.5	-0.60%	-0.94%	-1.50%	-0.6	-1.2	-2.4
1e	BTL 25%	Non-OECD diesel 50%*	4.0%	7.2%	10.8%	4.4	9.6	17.8	-4.6%	-8.5%	-13.2%	-4.9	-11.1	-21.2
2a	Cellul 25%	BAU	4.95%	9.00%	13.05%	5.4	12.0	21.6	-4.15%	-7.45%	-10.80%	-4.5	-9.75	-17.3
2b	-	OECD hybrid 50%	-0.76%	-2.00%	-2.64%	-0.8	-2.7	-4.4	-0.77%	-2.01%	-2.66%	-0.8	-2.6	-4.3
2c	Cellul 25%	OECD hybrid 50%	4.15%	6.82%	10.07%	4.6	9.1	16.7	-4.89%	-9.31%	-13.17%	-5.2	-12.1	-21.1
2d	-	Non-OECD hybrid 50%	-0.42%	-1.63%	-3.32%	-0.5	-2.2	-5.5	-0.40%	-1.55%	-3.16%	-0.4	-2.0	-5.1
2e	Cellul 25%	Non-OECD hybrid 50%	4.51%	7.22%	9.30%	4.9	9.7	15.4	-4.53%	-8.88%	-13.62%	-4.8	-11.6	-21.9

#	Fuel status by 2050	Vehicle: status by 2050	Global WTW mobility energy change (% and absolute)						Global WTW mobility fossil energy change 2050 (% and absolute)					
			Energy change (%)			Energy change (EJ)			Energy change (%)			Energy change (EJ)		
			2020	2035	2050	2020	2035	2050	2020	2035	2050	2020	2035	2050
3	H_2	OECD FCV 25%	+0.2%	+1.2%	+3.6%	+0.2	+1.6	+6.0	-0.2%	-1.2%	-3.8%	-0.2	-1.6	-6.2
3a	OECD pass-km growth -30%		-3.49%	-5.94%	-7.35%	-3.8	-7.9	-12.1	-3.50%	-5.98%	-7.42%	-3.8	-7.8	-11.9
3b	Non-OECD pass-km growth -30%		-1.53%	-4.01%	-7.65%	-1.7	-5.4	-12.6	-1.44%	-3.81%	-7.31%	-1.5	-5.0	-11.7

On the whole the following conclusions are reported:

- Energy efficiency potential in diesel and hybrid vehicles is most cost effective
- Fuel cell and electric vehicles have a high reduction potential but these technologies will be less cost effective than conventional technologies even by 2050
- BTL and Cellulosic Ethonanol fuels have a high potential of reducing fossil energy consumption but cost effectiveness is highly dependent on the price of oil
- CTL increases CO2 emissions even with CCS (by 30%)
- Government intervention should ensure an economic incentive for energy saving technologies
- Production incentives should be technology neutral

O.7 Other remarks

Strengths:

- A lot of detail
- Clear distinction between quantitative and qualitative assessments

Weaknesses

- Focus on energy use, not CO2 emissions
- Only transport section
- Piecemeal Scenarios

P Getting into the Right Lane for 2050

PBL, 2009
J.A. Bakkes
Getting into the Right Lane for 2050 A primer for EU debate
Bilthoven : Planbureau voor de Leefomgeving, 2009

P.1 Scenario Summary

The study examines EU policy challenges towards 2050 in a global context. The situation of the EU will change as economic gravity shifts towards Asia. By back casting from 2050 to present day the study identifies key strategic issues on witch the EU policy strategy can anticipate By acting "early" the EU can have the most global influence.

P.2 Context

The study was independently performed by the Dutch Environmental Assessment Agency (PBL) in association with the Stockholm Resilience Centre. The study presents a vision for 2050. Its objective is to identify political issues about which strategic choices need to be made in the near future to realise the vision. For each issue broad guidelines for the policies and political strategies needed are presented. Information is presented on the vision for 2050 and a base line scenario., The main goal is to assist policymakers in initiating the policy instruments needed in an early stage.

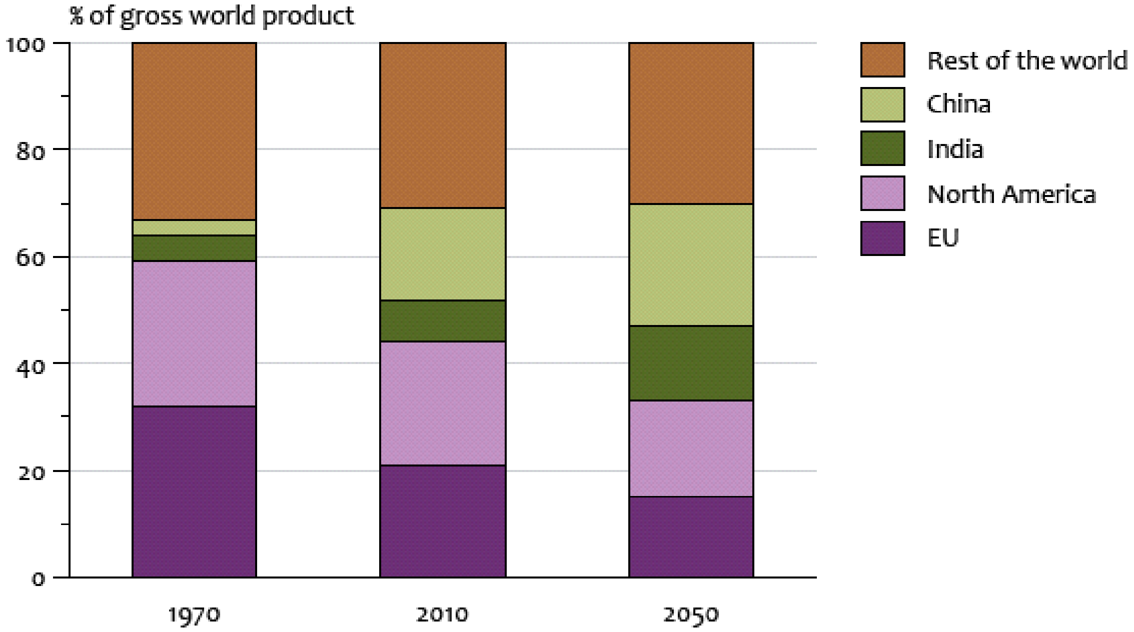
P.3 Scope

The study does not limit itself to transport only. It focuses on three main points: Land use/agriculture, Energy use/climate change and mobility/transport. For mobility all modes are considered. The vision for 2050 is only provided for the EU but in assessing possibilities and the baseline scenario global concerns and worldwide estimations are included.

P.4 Wider assumptions

No assumptons on oil prices or GDP growth are reported. A changing global GDP distribution is reported[13](also see the figure below) The population of the world is expected to rise to 9 billion[11] by 2050. The BAU scenario is based on the OECD environmental Outlook[12,13].

[11] United Nations World Population Prospects, the 2007 revisions, UN Population devision, New York, USA
[12] Environmental Outlook to 2030, Organisaton for economic cooperation and development, Paris
[13] Background report to the OECD envrionmental outlook to 2030 Overviews, details and methodology of model-based analysis. Netherlands environmental assessment agency, bilthoven and OECD, Paris



For the vision the assumption is made that to limit global warming to 2°C a CO_2 reduction of 80/95% for the large income countries is needed.

P.5 Technical details

The basic modelling method is Backcasting. Modelling technique is described in another study[14].

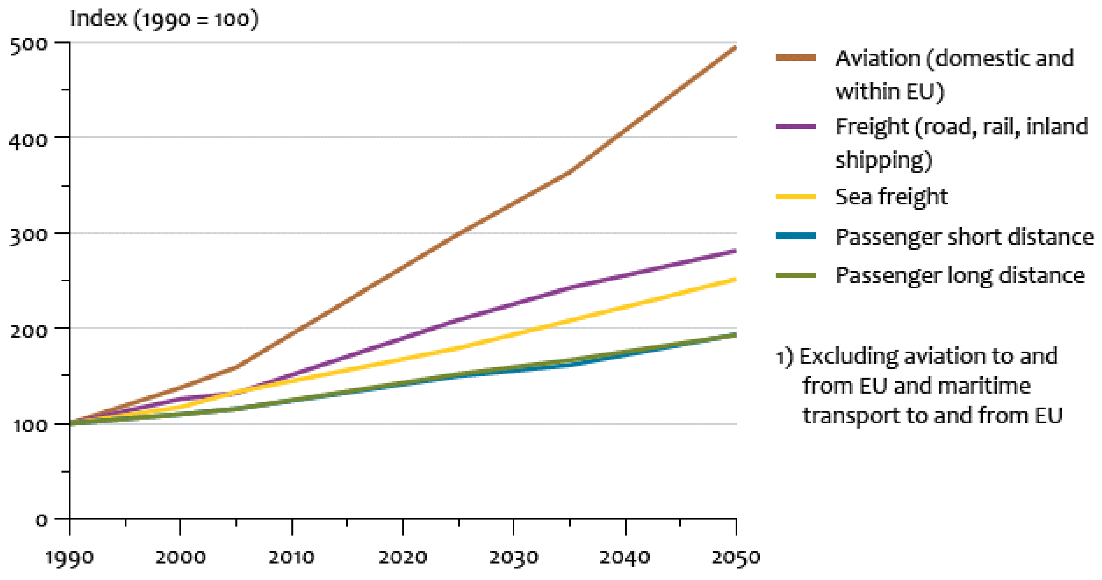
P.6 Results

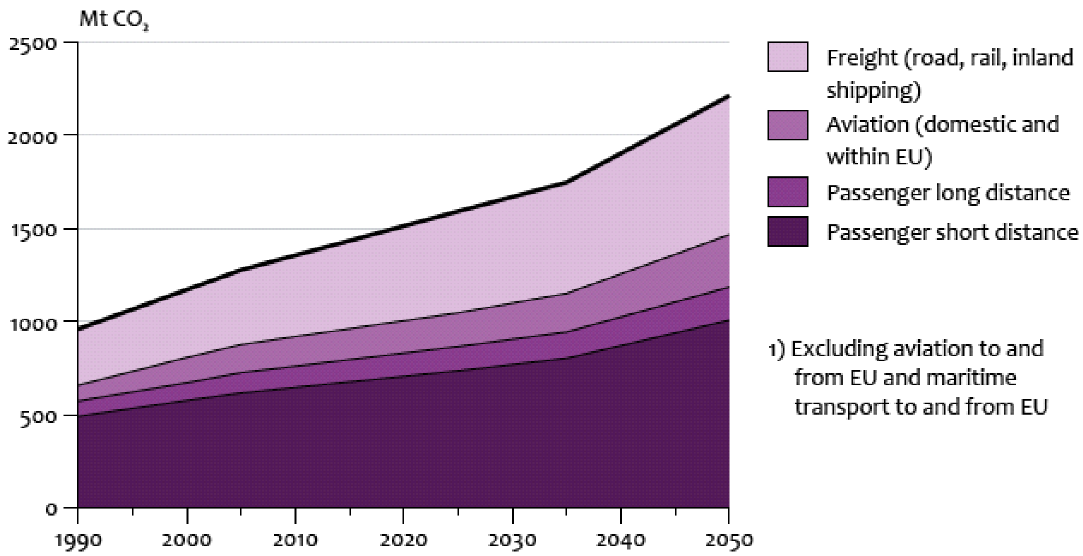
For the baseline scenario some other studies are combined to give the bandwidth of the BAU scenario. No details of the BAU scenario is presented. The reduction options for transport that are needed to realise the vision are taken from another study[14]. The following figures show the baseline CO_2 emissions and the contributions to the reduction from three groups of options.

