



# EU Transport GHG: Routes to 2050?

## Towards the decarbonisation of the EU's transport sector by 2050

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4 June 2010

### Partners



The project is funded by the European Commission's Directorate-General Environment



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Suggested citation: Skinner I, van Essen H, Smokers R and Hill N (2010) *Towards the decarbonisation of EU's transport sector by 2050* Final report produced under the contract ENV.C.3/SER/2008/0053 between European Commission Directorate-General Environment and AEA Technology plc; see [www.eutransportghg2050.eu](http://www.eutransportghg2050.eu)

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## Glossary<sup>1</sup>

BAU	Business as usual, i.e. the projected baseline of a trend assuming that there are no interventions to influence the trend.
BEV	Battery electric vehicle, also referred to as a pure electric vehicle, or simply a pure <b>EV</b> .
Biofuels	A range of liquid and gaseous fuels that can be used in transport, which are produced from biomass. These can be blended with conventional fossil fuels or potentially used instead of such fuels.
Biogas	A gaseous biofuel predominantly containing methane which can be used with or instead of conventional natural gas. Biogas used in transport is also referred to as biomethane to distinguish it from lower grade/unpurified biogas (e.g. from landfill) containing high proportions of CO <sub>2</sub> .
Biomethane	Biomethane is the term often used to refer to/distinguish biogas used in transport from lower grade/unpurified biogas (e.g. from landfill) used for heat or electricity generation. Biomethane is typically purified from regular biogas to remove most of the CO <sub>2</sub> .
CNG	Compressed Natural Gas. <b>Natural gas</b> can be compressed for use as a transport fuel (typically at 200bar pressure).
CO <sub>2</sub>	Carbon dioxide, the principal <b>GHG</b> emitted by transport.
CO <sub>2</sub> e	Carbon dioxide equivalent. There are a range of GHGs whose relative strength is compared in terms of their equivalent impact to one tonne of CO <sub>2</sub> . When the total of a range of GHGs is presented, this is done in terms of CO <sub>2</sub> equivalent or CO <sub>2</sub> e.
DG TREN	European Commission's Directorate-General on Transport and Energy. This DG was split in 2009 into DG Mobility and Transport (DG MOVE) and DG Energy.
Diesel	The most common fossil fuel, which is used in various forms in a range of transport vehicles, e.g. heavy duty road vehicles, inland waterway and maritime vessels, as well as some trains.
EEA	European Environment Agency.
EV	Electric vehicle. A vehicle powered solely by electricity stored in on-board batteries, which are charged from the electricity grid.
FCEV	Fuel cell electric vehicle. A vehicle powered by a fuel cell, which uses hydrogen as an energy carrier.
GHGs	Greenhouse gases. Pollutant emissions from transport and other sources, which contribute to the greenhouse gas effect and climate change. GHG emissions from transport are largely <b>CO<sub>2</sub></b> .
HEV	Hybrid electric vehicle. A vehicle powered by both a conventional engine and an electric battery, which is charged when the engine is used.
ICE	Internal combustion engine, as used in conventional vehicles powered by petrol, diesel, LPG and CNG.
Kerosene	The principal fossil fuel used by aviation, also referred to as jet fuel or aviation turbine fuel in this context.
Lifecycle emissions	In relation to fuels, these are the total emissions generated in all of the various stages of the lifecycle of the fuel, including extraction, production, distribution and combustion. Also known as WTW emissions.
LNG	Liquefied Natural Gas. <b>Natural gas</b> can be liquefied for use as a transport fuel.

<sup>1</sup> Terms highlighted in bold have a separate entry.

LPG	Liquefied Petroleum Gas. A gaseous fuel, which is used in liquefied form as a transport fuel.
MtCO <sub>2e</sub>	Million tonnes of <b>CO<sub>2e</sub></b> .
Natural gas	A gaseous fossil fuel, largely consisting of methane, which is used at low levels as a transport fuel in the EU.
NGV	Natural Gas Vehicle. Vehicles using natural gas as a fuel, including in its compressed and liquefied forms.
NO <sub>x</sub>	Oxides of nitrogen. These emissions are one of the principal pollutants generated from the burning of fossil and biofuels in transport vehicles.
Options	These deliver <b>GHG emissions</b> reductions in transport and can be technical or non-technical.
Petrol	Also known as gasoline and motor spirit. The principal fossil fuel used in light duty transport vehicles, such as cars and vans. This fuel is similar to aviation spirit also used in some light aircraft in civil aviation.
PHEV	Plug-in hybrid electric vehicle, also known as extended range electric vehicle (ER-EV). Vehicles that are powered by both a conventional engine and an electric battery, which can be charged from the electricity grid. The battery is larger than that in an <b>HEV</b> , but smaller than that in an <b>EV</b> .
PM	Particulate matter. These emissions are one of the principal pollutants generated from the burning of fossil and biofuels in transport vehicles.
Policy instrument	These may be implemented to promote the application of the <b>options</b> for reducing transport's <b>GHG emissions</b> .
TTW emissions	Tank to wheel emissions, also referred to as direct or tailpipe emissions. The emissions generated from the use of the fuel in the vehicle, i.e. in its combustion stage.
WTT emissions	Well to tank emissions, also referred to as fuel cycle emissions. The total emissions generated in the various stages of the lifecycle of the fuel prior to combustion, i.e. from extraction, production and distribution.
WTW emissions	Well to wheel emissions. Also known as <b>lifecycle emissions</b> .