[14] Banister, D. (2009) Getting in the right lane. Low Carbon European Transport Beyond 2050 Paper. Transport Studies United, Oxford University, Oxford

P.6.1 Business as usual

Transport volume and CO2 emissions in the BAU scenario are presented in the following figures:





P.6.2 GHG reduction scenarios

At the basis of the vision lies a reduction of 80% CO2 emission compared to 1990, also for the transport sector. This is achieved by:

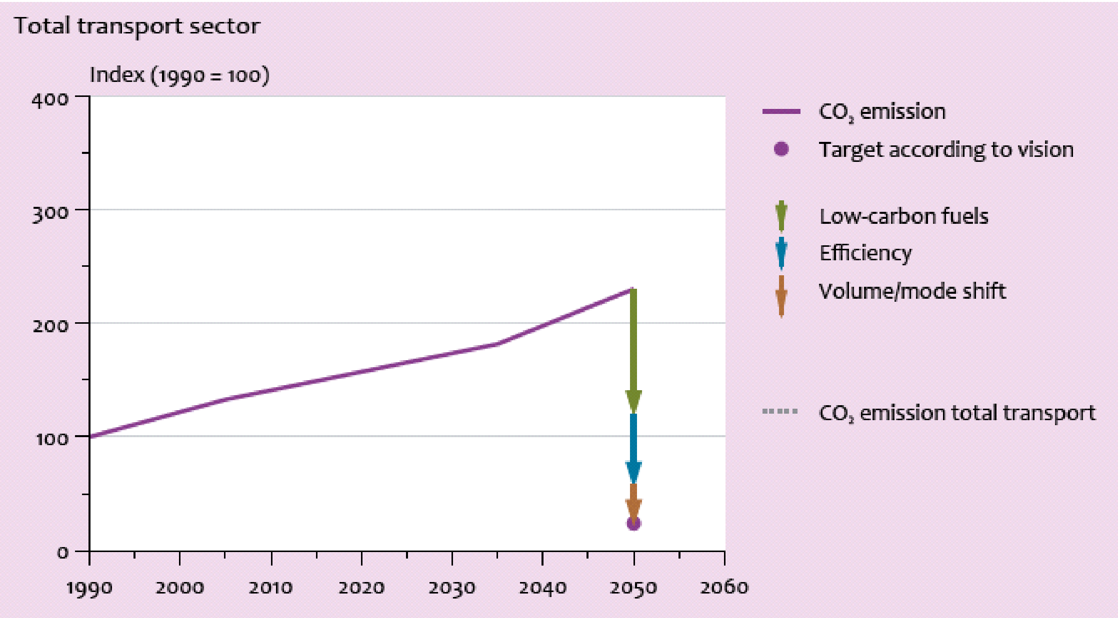
- Low carbon fuels (hydrogen, electricity, and biofuels
- Enhanced vehicle efficiency and logistics
- Reducing traffic volumes
- Shift to more energy efficient modes

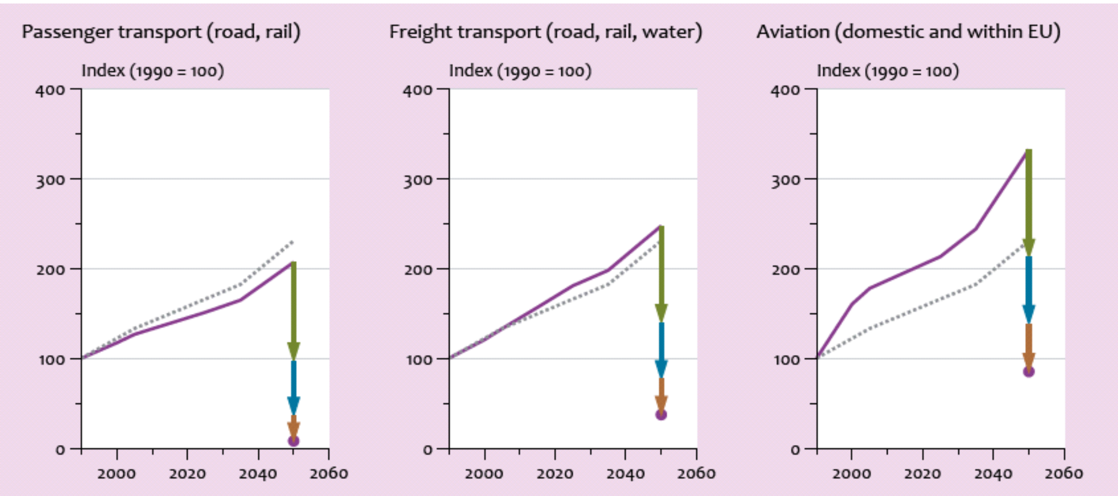
Passenger transport contributes most to the reduction. Reductions of 95% are possible. Current cars are replaced by hydrogen or electric vehicles and the electricity and hydrogen is supplied by low or zero carbon power generation technologies. In urban areas move to public transport, self propelled modes or intermediate modes such as electric scooters.

Road freight reduces its emissions by a factor of 6 (17% of 1990 emissions) by using bio-diesel and maximising energy efficiency and logistics. There is also a small modal shift towards rail and inland shipping.

Aviation and shipping reduce their emissions by a factor 6 to 10 (10% - 17% of 1990 emissions). A share of 50-75% of advanced bio-fuels is used in combination with technological, operational and logistic measures (such as speed reduction for shipping). Air travel demand is partly shifted to high speed rail in the EU making high speed, low carbon rail the most common method of transportation between member states.

The following figure indicates the distribution between the types of measures.





P.7 Other remarks

Strengths

- More than just transport.

Weaknesses

- Most details in another study
- Transport reductions greater than most other studies

Q RECIPE Synthesis Report

RECIPE, 2009
O. Edenhofer, O., C. Carraro, J.-C. Hourcade, K. Neuhoff, G. Luderer, C. Flachsland, M. Jakob, A. Popp, J. Steckel, J. Strohschein, N. Bauer, S. Brunner, M. Leimbach, H. Lotze-Campen, V. Bosetti, E. de Cian, M. Tavoni, O. Sassi, H. Waisman, R. Crassous-Doerfler, S. Monjon, S. Dröge, H. van Essen, P. del Río, A. Türk
RECIPE - The Economics of Decarbonization. Synthesis Report
Potsdam : Potsdam Institute for Climate Impact research (PIK) , 2009

Q.1 Scenario Summary

Short introduction of the study.

Q.2 Context

Recipe is composed by the Potsdam-institut für klimafolgenforschung, Centro euromediterraneo per I cambiamenti climatici, Centre international de recherché sur Lénvironnement et le développement and the University of Cambridge electricity policy research group. Its objective is to provide policy makers with a roadmap towards a low carbon world economy. It wishes to relate the feasibility and afforablility of abatement with policy measures needed to stabilize the atmospheric CO2 concentrations and limit the probability of exceeding 2˚ global warm-up.

It contains a reference BAU scenario and two policy scenarios. One moderately ambitious scenario limiting CO2 concentrations to 450 ppm and an ambitious scenario at 410 ppm.

Q.3 Scope

The focus of this study is on energy generation and economy. Three modelling systems are used and compared with one another. One of these models (Witch) does not incorporate a “transport module”. Of the other two systems IMACLIM-R has the most detailed transport modelling. In the reported results transport modes are generally not distinguished.

The study is intended for European policies but does incorporate global markets and issues. Most results are presented up to the year 2100, but the main projection is stabilisation of the CO2 concentration and preventing global warming of more than 2’C by 2050. The study does not have a fixed “outlook year”.

Q.4 Wider assumptions

The future development of low-carbon technology in transport (and also the other sectors) is uncertain. This limits the possibilities of projection.

There will be a smaller share in the global GDP for Europe (GDP projections not reported but they are used as input for the models). The population of the world will peak in 2070 at 9,5 billion stabilising to 9 billion in 2100.

Q.5 Technical details

Three modelling systems are used to calculate the scenarios:

- IMACLIM-R
- REMIND-R
- WITCH

The results are compared with each other and combined to give a bandwidth of the overall scenario.

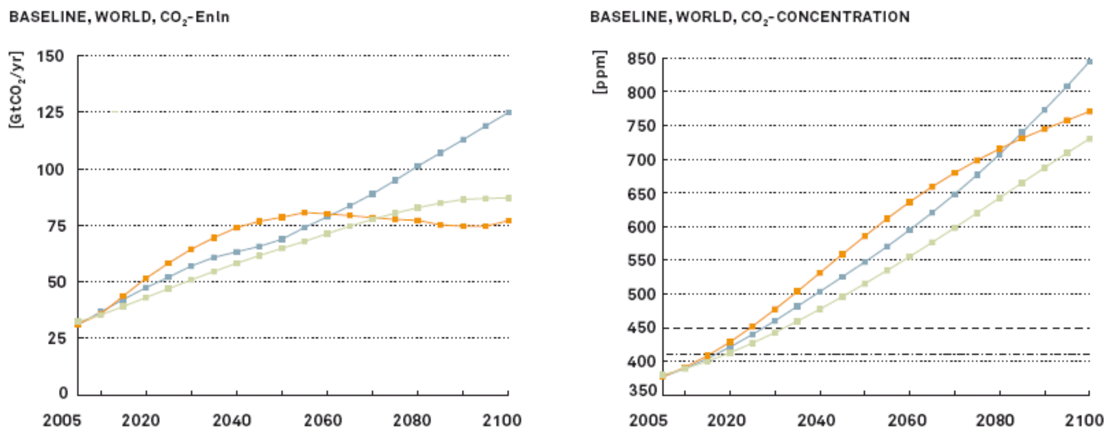
The projection method is based on a stabilisation of the atmospheric CO2 concentration at 450 or 410 ppm. Thereby giving The nessecary measures, and abatements costs are then calculated from these fixed limits (backcasting).

Q.6 Results

Reference BAU scenario:
The overall concentration of CO2 stabilises at 730 – 840 ppm in the BAU scenario. This scenario assumes that no climate mitigation measures or policies are taken (on top of the current policies).

In the unabated situation the transport demand will g row a factor of 2-3 times and up to 4,5-6 times more energy will be needed in the transport sector in 2100. Alternative fuels are needed to meet the demand (as oil production is unable to keep up). Most of this is expected to come from coal liquification.

The figure below shows the results from the tree modelling systems for the BAU CO2 emissions and concentration. (note that the concentration does not stabilise in 2100).



Q.6.1 GHG reduction scenarios

For both reduction scenarios and all sectors the following results are reported;

The additional investment in low-carbon technology needed to develop the technologies needed to reduce emissions to either of the proposed levels is 0,2-1% world GDP. There will be less investment in fossil fuel based energy generation. Long term climate policies reducing uncertainty for private investors are imperative.

Among the technologies needed, CCS and renewables have the highest potential. The will need to be a small nuclear contribution to make the power sector fully decarbonised by 2050. Even in the mitigation scenarios the demand for power will increase by a factor of 2-3.

Industry will focus on improving existing installations (due to the long life installations and replacing installations by state of the art low-carbon ones whenever needed and financially possible.

The policy options that are most vital are:

- Gradual global introduction of an ETS for all sectors
- R&D support high priority
- Biofuels only accepted when incorporating WTW/production emissions

- General policy for sustainable agriculture and rural developement
- Vehicle regulation
- Long term stabile climate policies

For transportation the different modelling systems lead to different conclusions as to the technologies used.

IMACLIM-R

- Most important technology is Coal liquefication combined with CCS
- Biomass is used from 2020
- Reductions in energy demand (plug ins & energy efficiency and infrastructure to decrease transport intensity of the economy)

REMIND-R

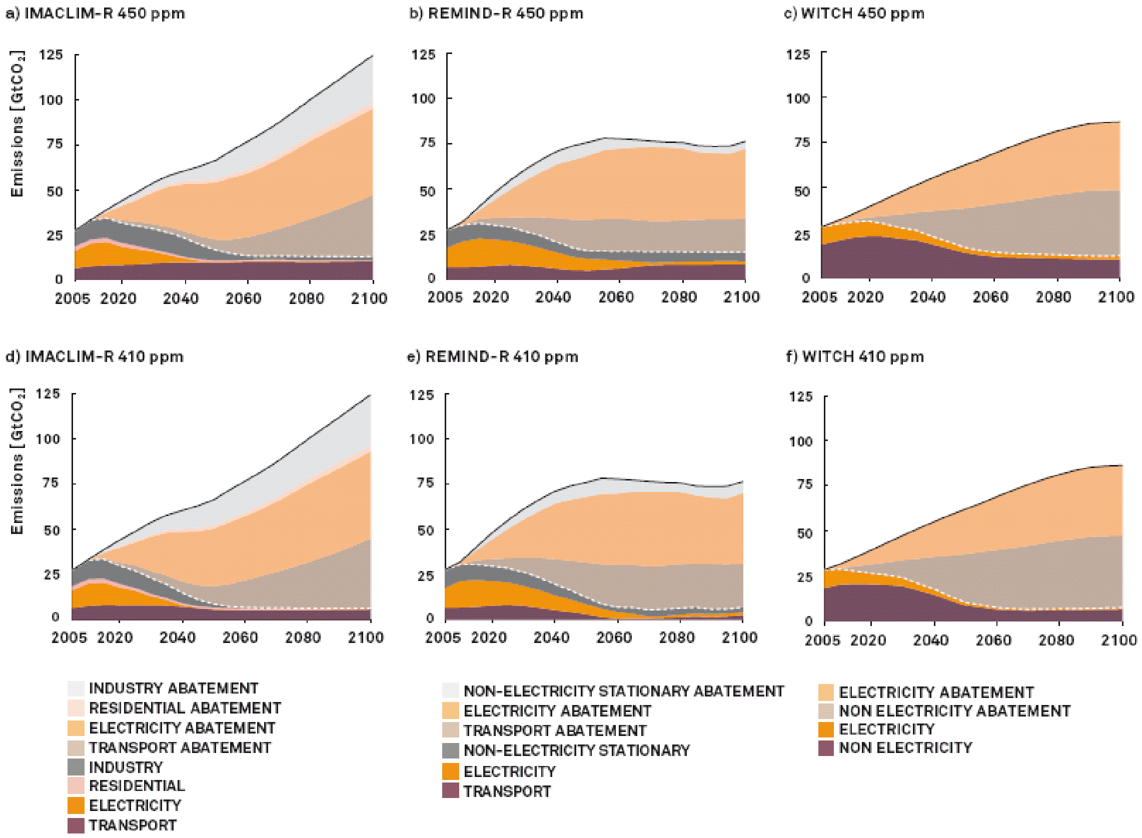
- Biomass is used from 2030
- Hydrogen fuel cell vehicles are the principle mitigation method
  - o Biomass to hydrogen provides one third of the hydrogen needed
  - o Coal to hydrogen with CCS provides the rest
- Electrification insignificant

WITCH :

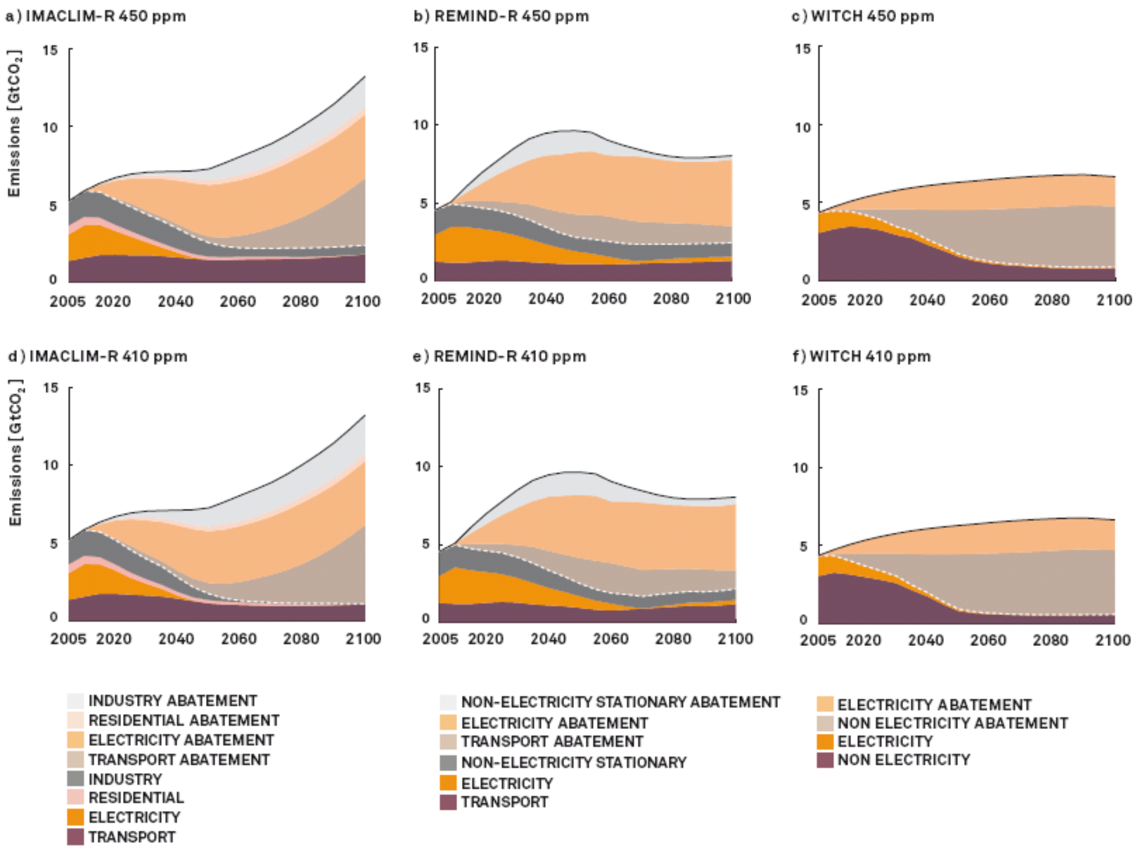
- No transport details

The main differences between the scenarios is the scale of the mitigation and the costs thereof. For the 450 ppm scenario the cost (welfare loss) is estimated at: 0,1 – 1,4 % and for the 410 ppm scenario 0,7 - 4 % of the global GDP.

The global CO2 emissions are presented by the following figure



The European Emissions by the next figure



Q.7 Other remarks

Strengths

- Global validity and the inclusion of other sectors
- Very detailed economics of the measures
- Comparison of multiple modelling systems

Weaknesses

- No details on potential and application of specific technologies

R Blueprint Germany, a strategy for a climate safe 2050

WWF, 2009
Prognos, Öko-Institut and Dr. Ziesing
Blueprint Germany, a strategy for a climate safe 2050: summary
S.l. : WWF Germany, 2009

R.1 Scenario Summary

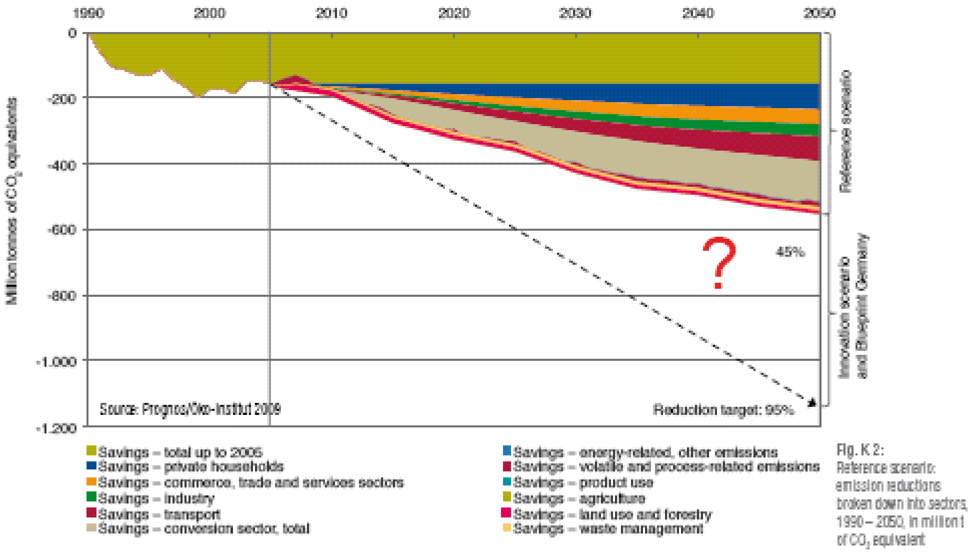
The continuation of today's German reduction policies can only achieve CO_2 emission reductions of approximately 45 % in 2050 compared to 2005, while the target is 95 %. The innovative scenario achieves 87 %, and the remaining gap should be filled with measures that are beyond the general framework specified in the reference and innovative scenario. The scenario in which 95 % reduction is achieved is called the Blueprint Germany scenario but is not quantified.

R.2 Context

The study is performed to answer the following questions; how can and must a highly industrialised and technology – based society be transformed in order to reach this goal? Which technical measures and political instruments are required if economic growth, safety and comfort are to be warranted in the future? Will we have to make sacrifices or can we replace quantity by quality?

WWF commissioned a working group including Prognos / Öko – Institut / Dr. Ziesing to perform a quantitative analysis of above mentioned issue for Germany.

Two scenarios are constructed; the baseline scenario contains an ambitious continuation of today's energy and climate protection policy. The second scenario is the so called 'innovative' scenario that investigates the transformation to a low – carbon society geared towards a 95 % reduction. The continuation of today's energy and climate protection policy clearly fails to reach the target by 2050, see underlying figure.



Source: WWF, 2009.

R.3 Scope

The modes that were included in the study were: Passenger rail, short distance public transport (roads), motorised individual road transport, passenger air transport, Inland waterway transport, rail freight transport, road freight transport and air cargo transport.

Its geographic scale was on country level (Germany) with outlook years 2030 and 2050. More sectors than merely transport were included (households, transport, industry, electricity generation, non – energy GHG and other energy related GHG)

R.4 Wider assumptions

Demographically the following changes were expecten:

- Population decline of 12.5 % from 2005 to 2050.
- Continuation of ageing.
- Household size decline of 2.1 to 1.86 persons.

Economically the following assumptions were used:

- GDP growth of between 0.6 % p.a. for the period 2025 – 2030 and 1.4 % p.a. for the period 2030 – 2050.
- Unemployment will decrease.
- Services factor has a gross value added around 46 % between 2005 and 2050.
- Industry grows with 20 % between 2005 and 2050.

Basic assumptions for the transport sector included:

- Absolute passenger transport declines with 10 % between 2005 and 2050 due to decline in population.
- Freight traffic performance increases with 86 % between 2005 and 2050; freight traffic by rail with 191 %, freight with 67 % and inland navigation with 47 % (not defined what that exactly is). The share of rail transport in freight rises from 17 % in 2005 to 26.5 % in 2050.
- Air transport performance rises by 7 % between 2005 and 2050. But much slower than road freight.
- The sustainable biomass potential is very limited in Germany and is estimated at approx. 1,200 PJ of primary energy

R.5 Technical details

Not specified.

R.6 Results

R.6.1 Business as usual (Reference scenario)

The BAU scenario is based on the continuation of today’s energy and climate protection policy.