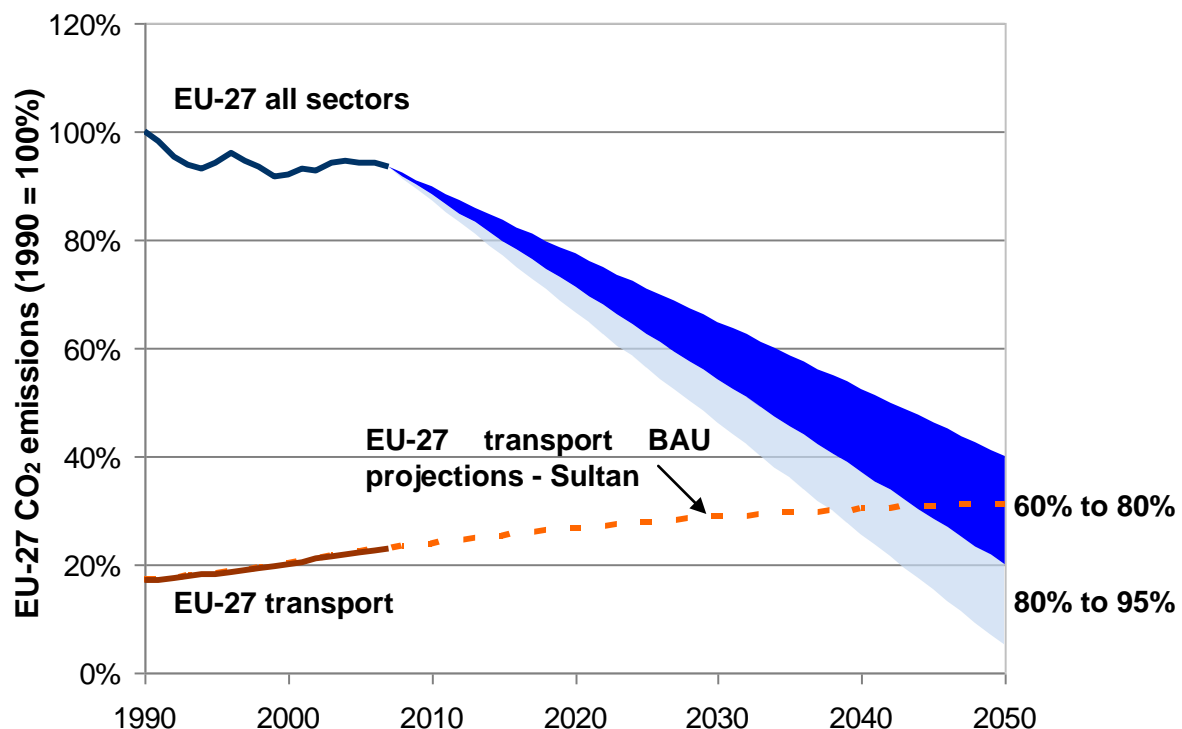
## Executive Summary

### Introduction and background to this project

In March 2010, the European Commission announced that it would make proposals to decarbonise transport. This announcement implicitly recognises that reducing greenhouse gas (GHG) emissions from transport is fundamentally important in meeting ambitious long-term, economy-wide GHG reduction targets. As yet, there has been no international agreement on such targets, but in December 2009 EU leaders called for international action in line with the EU objective of reducing GHG emissions by between 80% and 95% by 2050 compared to 1990 levels.

Decarbonising transport is likely to be challenging given that transport's greenhouse gas (GHG) emissions have continued to increase in recent years in spite of reductions in most other major sectors of the economy. This trend has the potential to undermine the EU's ability to achieve its long-term, economy-wide GHG reduction objective (see Figure 4). Under the assumptions used in this project, which included a continuation of recent improvements in vehicle efficiency, transport's GHG emissions in 2050 would be 74% higher than they were in 1990 and around 25% above 2010 levels without additional policy intervention. This increase is largely due to the anticipated growth in transport demand, particularly for maritime transport, which is projected to increase by more than 65% between 2010 and 2050, aviation, for which an increase of more than 50% is expected, and road freight (more than 45%).

Figure 1: EU overall emissions trajectories against transport emissions (indexed)<sup>2</sup>



<sup>2</sup> Based on a graph supplied by Peder Jensen of the EEA



In this context, it is important for the Commission to consider the long-term policy actions that might be necessary to reduce transport's GHG emissions, in order to build on the policy instruments already in place. This project aimed to provide information and analysis to assist the Commission with its thinking in this respect. It was undertaken for DG Climate Action (previously DG Environment) between December 2008 and March 2010 by a team led by AEA, and also involved CE Delft, TNO, ISIS and Milieu. The aim of the project was to identify the GHG reductions that might be achieved from all modes of transport, including international aviation and maritime transport, by 2050 and the policy instruments that might be required. It was based on a review of the evidence, extensive stakeholder engagement and the development of an illustrative scenarios tool called SULTAN<sup>3</sup>.

There are particular challenges associated with a project that is attempting to look 40 years into the future. First, it is difficult to know whether the transport vehicles and services of 2050 will be similar to, or distinctly different from, those of 2010. Second, as transport is largely a derived demand, which is determined by wider societal and economic developments, the society and economy of 2050 will be an important element in determining transport demand in 2050. However, given that some of the vehicles that will appear in the fleet in the next 10 years are likely to still be operating in 2050, particularly ships and aircraft, action taken in the next 10 years will influence transport's GHG emissions in 2050. Additionally, changes to the structure of the transport system, e.g. through changes in spatial planning, often take years to have their full impact, while new technologies typically take a number of decades to develop and mature. Hence, while challenging, this project was important in identifying what could be done given existing expectations.

### **The review of evidence**

An important element of the project was a review of evidence on available options, i.e. technical and non-technical measures that potentially reduce transport's GHG emissions, and on potential policy instruments that could stimulate the uptake of these options. This review was presented to and discussed with stakeholders at a series of meetings throughout the project.

The review identified that there were technical options that could reduce the GHG emissions of all modes of transport. These included options to reduce the GHG intensity of existing conventional fuels (through increasing the use of biofuels), improvements to the energy efficiency of existing vehicles and increased use of alternative energy carriers, such as electricity and hydrogen. Whilst it is not possible to anticipate technologies that have not yet been invented, an attempt was made to look at whether there are any promising concepts that could have a revolutionary impact on the transport sector and a major impact on GHG emissions. Most such technologies appear to raise the risk of increasing GHG emissions. Personal Rapid Transit systems appear to be one of the few options that might offer significant reduction potential, albeit for a limited part of the transport market.

The review concluded that energy efficiency improvements on some new vehicles of up to 50% are anticipated by 2050 (compared to 2010 levels), particularly for aircraft and ships, whereas for other modes the potential improvements are likely to be less without the use of alternative fuels and energy carriers. A range of non-technical options that could be taken up across all of the modes was also identified, including optimising speeds and routes, maximising utilisation of vehicles, maximising the use of co-modality and improving the structure of the transport system.

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<sup>3</sup> SULTAN (**S**Ustainab**L**e **T**r**A**Nsport) is an Excel-based tool that employs a backcasting approach to identify the potential implications for transport's GHG emissions of the uptake of a range of technical and non-technical options, supported by appropriate policy instruments. The tool is **not** based on a least-cost approach and is **not** predictive.

### Risks and uncertainties

It is important to note that the project was a backcasting exercise and therefore considered what would need to be put in place, but did not in great detail take account of whether the policies were likely to be implemented. While the technical reduction potential of the options considered was thoroughly considered, this does not guarantee that the options can or will actually achieve such GHG reductions in practice. There are likely to be different concerns and interests at play that may hamper the putting in place of many of the policies envisaged.

Another major uncertainty arises from the boundaries of the project and the assumptions that are made in other studies that have fed into this project. This is particularly the case for the decarbonisation of the energy used in transport. For example, while biofuels have the potential to reduce the GHG intensity of existing fuels, there are concerns about the availability of such fuels and the GHG reductions that are delivered once wider impacts, such as those associated with land use change, are taken into account. Similarly, electricity and hydrogen have the potential to deliver low carbon energy to some transport vehicles, but this requires that this energy is produced from essentially carbon-neutral sources. Challenges also exist in terms of the cost of these carriers and energy storage.

These risks and uncertainties merit further investigation, but point to the GHG reductions identified in the project as representing an upper bound of likely achievability. They also underline the need for a broad, ambitious and co-ordinated strategy to reduce transport's GHG emissions that requires the uptake of a wide range of technical and non-technical options.

### Scenario analysis: estimating the potential of all GHG reduction options

Taking into account these potential risks and uncertainties, a series of scenarios were developed in the SULTAN illustrative scenarios tool to estimate the potential GHG emissions that could be achieved in the transport sector. The first scenario focused on what could be achieved by substituting conventional fuels with biofuels. In this scenario, it was assumed that by 2050 biofuels could achieve well-to-wheel average GHG emissions savings of 85%, which is more than double the average savings in 2010, but that their use would be limited by the maximum production potential that has been estimated for the EU. In this case it was estimated that transport's GHG emissions would still be almost 30% higher than 1990 levels by 2050, although these would be slightly lower than transport's GHG emissions in 2010 (see Figure 14i).