R.6.2 GHG reduction scenarios

INNOVATIVE SCENARIO

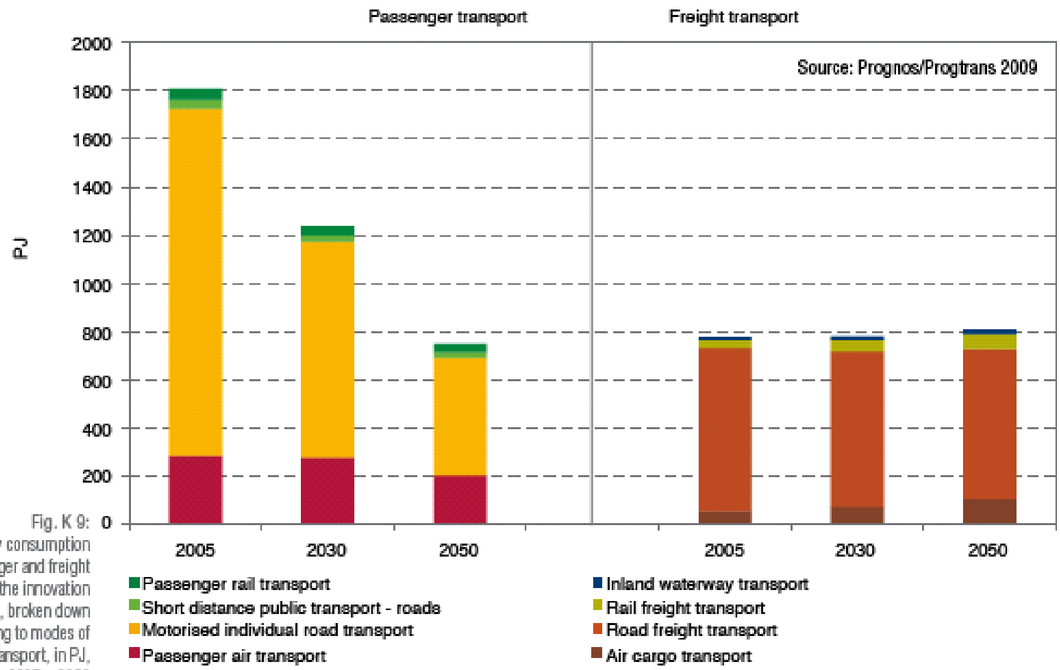


Fig. K 9: Final energy consumption by passenger and freight transport in the innovation scenario, broken down according to modes of transport, in PJ, 2005 – 2050

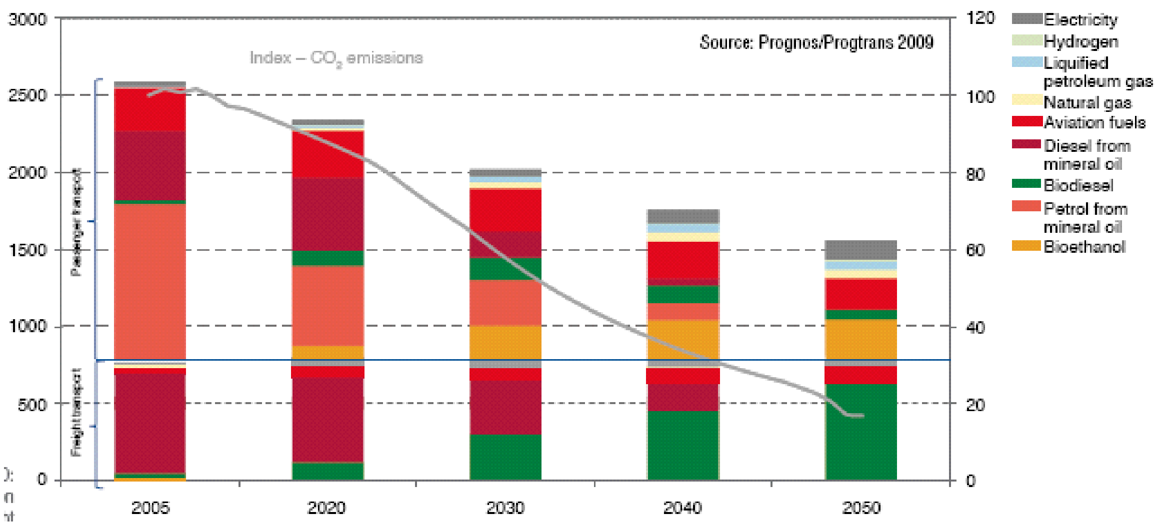


Fig. K 10: Final energy consumption by passenger and freight transport in the innovation scenario, broken down according to energy sources, in PJ, index of direct CO_2 emissions, 2005 – 2050

Source: WWF, 2009.

Modes		Emissions / reductions	Assumptions on Economy	Reduction options included *	Policy instruments included **
(as disaggregated as possible)		(in relevant units)	(if different from BU)	(very short description)	(very short description)
Total		83 % (from 180 million tons to 30 million tons CO_2)		– Introduction EVs. – Decline of specific energy consumption of ICEVs. – Large part of freight transport shifts to rail. – Air traffic performance increases. – Final energy demand mainly covered by biofuels and electricity.	– Double rail network capacity in 2030. – Boost public passenger transport performance by 2030. – Stricter limit values passenger cars. – HGV fleet limit values of about 30 % by 2030. – HGV road toll. – Fuel tax. – Increase biofuel share. – Speed limit on all motorways.
Freight					
	individual freight modes if distinguished	No distinction			
Passenger					
	individual passenger modes if distinguished	No distinction			

*
Central elements for the reductions in the transport sector are **vehicle efficiency** in **motorised individual transport**, **electrification of motorised individual transport** and the contribution of **freight transport switching to renewable energy sources**. With respect to these the following details are presented:

- Electric vehicles will be introduced to the passenger car fleet. Vehicles with combustion engines without a hybrid part will no longer be of any relevance after 2045. In 2050, hybrid electric vehicles account for around 36% of cars, plug-in hybrids for 28% and battery electric vehicles for 18%.
- By 2040, the average specific energy consumption of new passenger cars with combustion engines declines by approx. 60%. By 2050, the average fleet consumption (calculated over the entire vehicle fleet and performance) falls by 64%; specific CO2 emissions per vehicle kilometer decline to approx. 40 g per km.
- In freight transport, a large part of transport growth shifts to rail transport. Electrification of the HGV fleet is not assumed; this is due to the power density which this requires and for which no battery technologies are foreseeable. Specific consumption by HGVs falls by approx. 25%.
- Air traffic performance (domestic principle) declines both for passenger and for freight transport. Between 2005 and 2050, energy efficiency increases by approx. 40%. This means that energy consumption by air traffic falls in total by 10%.

- Due to the more efficient vehicles and the efficiency advantage in terms of final energy of electric vehicles and rail transport, final energy consumption by the transport sector declines in total in the period under review by 41%.
- In 2005, final energy demand by transport will hence be mainly covered by biofuels (59%) of the second and third generation and by electricity (12%). Hydrogen and gas have a minor role to play.

By 2050, all mineral-oil based fuels in the innovation scenario will be replaced by second and third generation biofuels. This means that the sustainable biomass potential available in Germany is almost completely exhausted. (This calls for a strategic decision concerning the targeted use of the biomass potential in the transport sector, rather than in favour of the generation of low-temperature heat).

- With a view to the political instruments for implementation for the 2030 perspective, this means the following set of measures:
- An investment programme to double the capacity of Germany's rail network by 2030.

- An investment programme to boost by 25% the performance of public passenger transport by 2030 (and to make public passenger transport more attractive).
- Stricter limit values for passenger cars to be set at 70g of CO2 per km in 2030 (without the inclusion of biofuels and without the non-inclusion of electric vehicles).
- Creation of HGV fleet limit values of about 30% below the current values by 2030 (including the establishment of a suitable test cycle and calculation basis);
- Increase in the HGV road toll to 50ct per km in 2030, granting of an efficiency bonus and expansion to include all HGV and the entire road network
- Increase in fuel tax to a level that results in 2030 in a price of €2.50 per litre for conventional petrol.
- Considerable increase in the share of biofuels by combining high and reliably verifiable sustainability standards for biomass and a further-developed biofuel quota based on a biomass strategy (the height of the quota is determined by the sustainability standards and the CO2-emissions reduction potential) by the year 2030.
- A speed limit of 120kph on all motorways.

BLUEPRINT SCENARIO

In addition to the innovative scenario, the following 'strategic safeguards' must be in place:

- In the field of motorised individual transport,
    - transport avoidance or transport shifting should reduce performance by 2030 by around 20% and by 2050 by around 30%;
    - specific final-energy consumption of the vehicle fleet (including the efficiency effects resulting from electric vehicles) should be reduced by more than 60% by the year 2050;
    - the aim should be to achieve a 7% share of electric drives in total performance by 2030 and around 50% by 2050;
    - the aim for the year 2050 should be to achieve almost complete coverage of final energy demand through renewable (biofuels) or emission-free (electricity, hydrogen) energy sources.

- In the field of road freight transport,
    - performance in 2050 should not exceed the current level by more than one third;
    - specific energy consumption by the entire vehicle fleet should be reduced from today until 2030 by 30% and by 2050 by around 50%;
    - the entire remaining fuel consumption must be converted to renewable energy sources (biofuels, hydrogen) by 2050.

- In the field of air transport,
    - Specific energy consumption by the entire aircraft fleet should be reduced by 20% by the year 2030;
    - fuel use must be fully converted to regenerative energy (biofuels) by the year 2050.

R.7 Other remarks

The study recommends strategic safeguards and political instruments and indicates what *will* happen in the scenarios.

Insight in methodology is not given, only framework data and assumptions. It provides a somewhat fixed trajectory, but does not tell why it will happen.
The blueprint scenario outcome appears to be reached by backcasting method, strategic safeguards and political instruments are based on the 2050 reduction target.

S Green4Sure, het Groene Energieplan

CE, 2007
F.J. Rooijers, B.H. Boon, J. Faber
Green4sure, het Groene Energieplan
Delft : CE Delft , 2007

S.1 Scenario Summary

The Green4sure scenario is set against the reference scenario, which is based on the Strong Europe scenario (by CPB). The difference between the two scenarios is that Green4sure contains enough policy recommendations to achieve 50 % CO_2 emission reduction by *all* sectors in 2030 compared to 1990. The transport sectors is expected to reduce emissions by 35 %. However, no emission reduction figures are given for the reference scenario.

S.2 Context

Commissioned by six Dutch environmental and social organisations, CE Delft performed this research to create an overview of how it is possible for Dutch society to achieve a 50 % reduction of CO_2 emissions by 2030 (compared to 1990). The Green4sure plan consists of governmental instruments to influence choices made by consumers and companies. The general approach is the allowance of CO_2 budgets per sector, accompanied by supportive instruments (like efficiency norms and renewable energy norm), and temporarily instruments (like subsidies). The study is mostly qualitative, and focuses on all CO_2 emitting sectors in the Netherlands.

S.3 Scope

- Transport is not distinguished in any modes.
- Geographic scale: the Netherlands.
- The target year is 2030.
- The analysis has a focus on all sectors of the Netherlands, transport is not treated extensively.

S.4 Wider assumptions

The analysis is done with the Strong Europe scenario as reference scenario, the SE scenario is characterized by free trade, strong European and international cooperation.
High population growth and moderate economic growth. No further details are given.

S.5 Technical details

Not available.

S.6 Results

S.6.1 Business as usual

STRONG EUROPE SCENARIO

Modes		**Emissions**	**Demands / volumes**	**Assumptions on Economy**	**Autonomous development**	**Policies assumed**
(as disaggregated as possible)		(in relevant units)	(if available)	(very short description)	(very short description)	(very short description)
Total		N.A.	N.A.	Strong Europe scenario by CPB: Free trade, strong European and international cooperation. High population growth and moderate economic growth.	N.A.	Advancing CO_2 norms for passenger vehicle efficiency (120 gram CO_2 / km in 2020). 10 % compulsory use of biofuels in 2020.
		Aviation emission increase of 21 Mton in 2030 compared to 1990.				

No relevant data are presented in this study. Only a detail on aviation emissions as example.

S.6.2 GHG reduction scenarios

GREEN 4 SURE SCENARIO

Modes	Emissions / reductions	Assumptions on Economy	Reduction options included	Policy instruments included
(as disaggregated as possible)	(in relevant units)	(if different from BU)	(very short description)	(very short description)
Total	- 35 % in 2030 compared to 2005.		N.A.	– Investments in public transport. – Advancing CO_2 norms for vehicle efficiency passenger cars (100 g CO_2 / km in 2020 and 85 g CO_2 / km in 2030). – Improvement of light duty vehicle efficiency of 20 % in 2030 and 24 % for trucks in 2030. – 10 % compulsory use of *climate neutral* biofuels in 2020.
	Aviation emissions decease of 4 Mton in 2030 compared to 1990.			

S.7 Other remarks

This study is considered as a general approach, with no explicit focus on transport. Only transport related emission reduction policy instruments are presented for both scenarios.

T World Energy Outlook 2009

OECD/IEA, 2009
World Energy Outlook 2009.
Paris : OECD, International Energy Agency, 2009

T.1 Scenario Summary

Short introduction of the study.

T.2 Context

World Energy Outlook 2009 is published by the International Energy Agency. The results of the analysis presented aim to provide policy makers, investors and energy consumers alike with a rigorous, quantitative framework for assessing likely future trends in energy markets and the cost-effectiveness of new policies to tackle climate change, energy insecurity and other pressing energy-related policy challenges.
More specifically, this report is intended to inform the climate negotiations by providing an analytical basis for the adoption and implementation of commitments and plans to reduce greenhouse-gas emissions (IEA, 2009: 53).

Two scenarios are analyzed, the 450 scenario (where CO_2 concentration is 450 ppm in 2030) is set against the reference scenario (which basically is the extrapolation of past trends including policies till mid 2009).

T.3 Scope

The outlook years are 2007 – 2030 and the level of analysis is from the global down to the regional and national scale for some countries. Transport modes are divided in road, aviation, international shipping and other transport. Road transport tends to focus on passenger light duty vehicles.

T.4 Wider assumptions

The Reference and 450 scenario projections are based on a set of background assumptions on factors what drive energy demand and supply. Chief amongst these are population growth, economic growth, (both are equal in the two scenarios), energy prices, CO_2 prices and technological development. The latter three follow a different trajectory in the two scenarios.

- Population growth: annual global average of 1.0 % global in the period 2007 – 2030.
- Economic growth: annual global average of 3.1 % in the period 2007 – 2030.
- CO_2 prices. In the reference scenario carbon pricing is limited to the power industry and sectors in EU countries. Prices: $ 43 in 2020 and $ 54 in 2030.
  The 450 scenario assumes carbon pricing from 2013 in OECD+ countries (OECD+ are the OECD countries + non OECD EU countries), and from 2021 in Other Major Economies (OME are China, Russia, Brasil, South Africa and Middle East). Prices: $ 50 in 2020 and $ 110 in 2030.
- Energy prices, see underlying figure.

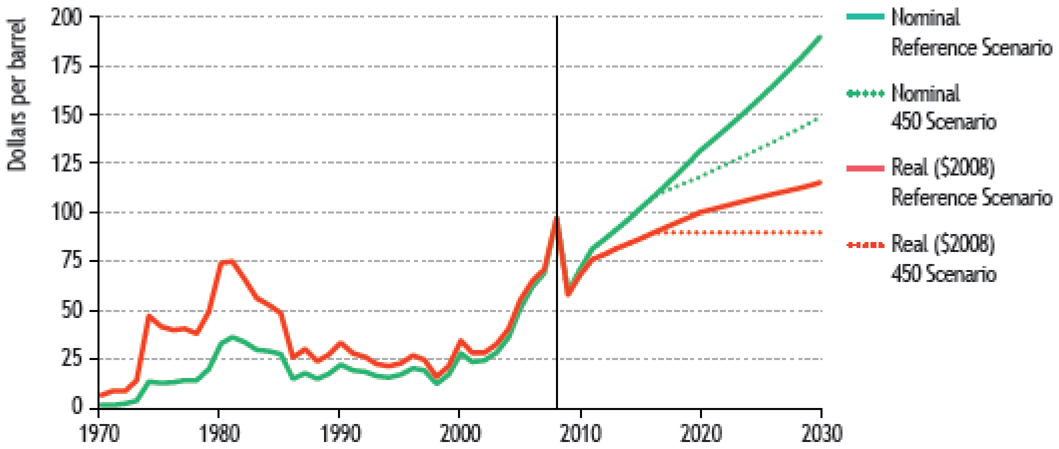


Figure 1: Average IEA crude oil import price (annual data)
Source: IEA, 2009: 65.

- In the reference scenario it is assumed that the performance of currently available technologies improves, particularly in terms of efficiency, over the projection period. In the 450 scenario it is assumed that several new technologies that are approaching commercialization are deployed at various points over the projection period (IEA, 2009: 69). These include: Carbon Capture and Storage, concentrating solar power, electric and plug – in hybrid vehicles and advanced biofuels.
- The 450 scenario can be achieved when all sectors contribute, this contribution to GHG emissions savings, shown in the next figure.

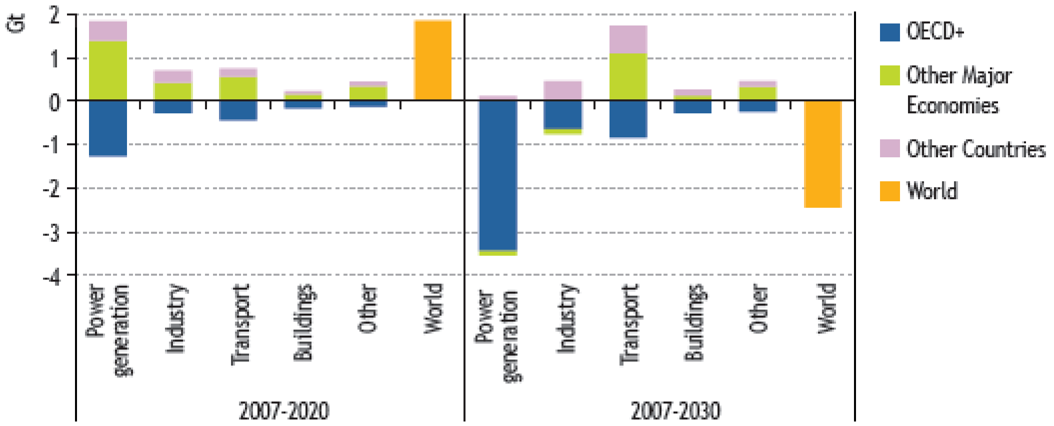


Figure 2: Change in energy related CO_2 emissions by sector and region in the 450 scenario relative to 2007 levels.
Source: IEA, 2009: 222.

T.5 Technical details

N.A.

T.6 Results

T.6.1 Business as usual

Modes		Emissions	Assumptions on Economy	Autonomous development	Policies assumed
(as disaggregated as possible)		(in relevant units)	(very short description)	(very short description)	(very short description)
Total		41 % increase to 9.3 Gt CO_2.	– GDP: annual global average: + 3.1 %. – Increasing fuel prices (see section wider assumptions).	– Increased demand for individual mobility in developing countries.	– CAFE standards US. – Tax exemptions China for vehicle with engine smaller than 1.6 L. – 120 g CO_2/ km standard in EU by 2015.
Freight					
	individual freight modes if distinguished	See below.			
Passenger					
	individual passenger modes if distinguished	See below.			

CO_2 Emissions (Mton) differentiated by transport mode as follows:

	1990	2007	2030
Road:	3291	4835	6920
Aviation:	538	742	1067
Int. Shipping:	358	613	780
Other:	387	433	437

Source: IEA, 2009: 185.

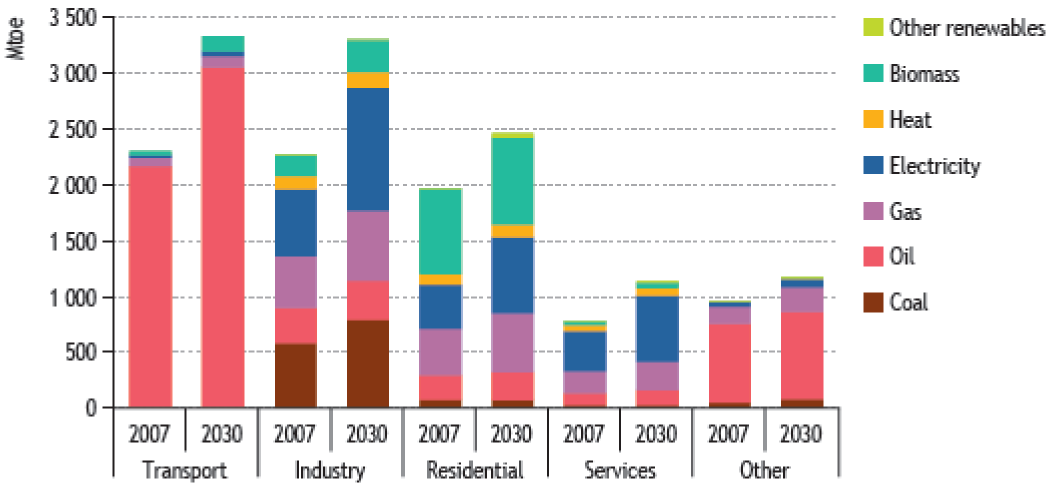


Figure 3: World final energy consumption by fuel and sector in the Reference scenario.
Source: IEA, 2009: 79.

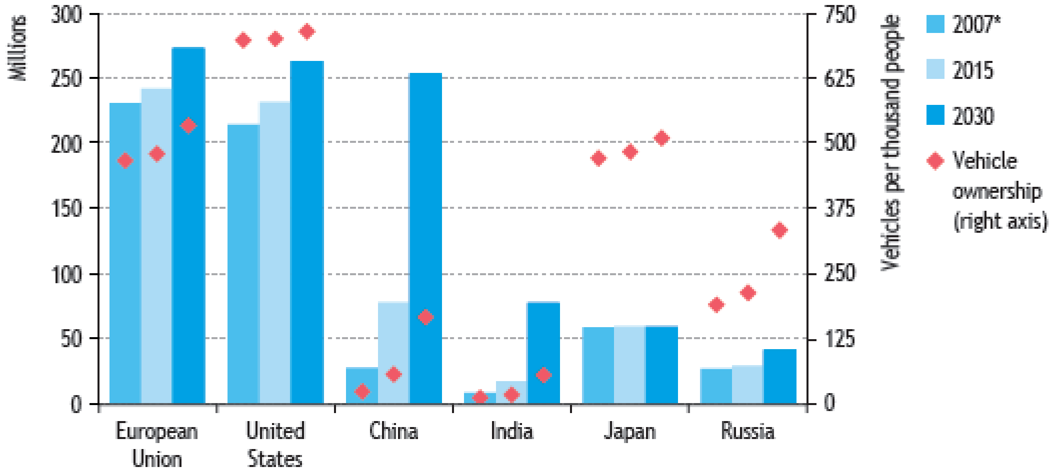


Figure 4: Passenger light duty vehicle fleet and ownership rates in key regions in the reference scenario.
Source: IEA, 2009: 83

T.6.2 GHG reduction scenarios

Modes		Emissions / reductions	Assumptions on Economy	Reduction options included	Policy instruments included
(as disaggregated as possible)		(in relevant units)	(if different from BU)	(very short description)	(very short description)
Total		CO_2 reduction of 670 Mt (or 9 %) by 2020 and 1.6 Gt (or 18 %) by 2030. Total emissions are 7.1 Gt in 2020 and 7.7 Gt in 2030.	Same retail fuel prices as in reference scenario. (lower int. Oil prices are offset by higher end use taxed, to minimise the rebound effect).	– More efficient ICEVs. – Increased biofuels consumption (**road transport and aviation**). – Penetration of more advanced hybrid and pure electric vehicles.	Road transport: – CO_2 emission standards (see also figure 7). Averages for each region: – 80 g CO_2 / km in OECD + – 90 g CO_2 / km in Other Major Economies – 110 g CO_2 / km in Other Countries.
Freight					
	N.A.				
Passenger					
	N.A.				