The potential GHG emissions resulting from improvements in the technical energy efficiency of vehicles were estimated in another scenario in SULTAN, which concluded that these could deliver a reduction in transport's GHG emissions of 12% on 1990 levels by 2050. For new cars, this assumed the virtual elimination of pure internal combustion engines from the vehicle fleet and that these were replaced with significant numbers of hybrids, plug-in hybrids, electric and fuel cell cars. For other modes the potential for such a shift in technology is much more limited, but shifts to alternative energy carriers were assumed where it was considered that this might be possible. This scenario also assumed that the production of electricity and hydrogen used by transport would essentially be carbon-neutral.

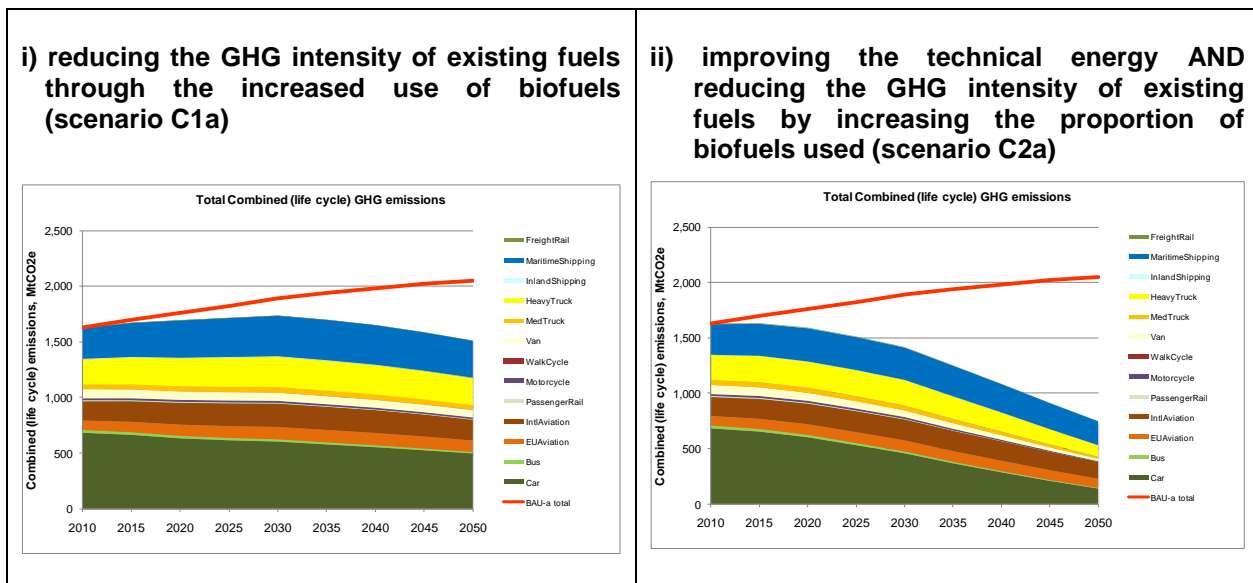
If all technical options were taken up, i.e. if biofuels were used to reduce the GHG intensity of fuels, in addition to very significant improvements to the technical energy efficiency of vehicles, it was estimated that GHG savings of 36% on 1990 levels could be achieved by 2050 (see Figure 14ii)<sup>4</sup>. Consequently, on the basis of the scenarios developed for SULTAN,

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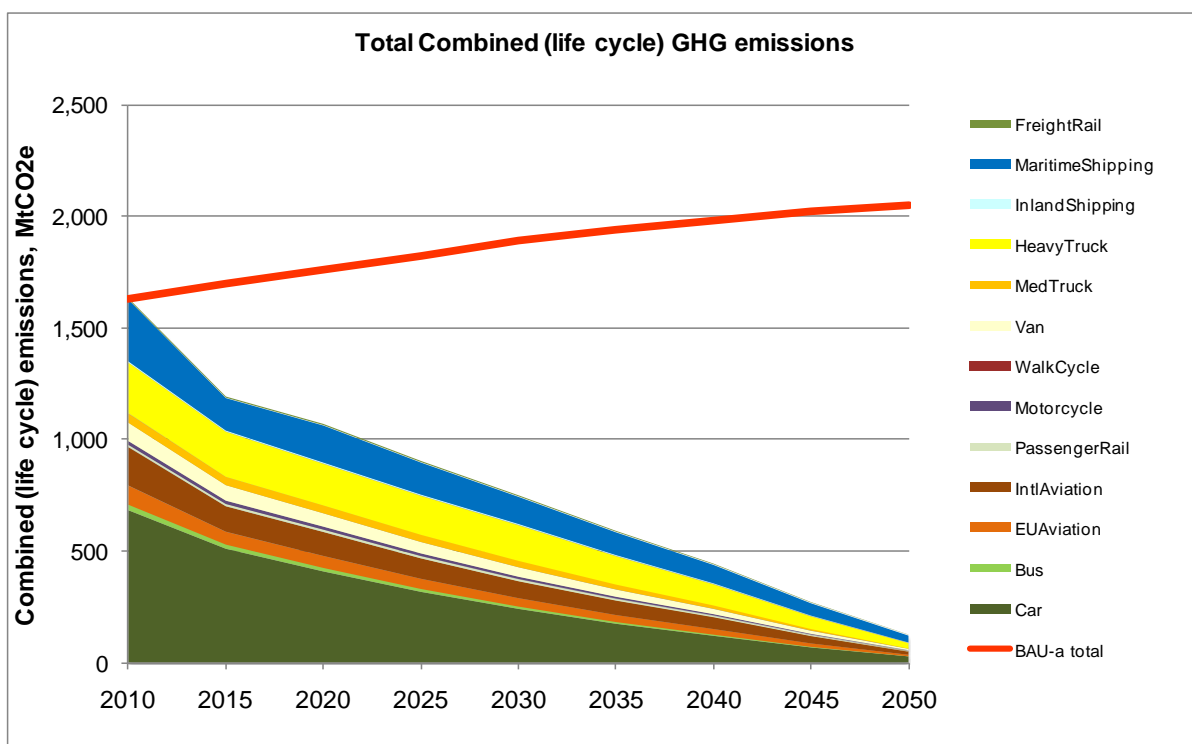
<sup>4</sup> Note that the separate figures for biofuels and improvements in the technical efficiency of vehicles are not additive, as the uptake of both options would reduce the individual impact of the other.

it can be concluded that it seems very difficult (if not impossible) to reduce GHG emissions from transport by 50% or more through the uptake of technical options alone.