ROAD TRANSPORT:

Globally, average on road CO_2 emissions of new sold PLDVs reaches 125 g CO_2 / km in 2020 (= 28 % decrease from Reference scenario and 40 % decrease from today's level) and 90 g CO_2 / km in 2030.

Road transport accounts for 92% of total transport savings by 2020 (or 610 Mt) and 81% by 2030 (or 1.3 Gt), when **PLDVs account for more than 60% of total road-transport savings.** Most of these savings, however, are offset by the strong growth in transportation demand in non-OECD countries. As a result, total emissions from transport continue to rise through to 2030.

Globally, the PLDV fleet increases in efficiency by 38% in 2030 relative to the Reference Scenario, as a result of further improvements to gasoline and diesel internal combustion engines, non-engine improvements to auxiliary systems (*i.e.* lighting and air conditioning) and tyres, and the increased market penetration of more advanced engine technologies, such as plug-in hybrids and electric vehicles. By 2020 only 52% of sales are of vehicles with conventional internal combustion engines and this figure declines to 42% by 2030 (Figure 5). Hybrid vehicles are very important for short-term emission reductions, accounting for 32% of all sales by 2020 in the 450 Scenario. This share is undoubtedly ambitious: it illustrates the extent of the challenge for road transport in the 450 Scenario.
In the period after 2020, as plug-in hybrids and electric cars become more available, the share of hybrids declines, reaching 29% of sales by 2030; however, this is still an increase in absolute terms of about 7 million vehicles in 2030 with respect to 2020 (IEA, 2009: 237 – 239).

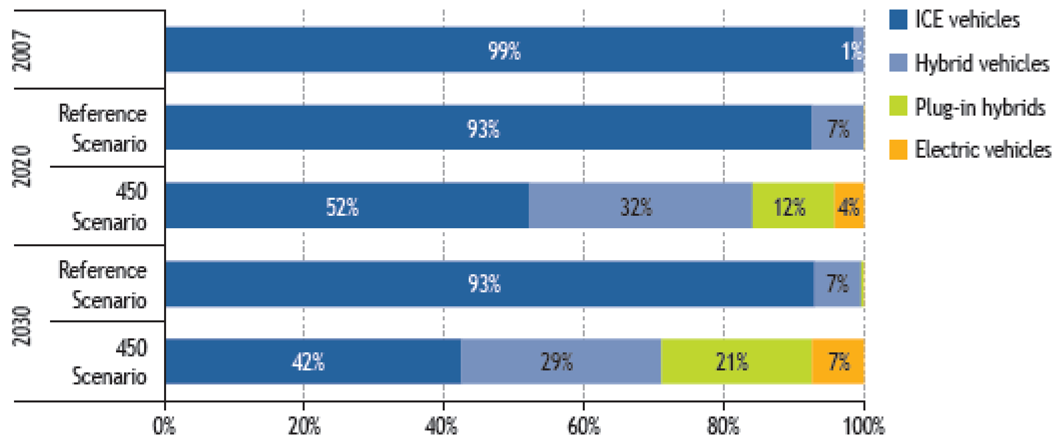


Figure 5: Share of global passenger vehicle sales by engine technology and scenario.
Source: IEA, 2009: 239.

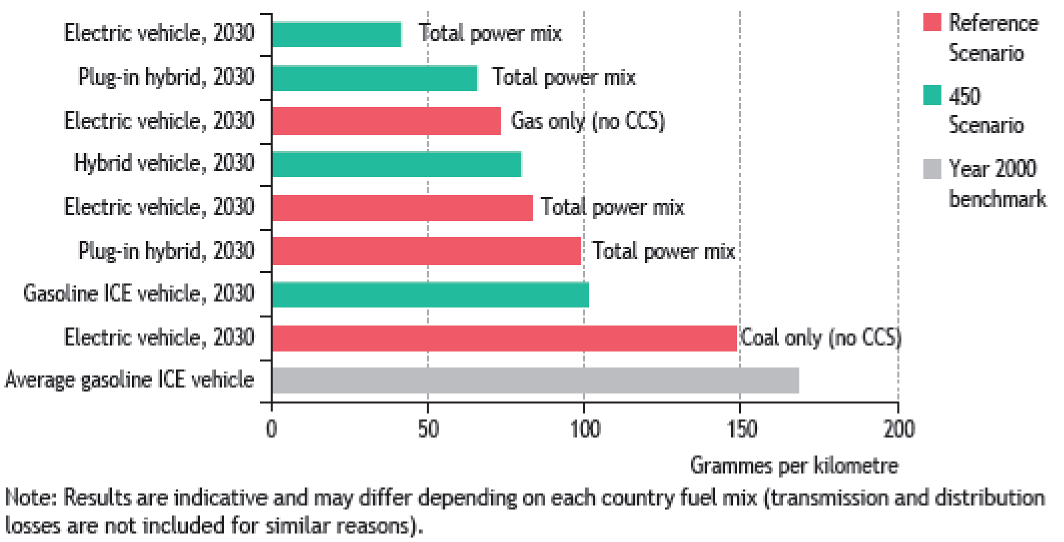


Figure 7: CO_2 emissions per kilometre by vehicle type and scenario.
Source: IEA, 2009: 240.

Some of the technology improvements in the PLDV fleet that are driven by the assumed international sectoral agreement partially flow over to the HDV fleet and help to offset the projected increase in demand for freight through the Outlook period. By 2030, **HDVs account for almost 40% of road-transport emission savings.** The global average HDV fleet is 20% more efficient by 2020, achieving a CO_2 emissions reduction from an estimated 340 gCO_2/km in 2007 to 270 gCO_2/km in 2020, and 227 gCO_2/km in 2030 (reaching a 34% improvement in efficiency from today). Savings come from both engine and non-engine vehicle efficiency improvements, increased biofuels consumption, modal shift to rail and more efficient logistics. The latter, *e.g.* increased load factors, reduction of empty runs and better driver training, come at low or negative costs.

AVIATION:

Aviation emissions, despite the assumption in the 450 Scenario that international sectoral agreements are reached, rise by 13% between now and 2020, and by 15% by 2030, reaching 0.85 Gt. Nonetheless, aviation is the second-largest contributor to CO_2 emission reductions in the transport sector, and its **share in emission savings, relative to the Reference Scenario, is 6.6% by 2020 (44 Mt) and 13.2% by 2030 (217 Mt).**

The savings are achieved via international sectoral agreements that encourage increased biofuels consumption and additional implementation of a mixture of technical, operational and infrastructure measures.

The other half of the savings come from second- and third-generation biofuels. The American Society for Testing and Materials (ASTM) International Aviation Fuels Sub-committee passed a new aviation fuel specification in July 2009, permitting the use of synthetic and renewable fuels in aviation. However, the remaining technical hurdles and problems of production on a sufficient scale see aviation biofuels appearing in the market only around 2020, with volumes reaching 42 million tonnes oil equivalent (Mtoe) globally by 2030 at a global blending ratio of 15%. (IEA, 2009: 241).

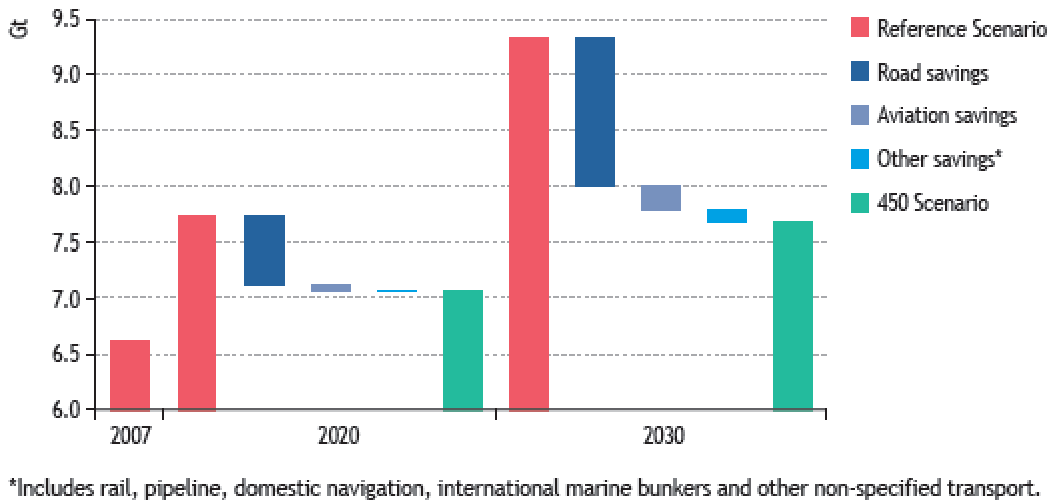


Figure 6: Energy related CO_2 emission reductions in transport by sub – sector in the 450 scenario compared to the reference scenario.
Source: IEA, 2009: 237.

Table 5.3 • CO_2 savings due to national policies and measures and sectoral approaches, 2020

Region	Country	Sector	Policy target in 2020	Savings in 2020 vs Reference Scenario (Mt)
OECD+	US	Transport*	PLDV sales fuel-economy standard at 110 gCO_2/km**	-129
		Buildings	Standards on new buildings efficiency and refurbishment	-45
	Japan	Transport	PLDV sales fuel-economy standard at 90 gCO_2/km	-21
		Buildings	Standards on new buildings efficiency and refurbishment	-4
	EU	Transport	PLDV sales fuel-economy standard at 90 gCO_2/km	-111
		Buildings	Standards on new buildings efficiency and refurbishment	-30
	Other OECD+	Transport	PLDV sales fuel-economy standard at 105 gCO_2/km	-66
		Buildings	Standards on new buildings efficiency and refurbishment	-18
	OECD+	Other energy sector	Savings due to reduced throughput and increased efficiency	-58
		Other savings		-21
Sub-total				*-503*
Other Major Economies	China	Power generation	16% of installed capacity of nuclear, wind and solar, 300 GW of hydro	-398
		Industry	Rebalancing towards services (+47% of GDP in 2020)	-211
		Industry	Sectoral standards for iron and steel and cement	-230
		Transport	PLDV sales fuel-economy standard at 110 gCO_2/km	-60
		Buildings	Standards on new buildings efficiency, appliances and lighting	-144
	Russia	Power	Nuclear generation at 31 GW	-31
	South Africa	Power	More efficient coal	-16
	Middle East	Electricity demand	Efficiency standards for air conditioning and lighting, and industrial motors	-33
	All OME excluding China	Transport	PLDV sales fuel-economy standard at 110 gCO_2/km	-100
		Industry	Sectoral standards for iron and steel and cement	-34
Sub-total				*-1 255*
Other Countries	India	Power generation	Renewables capacity at 110 GW	-76
	Other Countries	Transport	PLDV sales fuel-economy standard at 120 gCO_2/km	-126
		Industry	Sectoral standards for iron and steel and cement	-111
Sub-total				*-312*
International aviation				*-28*
Total				**-2 098**

* In this table all transport targets for PLDV sales fuel-economy standards are for test cycle. The savings correspond to road transport.
** Grammes of CO_2 per kilometre.

Figure 7: CO_2 savings due to national policies and measures and sectoral approaches in 2020. Source: IEA, 2009: 206

U ERTRAC Road Transport Scenario 2030+

ERTRAC, 2009
ERTRAC Road Transport Scenario 2030+ : Road to Implementation
S.l. : The ***European Road Transport Research Advisory Council (ERTRAC), 2009***

U.1 Scenario Summary

The study was produced by the European road transport research advisory council (ERTRAC) and associates. It is a followup of the earlier ERTRAC Research framework: steps to implementation (March 2008). In the course of the work four strategic research priorities were established:

- Energy, Resources and Climate Change
- Urban Mobility
- Long-distance Freight Transport
- Road transport Safety

The present study provides a look into the future of these issues and charts opportunities in research, development and innovation in order to present a research agenda for the next decades.

U.2 Context

The aim of the study is to develop a common vision and to identify research priorities for the future. This can then be translated to a strategic Research Agenda for the next decades.

The study contains one scenario, the “common sense scenario. It also contains a “optimistic” and “pessimistic” deviation from this scenario. These function as indications of bandwidth of the “common-sense scenario”

U.3 Scope

This study focuses on road transport (both freight and personal). Some policies also cover aviation and shipping. Other sectors are not regarded. Geographically the study limits itself to effects in Europe. The outlook year is 2030 but occasionally statements are made that reach towards 2050.

The study does not model effects of policies itself but relies on literature and expert meetings. Few results are quantified. Most policies and trends are regarded qualitatively.

No BAU scenario is presented.

U.4 Wider assumption

Although the study focuses mainly on transport a large number of wider assumptions and results are reported. The most relevant among these are:

- 80% of population is expected to live in urban area’s
- Recycling well-advanced due to Climate change, security of supply and policy
- Air quality no longer a problem
- The current crisis will inhibit short term major investments

U.5 Technical details

A list of over 60 scenarios and studies was reviewed. Out of these a list of relevant issues and measures was composed. Key factors were discussed in expert workshops and the results were made into the “common sense” scenario and both alternatives.

U.6 Common sense scenario

Energy consumption and GHG emission in transport will stabilise due to policy driven efficiency gains In transportation these are mostly due to the following:

- Engine improvements
- Vehicle and transport systems
- Preplacement of non-renewable fuels by renewable fuels
- Greater inter modality of freight transport
- Non-renewable fuels will dominate total energy demand
- Electrification in urban transportation (both passenger and freight)

The results of these options are:

- 2050 road transport will be 50% more efficient than in 2010
- Volume of transport activity increase 40-50% by 2030
- Demand of road transport will increase by 80% (2030)
- 10%+ share of biofuels
- Transport costs will have increased by 30% in 2030
- Maintenance, driver support/coaching 10% increase for cars 15 % for HDVs
- Infrastructure and information efficiency 10-20% increase
- Vehicle improvements 40% for cars 20% HDVs (2001 baseline)
- Logistics/ business models 10% increase
- ICE's "over time" 30% more efficient (included in vehicle improvements)
- Electric and PHEVs make for 15% of new sold vehicles
- Renewable biofuels reserved for aviation and freight

Regardless of these changes crude oil and natural gas will represent 75% or more of transport energy demand. Most innovations are expected in passenger transport.

The policy instruments that are expected to lead to the greatest potential are:

- Public-Private partnerships to drive innovative developments in renewable energy technology.
- Long term framework policies; stable investment climate
- Policies that increase the cost of freight with less than 15% are not expected to have a significant impact

Policies and cost will cause a smaller than expected shift to renewable due to competitiveness in market. Also Climate change and security of supply issues will cause a smaller than expected displacement of non-renewable fuels by biofuel.

U.7 Other remarks

Strengths

- Many different stakeholders
- Attempt at realistic scenario
- Bandwidth information provided

Weaknesses

- No systematic modelling
- Results are not compared to a BAU scenario

V Energy Technology Perspectives

IEA, 2008
Energy Technology Perspectives 2008 : Scenarios and Strategies to 2050
Paris : International Energy Agency, 2008

V.1 Scenario Summary

We are facing serious challenges in the energy sector. The current trends in energy consumption are not sustainable and the situation is getting worse. Some very large increases in consumption are still ahead of us. A global revolution is needed in ways that energy is supplied and used. This will require a dramatic shift in government policies and an unprecedented level of co-operation among all major economies. The study provides a scenario analysis of the issues that will arise in the coming decades and offers a global roadmap to the most promising technologies and policy instruments.

V.2 Context

In the opinion of the IEA, a global revolution is needed in the way energy is supplied and used. This will entail a transformation of the world economy. The study provides a guide and road book as to how this could be achieved.

At the request of the G8 and the IEA energy ministers the report has been independently composed by the IEA (and partners)

The study contains two policy and technology scenarios. The ACT and the BLUE scenario. The first one being a relative conservative change scenario and BLUE being more ambitious. It also presents a BAU scenario

V.3 Scope

The scope is all energy consuming sectors (Transport, industry, build environment, power generation) and all regions (global). The outlook year is 2050.

With respect to transportation, all modes are taken into account ,but not always presented in a sidaggregated way in the figures and results. The detail of the calculations is high.

V.4 Wider assumptions

The global GDP will grow 4 fold by 2050. In developing countries the growth might exceed a factor of 10. For other general assumptions see the BAU or VISION scenarios

Major acceleration in R&D effort Factor of 2-10 increase in government support
Enhanced deployment programmes
Clear, predictable, long-term economic incentives for CO2 reduction in the market
Major shift in policies, if need be against public opposition
Fossil fuels remain a key element in world energy supply
Action and investment required in this decade
OECD countries account for 30% of emissions in 2050 (so developing countries and transition economies must take their share of abatement
Avoid lock in

Transport:

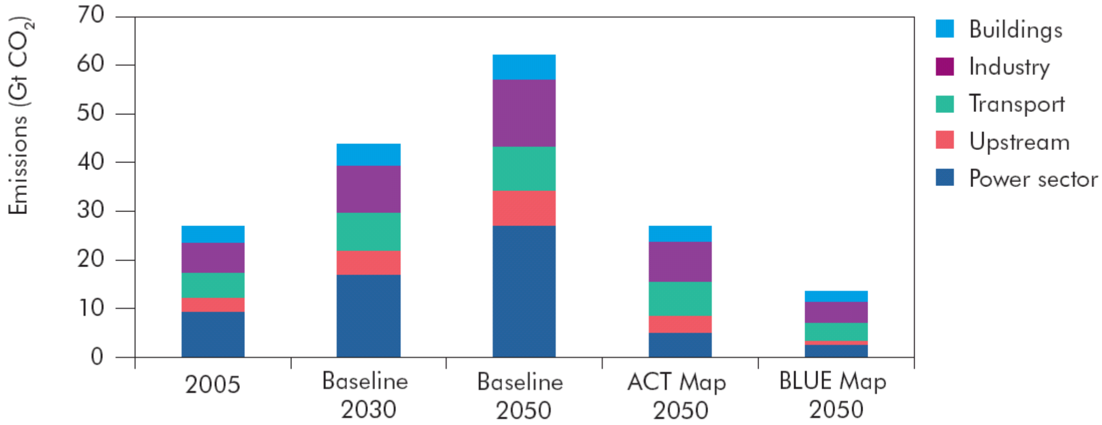
V.5 Technical details

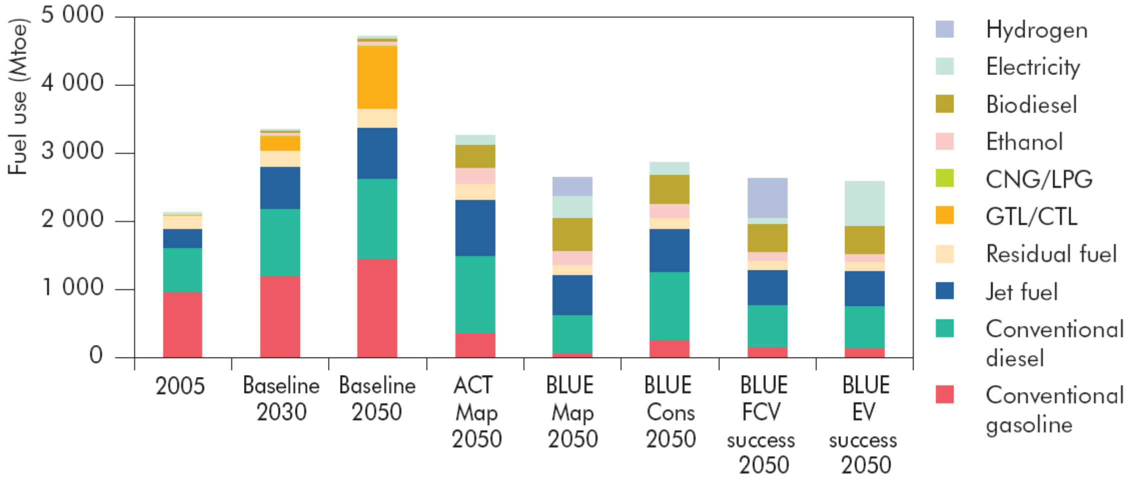
The projection method is back casting from a concentration combined with detailed modelling. For details on the modelling methods see the original report

V.6 Results

A good summary of the assumptions used for the modelling of the transport scenarios is given by figure 15.1 on pages 428 and 429. It is however to bulky to be reproduced here.

The following figures give an overview of the results in BAU and VISION scenarios. Please refer to the original rapport for more detailed representations.





V.6.1 Business as usual

Global CO2 emissions rise to 130% above 2005 levels. Fossil fuel consumption will remain to dominate and oil demand increases by 70% above 2005 levels. The highest growth is seen in developing countries.

Globally oil and gas prices become (very) high and security of supply concerns increase. The energy efficiency improvement rate is 0,9% per year

Autonomous development in the transport sector lead to:

- Automotive (passenger) travel increase by a factor 3, freight demand increases even more
- Efficiency gains by conventional technologies are limited at a maximum of 30-50%
- Transport energy use up increases by 50% by 2030 and doubles by 2050
- Nearly all fuel used comes from fossil fuel
- Conventional oil production peaks and declines. Shortfall made up by non-conventional Oil.
- Air fleet can become 30% more efficient

V.6.2 ACT scenario

The ACT scenario is the least ambitious scenario presented. It leads to emissions in 2050 that are at current level. This scenario is possible with currently developed technologies(Technologies with marginal costs of up to $50 per tCO2). Nontheless a major acceleration in R&D effort of a factor of 2-10 increase in government support for low carbon technologies is required. Also governments are to increase involvement in technology deployment programmes but should take care not to cause technology lock in.

In the other sectors a key role for emission reduction in power generation is envisioned. The end use energy efficiency is reduced by 36% compared to BAU. The shares of different technologies are:

- CCS 14%
- Nuclear 6%
- Renewables 21%

The overall energy efficiency increase rate is 1.4% and the total energy savings are 23% compared to BAU.