**Figure 2: Reductions in transport's GHG emissions by mode resulting from:**



**iii) the introduction of economic instruments to improve the economic efficiency of transport and the creation of a level playing field AND the stimulation of other technical and non-technical options for all modes (scenario C5c)**



A series of scenarios were developed in SULTAN based on the findings from the review of non-technical options. These concluded that if non-technical options were taken up in addition to technical options, GHG emissions from transport could be reduced by around 89% by 2050 compared to 1990 levels (see Figure 14iii). This required the introduction of policy instruments to stimulate the uptake of a range of non-technical options, including

improved spatial planning, speed enforcement, lower motorway speeds and more fuel efficient driving, to improve the efficiency of the transport system. Additionally, economic instruments were used to create a level playing field across all of the modes (from the perspective of their taxation), to internalise a range of external costs and to remove existing subsidies. Of these individual scenarios, harmonising fuel duties and VAT across the modes (at the level of those currently paid by private road transport) delivered GHG savings of over 10% compared to business as usual, while the inclusion of a high CO<sub>2</sub> charge in fuel prices has the potential to deliver nearly a 20% reduction compared to business as usual.

### **Both technical and non-technical options are needed**

It can therefore be concluded that in order to reduce transport's GHG emissions by around 89% compared to 1990, it is essential that both technical and non-technical options are taken up. Given the already ambitious assumptions underlying the technical scenarios, it would be very challenging (if not impossible) to deliver such levels of GHG emission reduction by stimulating technical options alone, particularly in light of the significant uncertainties and risks associated with the principal alternative fuels and energy carriers. Additionally, the modes with the largest projected growth have relatively fewer decarbonisation options and often have slower fleet turnovers.

### **The importance of co-benefits**

It is also important to note that many of these options also have the potential to contribute to the delivery of other EU and national policy objectives, as they deliver co-benefits. For example, any option that reduces the demand for energy contributes to delivering energy security objectives, while options that reduce the amount of fossil fuels used have the potential to reduce the amount of conventional pollutants emitted. Additionally, some of the options could be taken up for other reasons, e.g. co-modality in urban areas is often promoted to ease congestion and enable access. Taking these elements into account is vital to understand the cost-effectiveness of GHG reduction policies rather than focussing purely on the cost of GHG avoided.

### **The problematic issue of costs**

In order to ensure that the most appropriate policy action is undertaken, the issue of costs becomes important. However, the consideration of costs is problematic when attempting to assess the options and policy instruments that are needed for meeting a target that is 40 years into the future. Additionally, there are issues with attempting to estimate the costs associated with climate change, where there are risks of rapid and dramatic changes to the climate. While the estimation of the costs of GHG abatement and Marginal Abatement Cost curves are useful for comparing options, such assessments are too narrow to dominate the discussion on GHG abatement for a number of reasons. Of particular importance in relation to the delivery of a virtually carbon-neutral transport system is the fact that the stimulation of least cost options might not be appropriate, as a transition, rather than incremental changes, is required. Additionally, some of the options that are not yet cost effective have long lead times and therefore need to be implemented at an early stage in order that they can contribute to meeting the 2050 targets. Focusing on the least cost GHG abatement options also risks ignoring the co-benefits of these options, which can also be significant.

### **Impacts of speed and wider economic trends**

As transport demand is dependent on wider social and economic trends, achieving a virtually carbon-neutral transport system by 2050 also requires action in the wider economy and society. In recent decades, there has been an apparent link between existing patterns of economic development and the demand for transport, even though demand for passenger travel has been increasing at a lower rate than economic growth. While there is some evidence from the UK that demand for daily passenger transport might be reaching a saturation point, other evidence suggests that people are prepared to travel between 60 and

70 minutes a day. Consequently, as modes have become faster, and faster modes have become more widely available, travel has increased. On the other hand, one of the drivers of transport demand – population growth – is predicted to become a decline over the next 40 years. Hence, there are a number of alternative and potentially contradictory trends in transport and the wider economy and society that need to be better understood in order to ensure that transport can be virtually decarbonised by 2050.

### **Policy conclusions: How to achieve significant GHG reductions in transport**

In theory, in a perfect market, the use of economic instruments to internalise the external costs of transport, and thus reduce GHG emissions and other externalities, is the first best and most efficient approach. However, in practice, deviations from such an approach are necessary for a number of reasons, not least the challenge of addressing the split incentives that exist within the transport system, e.g. it is the manufacturers that are required to invest in (initially expensive) technology, whilst it is the users who benefit from the subsequent reduced fuel consumption. Hence, it will be necessary to apply both push (supply side) and pull (demand side) instruments. This is especially the case with respect to the transitional technologies that are needed, as these are characterised by long lead times and require high investments in (energy) infrastructure.

Hence, regulation to improve the energy efficiency of all vehicles – not just the road vehicles that are currently targeted by EU legislation – is needed, coupled with parallel legislation to reduce the GHG intensity of the fuels and energy used by all transport modes. This is particularly important as delivering virtually carbon-neutral electricity and hydrogen will also require action in sectors other than transport. Hence, regulations need to be designed so that they act together to foster the co-evolution of the transport and energy systems that are needed for a virtually carbon-neutral transport system. Additionally, systems need to be put in place to ensure that the fuels and energy used by transport deliver improvements in GHG intensity when measured over their entire lifecycles, and that the increased use of such fuels and energy carriers does not have other adverse environmental impacts. In most cases, such regulations will need to be developed at the EU level, although for international modes such as aviation and shipping, it might be more appropriate, although more difficult, for regulation to be at the global level, e.g. through the respective international organisations. Given the longer lifetimes and therefore lower fleet turnovers for these modes, it is particularly urgent that the necessary regulation is introduced as soon as possible.

In parallel, there is a need to internalise the external costs of transport, e.g. by including a CO<sub>2</sub> charge in fuel taxation and using kilometre charging to internalise the external costs of air pollution and congestion. Targeted economic instruments should also be applied to stimulate the purchase and use of more fuel efficient vehicles and less GHG intensive fuels and energy carriers, while existing hidden subsidies and perverse incentives should be eliminated. In the short-term, the EU has a role to play in enabling and stimulating these instruments, while in the longer-term, there might be a case for a more extensive instrument, such as a carbon tax or emissions trading for transport.

A range of other policy instruments are also important in reducing transport's GHG emissions, such as improved spatial planning, the enforcement, imposition (where necessary), and lowering of speed limits and instruments to stimulate co-modality. Information instruments should be used *inter alia* to increase awareness of the need to, and means, of reducing GHG emissions from transport, inform users of the range of transport options available and overcome any barriers relating to unfamiliarity with new technologies or transport modes. While economic instruments and regulation can help to stimulate innovation and the development of new technologies, other instruments are also useful in this respect, including support for fleet tests, demonstration programmes, research and development. Green public procurement should also be used to assist new, more expensive technologies to increase

their market share. In addition, the use of complementary instruments is important to address any rebound effects that might result from, for example, reductions in the marginal cost of travel resulting from the use of more energy efficient vehicles and any additional travel that might be stimulated by increases to the capacity of the transport network.