For the transport sector the following is achieved:

- Reductions
  - Fuel efficiency 6Gt/yr
  - 2e gen biofuel 1,8 Gt/yr
  - (PH)EV 0,5 Gt/yr
  - Hyrogen 0 Gt/yr
- Emission increase of 31% compared to 2005Next decades LDV's can be made 30% more efficient with little cost and existing technologies (supported by strict policies)
- Up to 50% reduction is possible with hybridisation and light weight materials
- Medium (urban) freight can achieve low cost reductions of up to 40% by 2030 (hybridisation, logistics, routing etc)
- HDVs can reduce by 40% (weight, aerodynamics, usage patterns, engine efficiency) but this requires truck fuel efficiency policy
- Strong increase in international shipping. Energy cuts of up to 30% are possible
- On top of BAU (30%) another 20% efficiency increase could be achieved in aviation

V.6.3 BLUE scenario

The BLUE scenario is more ambitious, it is based on a 50% reduction of GHG compared to current levels. This is only possible with unprecedented and far reaching cooperation and policies. Also there is a need for currently unavailable technologies. Technologies with abatement costs up to $200 (in the case of disappointing R&D $500) per tCO2 are included. A Major acceleration in R&D effort Factor of 2-10 increase in government support is required with enhanced deployment programmes and radical and urgent policy shifts

An overall oil demand reduction by 27% compared to 2005 is possible. The end use energy efficiency reduces by 44% compared to BAU. All sectors require CCS and fuel switching. There is a contribution required from Neuclear, CCS and renewable fuels:

- CCS 19%

- Nuclear 6%
- Renewables 21%

The energy efficiency improvement rate is 1.7% per year and the total energy savings are 33% compared tot BAU

For the transport sector:

- Reductions
    - Fuel efficiency 6,6Gt/yr
    - 2e gen biofuel 2,2 Gt/yr
    - (PH)EV 2 Gt/yr
    - Hydrogen 1,8 Gt/yr
- Total Emission reduction of 30% compared to 2005

V.7 Other remarks

Strenghts:

- All sectors
- High level of detail

Weaknesses:

- None

W International passenger transport and climate change: A sector analysis in car demand and associated CO_2 emissions from 2000 - 2050

Meyer et al., 2007
I. Meyer, M. Leimbach, C.C. Jaeger
International passenger transport and climate change: A sector analysis in car demand and associated CO¬2 emissions from 2000 to 2050.
In : Energy Policy, vol.35 (2007); p. 6332–6345

W.1 Scenario Summary

The paper provides global regionalized projections of passenger car demand, use and associated CO_2 emissions from 11 world regions. Derived demands serve as indicator of car related fuel consumption and associated CO_2 emissions, which are calculated on the basis of behavioural and technological scenarios. The obtained CO_2 emissions paths are sectoral baseline scenarios that indentify region – specific potentials of growth in car induced CO_2 emissions assuming that current trends continue to prevail.

W.2 Context

The reason for the study is to introduce a novel approach to projecting global regionalized sectoral car demands

Its objective is to apply traditional consumer demand theory in order to model global regionalized and long term demands for car stocks from where correlated CO_2 emissions are derived.

W.3 Scope

The analysed transport mode is passenger cars (with the emphasis on car stock numbers), no further distinction is made. The scale is global, and divided in 11 sectors. 2050 is the outlook year and the models are based on nation specific data, which taken together forms the sectors.

W.4 Wider assumptions

Aggregated cluster – specific time series of per capita car stock and per capita GDP are formed by weighted average according to population figures of the representative countries.

The analysis employs growth rates of GDP and population figures from Leimback and Toth (2003).

Expenditure series are calculated on the basis of consumption shares as given in the year before forecasting begins and are assumed to be constant. Also price variables for car stocks and generic goods are assumed to rise with 1 % and 2 % respectively.

W.5 Technical details

It is suggested that income is a major economic variable determining car demand, with higher levels of per capita income correlated with higher levels of car stocks and vice versa. Demand for car ownership thus appears to be positively correlated with per capita GDP.

In the first scenario the car stock demand is modeled with the use of a utility or preference function that represents consumer preferences and that mathematically serves as an objective function, this is modeled with the Stone – Geary preference function (Goldberger, 1987).

And for the second scenario the Gompertz model approach is used as a second method of estimating cluster-specific car stock demands. In contrast to the utility-based approach to demand, the Gompertz model abstracts from the use of marginal budget share parameters and from price specification.

The two car stock scenarios derived on the basis of equal driving forces in population and income show a range of possible car demands that widens over time, thus capturing uncertainties in the long term modeling of car demands.

W.6 Results

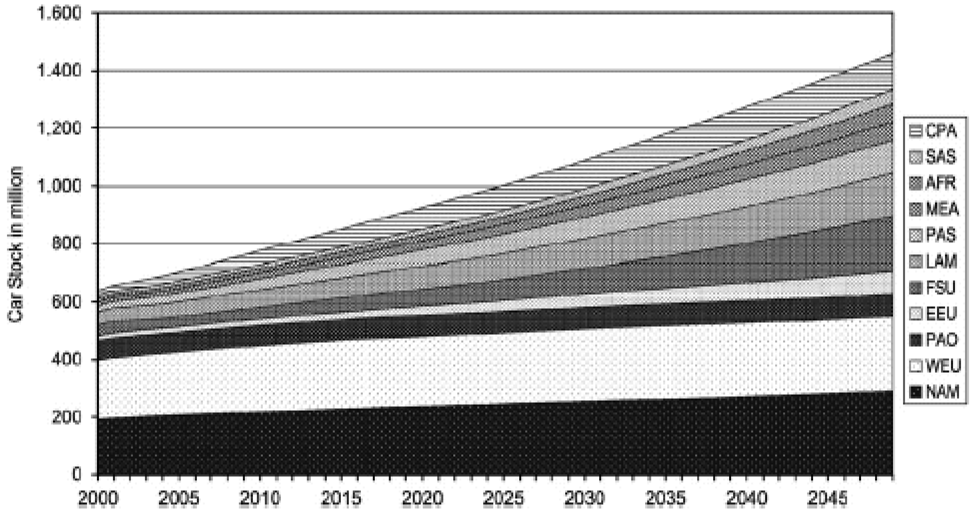


Fig. 4. Stone–Geary absolute car stock demand projections of 11 world regions from the price scenario (+1, +2), 2

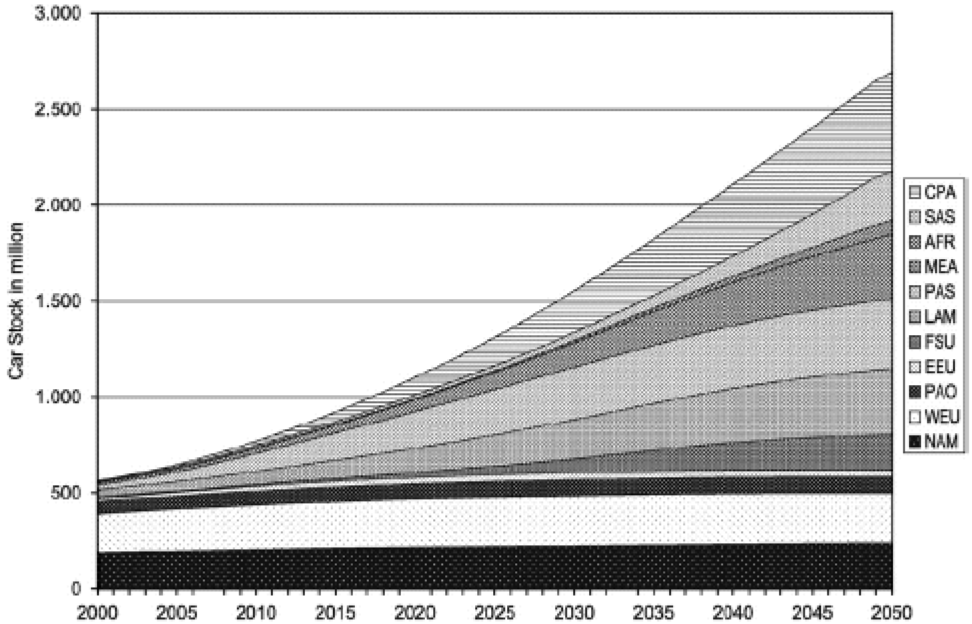


Fig. 5. Gompertz absolute car stock demand projections of eleven world regions, 2000–2050

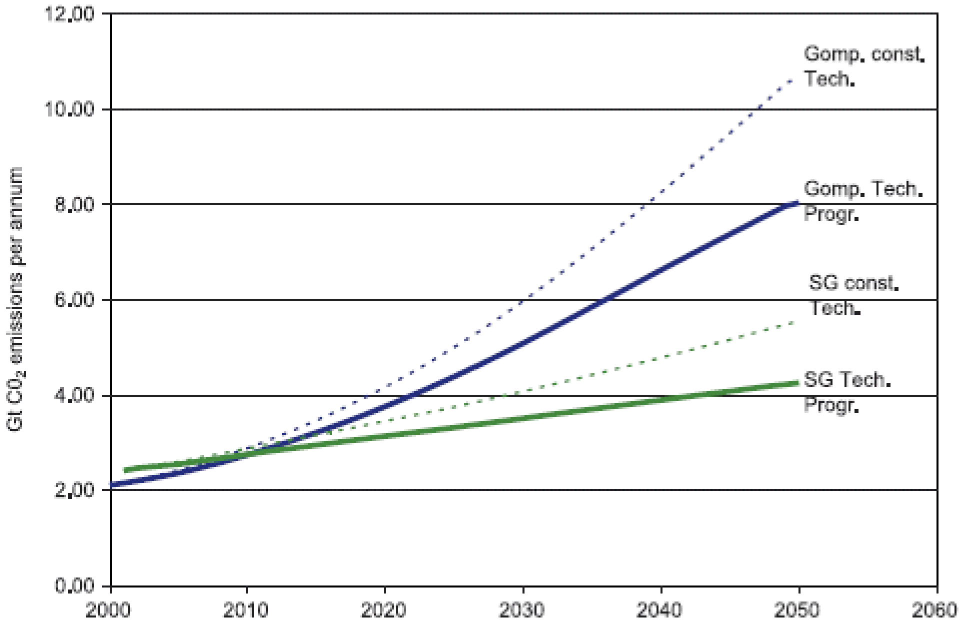


Fig. 9. CO_2 emissions scenarios from the global car fleet in use with and without fuel economy improvements.

Source: Meyer et al., 2007

W.6.1 Business as usual

Modes		Emissions	Demands / volumes	Assumptions on Economy	Autonomous development	Policies assumed
(as disaggregated as possible)		(in relevant units)	(if available)			
Total				– GDP growth – Population growth		None
Freight						
	individual freight modes if distinguished					
Passenger		4,3 (SG) - 8 (G) Gton CO_2 per annun				
	individual passenger modes if distinguished					

W.6.2 GHG reduction scenarios

For each scenario and relevant projection year a table in the form below. If there are too many scenarios only include the most relevant/ambitious ones.

Modes		Emissions / reductions	Assumptions on Economy	Reduction options included	Policy instruments included
(as disaggregated as possible)		(in relevant units)	(if different from BU)	(very short description)	(very short description)
Total			GDP growth. Population growth.	Vehicle fleet fuel consumption improvement of 1 L / 100 km each 20 years.	None.
Freight					
	individual freight modes if distinguis hed				
Passenger		- 33 % (G) and – 31 % S(G) in 2050.			
	individual passenger modes if distinguis hed				

W.7 Other remarks

The study is an extrapolation based on historic trends, which in this case do not lead to future reductions. Instead, it comes down to increased transport induced emissions in 2050.

Strong point is that it takes into account the possible future potential of world regions currently in development. While it also indicates that the car market in the developed countries is almost saturated, of which no high car stock growth is expected.

W.8 References

Leimbach, M. & Tòth, F.L. (2003). *Economic development and emission control over the long term: the ICLIPS aggregated economic model*. Climatic Change 56, 139–165.

Meyer, I., Leimbach, M. & Jaeger, C.C. (2007) *International passenger transport and climate change: A sector analysis in car demand and associated CO_2 emissions from 2000 to 2050.* Energy Policy 35, 6332 – 6345.