Given the GHG emissions reductions required, early policy action is needed to stimulate the uptake of the range of options available to the extent required. As noted above, the EU has a role in enabling and stimulating the use of many of these instruments, but action is also needed at the Member State and regional/local levels. In summary, at the EU level the following policy instruments are needed:

- Regulation of the energy efficiency of vehicles and the GHG intensity of fuels and energy carriers. Relevant standards for all vehicles for all modes should be developed, in cooperation with international bodies such as the IMO and ICAO where appropriate and possible. Once in place, such standards should be progressively tightened and developed in parallel with the equivalent policy targeting the GHG intensity of fuels and energy carriers.
- Standards and criteria to ensure that alternative fuels and energy carriers deliver GHG emissions and do not have other adverse sustainability impacts.
- Economic instruments to internalise the external costs of transport for all modes and the harmonisation of pricing policies for transport.
- The elimination of existing hidden subsidies and perverse incentives.
- Support for innovation and the development of new technology.
- Review of EU policy towards the development of transport networks.
- Development of evaluation tools to reflect better GHG emissions.

Additionally, some important policy instruments that are needed are usually considered to be the competence of Member States or regional and local authorities. The Commission and the relevant authorities should work together to achieve coordinated action and share good practice with respect to:

- Harmonising and lowering speed limits.
- Optimal spatial planning policies for GHG reduction in transport.
- Setting the framework for the differentiation of vehicle taxes (purchase, registration and circulation) by CO<sub>2</sub> emissions.
- Develop new business models for transport.

# 1 Introduction

## 1.1 The need to reduce transport's greenhouse gas emissions

In the run-up to the Conference of the Parties of the UN Framework Convention on Climate Change in December 2009, the leaders of the EU's Member States called for significant reductions in global greenhouse gas (GHG) emissions:

“The European Council calls upon all Parties ... to agree to global emission reductions of at least 50%, and aggregate developed country emission reductions of at least 80-95%... It supports an EU objective, in the context of necessary reductions according to the IPCC by developed countries as a group, to reduce emissions by 80-95% by 2050 compared to 1990 levels.”<sup>5</sup>

The key role that transport has to play in this long-term economy-wide aspiration was underlined by European Commission President Barroso in his *Political Guidelines for the next Commission*<sup>6</sup> where he emphasised the need to maintain the momentum towards a low carbon economy and towards decarbonising the transport sector in particular. In March 2010, the Commission, as part of its *Europe 2020* strategy<sup>7</sup>, announced that it would make proposals to decarbonise transport, and in doing so linked the need to decarbonise transport with the wider sustainable growth agenda.

These high level political statements set the framework within which this project was undertaken.

## 1.2 The aims and objectives of the project

In this context, it is clearly important for the Commission to begin to think about the long-term actions needed to reduce transport's GHG emissions. One of the main aims of this project was to provide information and analysis to assist the Commission with its early thinking on a co-ordinated approach to reducing the GHG emissions of all modes of transport.

Consequently, the approach taken within the project was to review existing evidence, and engage with EU level transport stakeholders, in order to identify the GHG reduction potential of various measures that could be applied in the transport system. The various GHG reduction potentials were then brought together in order to identify the extent of the GHG emissions reductions that could be delivered within the transport sector by 2050. Clearly, in order to reach ambitious economy-wide reduction targets, such as those supported by the European Council, action will need to be taken in all sectors of the economy. However, this project aimed to identify what transport might deliver in light of the orders of magnitude of the reductions that will be needed<sup>8</sup>. A full list of the papers and reports produced by this project can be found in Appendix 1; the documents themselves can be found in Appendices 2 to 20.

In order to identify the GHG reductions that transport could potentially deliver by 2050, an Excel-based illustrative scenarios tool (IST) called SULTAN (**S**Ustainab**L**e **T**rANsport) was developed. A backcasting approach was used under which the GHG reduction potential of

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<sup>5</sup> *Presidency Conclusions*, Brussels European Council, 29/30 October 2009; see <http://register.consilium.europa.eu/pdf/en/09/st15/st15265.en09.pdf>

<sup>6</sup> Barroso, J (2009) *Political Guidelines for the next Commission*, September 2009, Brussels

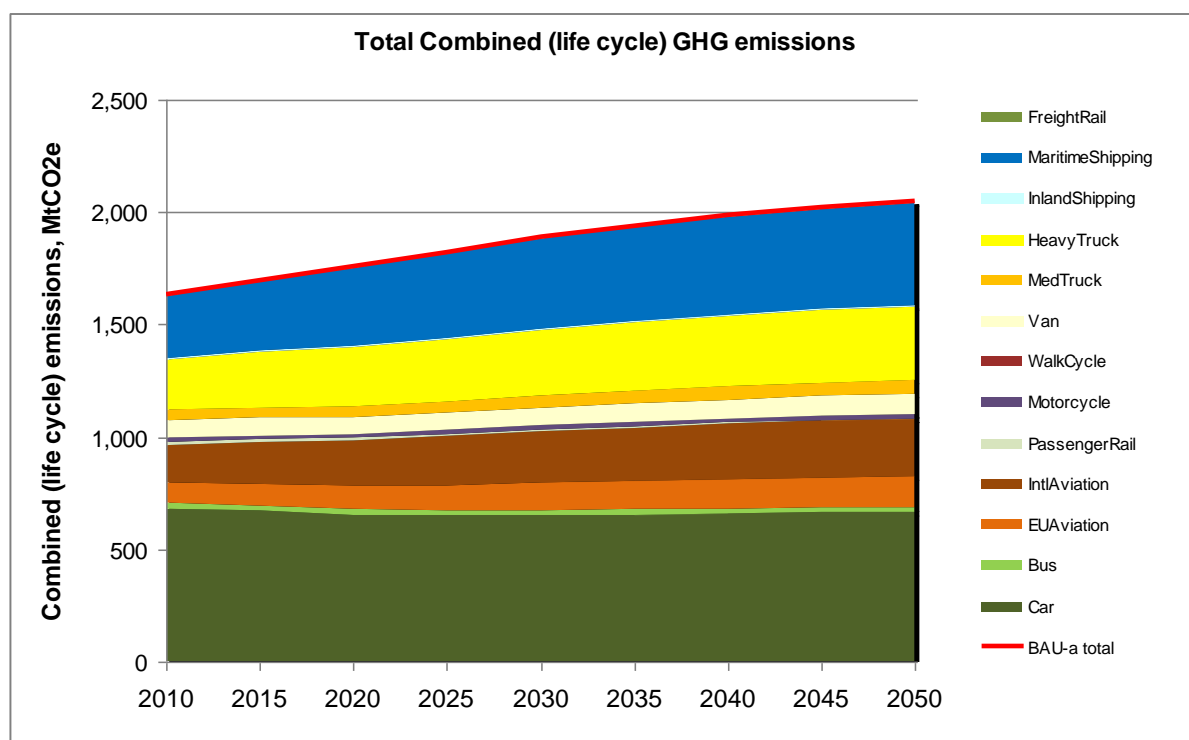
<sup>7</sup> European Commission (2010) *Europe 2020: A strategy for smart, sustainable and inclusive growth* COM(2010)2020, Brussels 3.3.2020.

<sup>8</sup> For a full description of the project methodology, see Appendix 20

various illustrative scenarios were identified (see Section 5 for more details of the approach and the GHG reduction potential of the various scenarios). It is important to note that the tool cannot be considered to be a model and is not based on a least cost approach; neither is the tool attempting to forecast what will happen. Rather it is trying to improve understanding of the potential GHG reductions that are possible from transport based on what is currently known and what might be envisaged, and to use this information to identify what policy action might be needed to reach certain objectives. Once the respective GHG reduction potentials were identified, policy frameworks, consisting of coordinated packages of complementary instruments, that potentially need to be implemented in order to stimulate the uptake of these options were developed (see Section 6).

The increasing political importance that is being attached to decarbonising transport reflects the fact that, of all the economy's sectors, transport has proved to be one of the most problematic in terms of reducing its GHG emissions. Since 1990, GHG emissions from transport, of which 98% are carbon dioxide (CO<sub>2</sub>), had the highest increase in percentage terms of all energy related sectors<sup>9</sup>. Furthermore, transport's GHG emissions are predicted to continue to increase, without additional measures, to over 2,000 MtCO<sub>2</sub>e by 2050 (see Figure 3).

**Figure 3: Business as usual projected growth in transport's GHG emissions by mode**



Source: SULTAN Illustrative Scenarios Tool, developed for this project

An increase of the order projected in Figure 3 would leave transport's GHG emissions 74% higher in 2050 than they were in 1990, when transport's GHG emissions were nearly 1,200 MtCO<sub>2</sub>e, and around 25% above 2010 levels. By mode, significant increases between 2010 and 2050 are projected for road freight (for which an increase of more than 45% is projected), aviation (more than 50%) and maritime (more than 65%) without additional policy instruments. Whilst GHG emissions from cars are still projected to contribute the most to the sector's GHG emissions in absolute terms in 2050, their emissions are projected to have

<sup>9</sup> DG TREN (2000) *Energy and transport in figures 2008-2009*

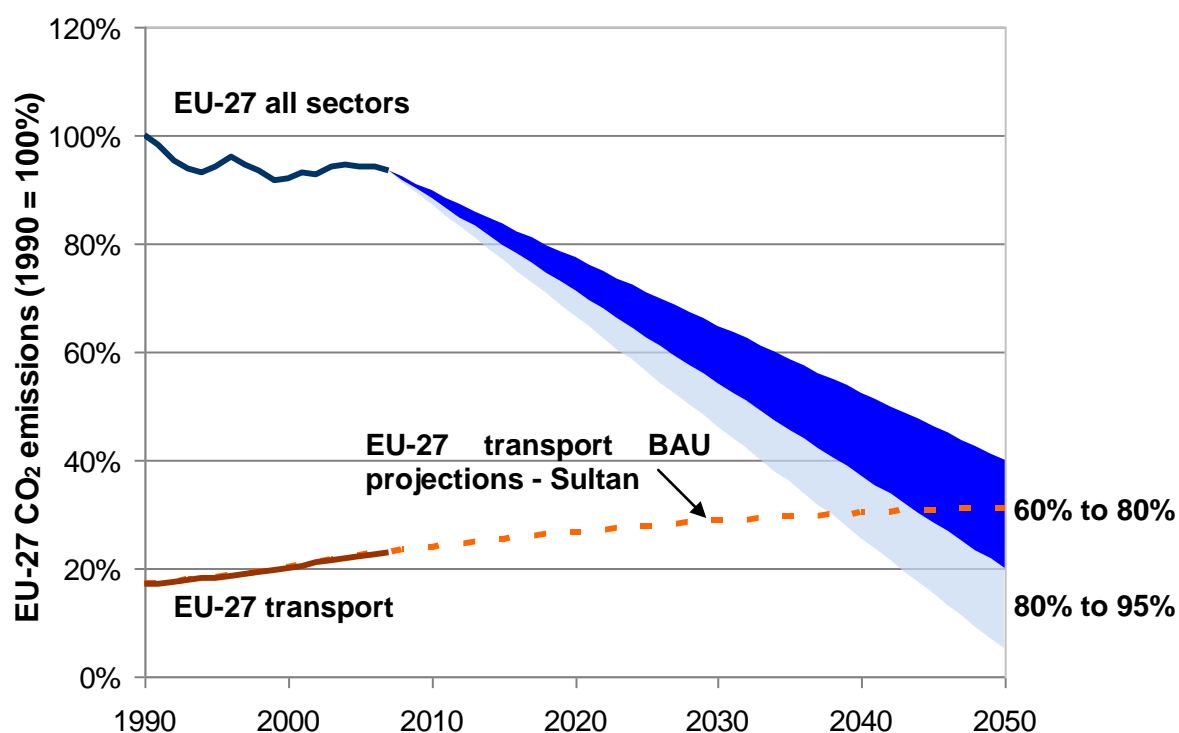


declined slightly from 2010 levels, as anticipated improvements in the energy efficiency of vehicles negate projected increases in demand.

Figure 3 shows the baseline, as projected by SULTAN. This is consistent with the range of results from other models and tools, although many of these only project to 2030<sup>10</sup>. Clearly, the predicted continued growth in the EU-27's GHG emissions from transport has the potential to prevent the EU meeting the long-term GHG emission reduction targets that the European Council supports, if no action is taken to reduce these emissions.

Figure 4 demonstrates that on current trends, transport emissions could be around 30% of economy-wide 1990 GHG emissions by 2050<sup>11</sup>. Whilst simplistic, in that it assumes linear reductions, the figure demonstrates that there is clearly a need for additional policy instruments to stimulate the take up of technical and potentially non-technical options that could potentially reduce transport's GHG emissions. The EEA believes that all available policy instruments need to be used to achieve the ambitious GHG reduction targets<sup>12</sup>.

**Figure 4: EU overall emissions trajectories against transport emissions (indexed)<sup>13</sup>**



The aim of this project, therefore, is to identify whether and, if so, how such GHG emissions might be achieved. Clearly, there are significant challenges for a project that is trying to look 40 years into the future and identify subsequent implications for policy. Thirty years ago, few would have predicted the prevalence, let alone the extent of the development, of mobile

<sup>10</sup> See Appendix 19 *SULTAN: Development of an Illustrative Scenarios Tool for Assessing Potential Impacts of Measures on EU transport GHG* for details of the assumptions used and approach taken in the SULTAN Illustrative Scenarios Tool to projecting business as usual GHG emissions; also see <http://www.eutransportghg2050.eu>

<sup>11</sup> The emissions included in this figure – for both the economy-wide emissions and those of the transport sector – include emissions from international aviation and maritime transport, in addition to emissions from “domestic” EU transport.

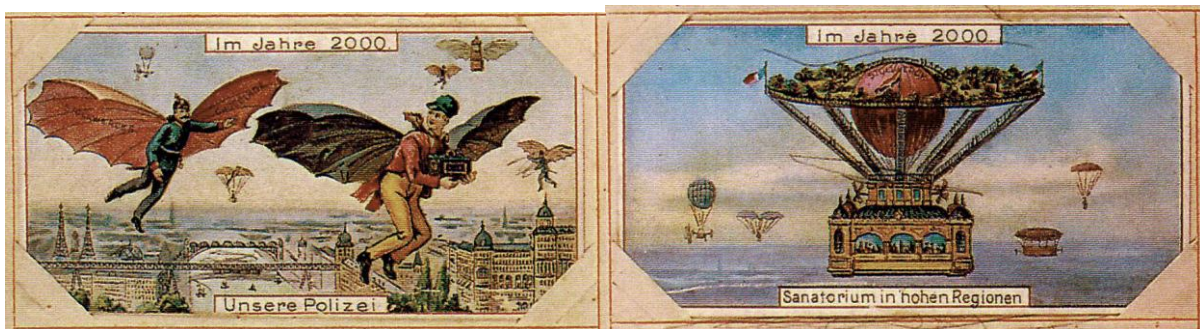
<sup>12</sup> EEA (2009) *Towards a resource-efficient transport system – TERM 2009: indicators tracking transport and environment in the European Union*, EEA Report No2/2010, Copenhagen.

<sup>13</sup> Based on a graph supplied by Peder Jensen of the EEA

phones and personal computers in 2010. The difficulties of predicting future transport trends is demonstrated in Figure 5, which illustrates that policing and healthcare in 2000 did not turn out the way in which some people had imagined in 1990. Having said that, the internal combustion engine was also the primary source of propulsion for road vehicles in 1970, and the cars in use 40 years ago are not that dissimilar, at least in outward appearance, from those of 2010. Consequently, it is more than likely that the vision presented in this project will not be correct, in the same way that the many other studies that have attempted to look at the future transport system will not be correct. However, the aim is to identify what could be achieved based on the best available knowledge obtained from both the literature review and the stakeholder engagement undertaken as part of this project.

An additional challenge for the study is that it covers all modes of transport, each of which is used differently and uses different technologies – a picture that is likely to become even more complex in the future (see Section 2). The aviation and maritime sectors are also more international in nature than road or rail and thus emit GHGs both domestically (i.e. journeys undertaken within a particular country) and internationally. These different characteristics will also influence the scope for emissions reductions by mode, as well as the measures that might be applied to reduce these emissions and the appropriate administrative level responsible for their introduction (i.e. international, European, national or local).

**Figure 5: Predictions from 1900- Policing and healthcare in the year 2000**



Source: *Verkehr im Jahre 2000*; Gebr. Stollwerck, Köln am Rhein

### 1.3 Review of projections and scenarios for transport in 2050

It is worth noting that this project was not the first that attempted to identify how transport's GHG emissions might be reduced up to 2030 and on to 2050. Many other reports have tried to model or develop scenarios to identify how transport's GHG emissions might develop and be reduced in the future. These studies include the identification of the options that might have to be taken up and of policy instruments that might have to be introduced in order to achieve these reductions. In order to provide a wider context for this project, in particular the illustrative scenarios tool, the principal long term scenario studies on the EU transport sector (up to 2030 and 2050), which included GHG emissions, were reviewed<sup>14</sup>.

The studies reviewed suggested that if no action was taken in addition to policy that has already been agreed (usually referred to as the business as usual or BAU scenario) *total global GHG emissions* for all sectors are expected to increase by between 150% and 200% compared to 1990 levels. Even those scenarios that assume that additional measures and policies are implemented (i.e. reduction or vision scenarios) expect an *increase* in the overall global GHG emissions compared to 1990 levels. A minority show a decrease in global GHG emissions compared to 1990 levels and only one scenario approaches an 80% reduction.

<sup>14</sup> See Appendix 17 *Review of projections and scenarios for transport in 2050* for more details; also see <http://www.eustransportghg2050.eu/cms/additional-reports/>

*Global transport emission trends* in the vision scenarios show reductions of the same order of magnitude as the economy-wide trends. This seems to contradict a statement that can be found in most of the studies that GHG emissions reductions in transport will lag behind economy-wide emissions reductions. A possible cause for this discrepancy is that many of the backcasting studies assume common reduction targets for all sectors and therefore automatically arrive at common reductions without taking into account the optimisation of costs. An alternative explanation might be that in the long run the cost effectiveness of GHG reductions in various sectors converges.

The *total economy-wide emissions in the EU* in BAU scenarios are expected to increase by less than 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 an EU wide reduction of 80% compared to 1990 levels are rare. However, a general consensus appears to be that Europe will be a forerunner in emissions reduction.

*Transport emissions in the EU* are expected to increase less in the BAU scenarios than for global emissions from transport, while in reduction scenarios these are expected to reduce more than the global total. In the reduction scenarios, for the EU (as was the case at the global level) most studies assume that transport will need to contribute its fair share to the reductions.

In addition to emission trends, various studies also present data on transport demand trends, which is a key driver for GHG emissions growth. *Transport demand* is universally expected to increase. The median increase for modes except aviation 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, although not to reduce overall demand.

More than half of the vision scenarios assume that the *carbon intensity* improvements resulting from technological innovation will counteract increases in demand, thus leading to an overall decrease in emissions relative to the current level. However, road transport is expected to continue to dominate both passenger and freight transport. Having said that, most studies exclude international or intercontinental shipping and aviation, which are two large sources of CO<sub>2</sub> emissions (as noted above). This omission leads to a bias in the estimates of potential emissions reduction.

*Technical options* are expected to contribute a major share of GHG emissions 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 technical options concern road transport and most innovations are expected in passenger transport. An autonomous improvement of about 20% is expected, but the total reduction potentials in the reduction scenarios are generally less than 50%. Of all technical options, biofuels are the most popular, especially for road freight transport and aviation. This is mostly due to the comparative lack of other technical solutions to reduce GHG emissions for these modes. More than half of the studies disregard (or ignore) concerns with the sustainability of biofuels, including those relating to their availability and GHG reduction potential (see Section 5.2.1). Of the *non technical options*, modal shift (or "greater intermodality") is expected to have the highest potential in most scenarios, but this is not assumed to be more than a few percentage points. Most studies assume that private road transport will continue to dominate both passenger and freight transport.

With respect to *policy instruments*, all studies appear to agree that to achieve significant reductions in GHG emissions, international cooperation is paramount. The scenario studies that incorporate global cooperation score best in terms of reduction potential; 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<sub>2</sub> emission targets are widely considered to be important to assist industry in reaching its full potential, but it is underlined that these instruments should be technologically neutral. Emissions trading systems or CO<sub>2</sub> taxes are often considered to be beneficial if applied fairly and in a way that is not restrictive to economic development.

Finally, most studies emphasize that *immediate action* is required to achieve the more ambitious reductions. These suggest that if we do not “act now”, significant reductions may be not realised or the costs of GHG reductions may increase dramatically.

## 1.4 Drivers of existing transport demand

Before considering how transport's GHG emissions might be reduced, it is important to note that transport is largely a derived demand. In other words, little transport is undertaken simply for the sake of it; rather undertaking transport, either moving passengers or goods around, serves wider social and economic objectives. Hence, transport demand is driven by a range of external factors, including:

- GDP growth and increasing personal incomes, generally.
- Globalisation.
- Tourism.
- Urbanisation.
- Population growth.
- Employment rates.
- Information and Communication Technology (as it reduces transport costs).
- Decreasing real cost of transport, particularly of the faster modes, including increased car ownership (making these more affordable for more people).
- Increasing speed of transport, which brings more distant goods, services, jobs, etc within reach.

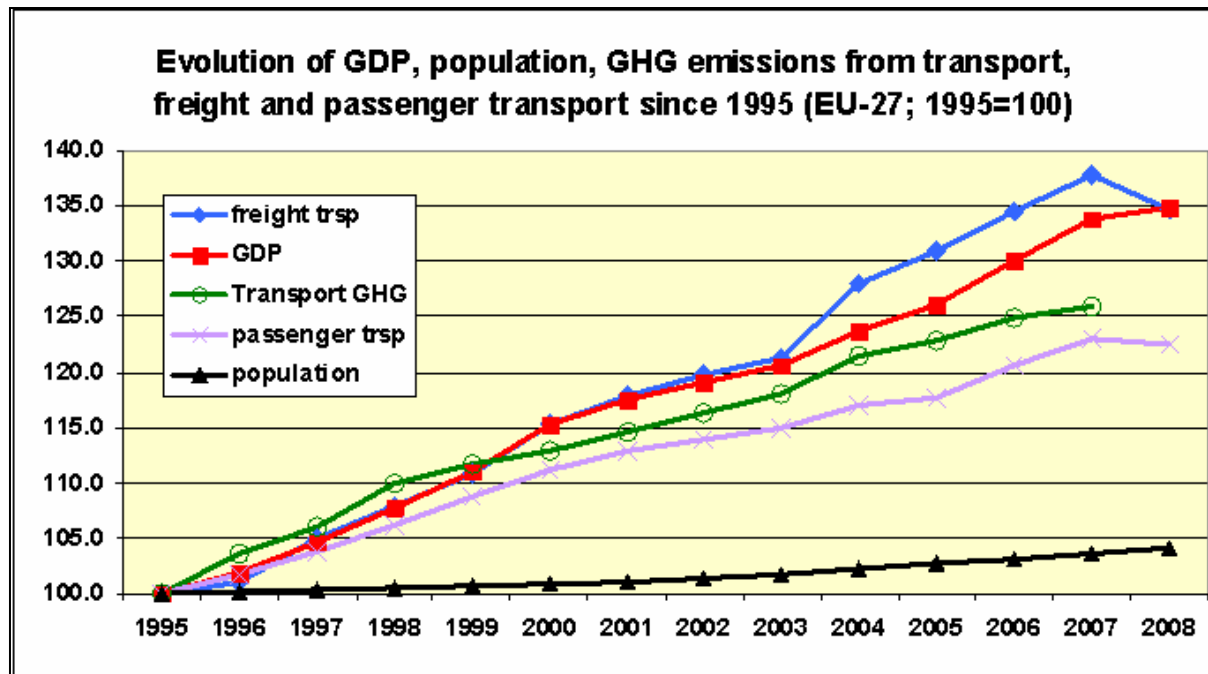
The extent to which these factors are dependent on transport, or whether there is the potential to decouple transport from the underlying trends, is a matter of debate. Recent data suggests that there has been a recent divergence in the growth in passenger transport compared to GDP growth, whereas freight has continued to grow at a higher rate (see Figure 6).

However, it is generally considered that the factors listed above lead to increases in demand and thus increase transport's GHG emissions. On the other hand, there are some external drivers that potentially reduce the demand for transport and thus its GHG emissions. Of particular importance in this respect are higher energy prices, which have experienced significant fluctuations in recent years that have influenced transport demand, although the long-term trend in energy prices, in real terms, is still declining.

Other factors have the potential to both increase and reduce transport demand, and the overall impact will depend on the net balance. For example, the provision of infrastructure could contribute to lower GHG emissions if, for example, this encourages the use of less GHG intensive modes, but could increase GHG emissions if overall capacity is increased or travel times are reduced. Similarly, an ageing population is likely to use public transport more

frequently, although there are increasing trends for the older population to drive further and use aircraft more for leisure purposes than before.

**Figure 6: Recent trends in GDP, population, demand for passenger and freight transport and transport's GHG emissions**



Source: DG TREN *Energy and Transport in figures*

## 1.5 Challenges of introducing new technologies and concepts

As was demonstrated by Figure 3 and Figure 4, GHG emissions reductions are likely to be needed from all modes if significant reductions in GHG emissions from the EU transport sector are to be achieved by 2050. A key factor in determining the role that different modes might play in reducing transport's GHG emissions are the timescales involved in developing new technologies and infrastructure and in stimulating the penetration of new technologies into the vehicle fleet<sup>15</sup>. Of importance in this respect is the fact that the lifetimes of vehicles used by different modes vary considerably.

Road vehicles tend to have shorter lifetimes than trains, aircraft and ships and they also tend to have shorter development times. In terms of the potential contribution to GHG reduction by 2050, one could therefore expect a full contribution from new road vehicle technologies by 2050, but the contribution from new technologies for rail, aviation and shipping would depend on a number of factors. This is not to say that these contributions might not be significant or vital, just that given the lifetime of these vehicles, full development and market penetration would be more challenging to achieve. Retrofitting offers a number of opportunities for GHG emissions reduction from these modes and needs to be fully explored.

Key factors in terms of GHG reduction are the use, lifetime and lifecycle emissions of the new technologies. For example, the GHG reduction benefit of a new vehicle is less obvious if the vehicle will complement rather than replace existing vehicles, if its lifetime is shorter than that of existing vehicles and if its lifecycle emissions are greater. There is the potential for

<sup>15</sup> See Appendix 16 *An overview of the factors that limit new technology and concepts in the transport sector* for a further discussion of this issue; also see <http://www.eutransportghg2050.eu/cms/additional-reports/>

policy measures to have unwanted, unintended impacts, if these factors are not taken into consideration. Such factors are relevant for the prioritisation of policy instruments (see Section 6.3.1).

The lifecycle GHG emissions of alternative energy carriers or fuels and the energy efficiency of vehicles are also important in determining the net GHG benefit of introducing these alternatives. Whereas the respective GHG emissions for petrol and diesel outside of their use are relatively similar, the advantages of alternative fuels, such as biofuels and alternative energy carriers, such as electricity or hydrogen, is that these have the potential to deliver significant GHG reductions when measured over the lifecycle of the fuel. In other words, these fuels make sense from the perspective of reducing transport's GHG emissions when the GHG emissions from the production of the fuel/energy carrier, i.e. the GHG emissions emitted in the course of extraction, production and distribution, are also taken into account. For transport, such lifecycle emissions are generally referred to as well-to-wheel (WTW) emissions, i.e. covering all GHG emissions emitted from the source of the fuel (e.g. the extraction of the oil at the well) until it is used (at the wheel). In the context of transport's WTW emissions, the consideration of well-to-tank (WTT) and tank-to-wheel (TTW) is also important in order to distinguish between the GHG emissions emitted before the fuel is put into a vehicle's fuel tank and those that are emitted in the course of a vehicle's use<sup>16</sup>. It is also important to be aware of the GHG emissions associated with the construction and maintenance of associated infrastructure.

## 1.6 The need for an alternative policy approach

In the last few years, the EU has put in place a range of policy instruments that are aimed at reducing GHG emissions from the transport sector, e.g.:

- Passenger car CO<sub>2</sub> Regulation<sup>17</sup>.
- Inclusion of aviation in EU Emissions Trading Scheme<sup>18</sup>.
- Clean road vehicles Directive<sup>19</sup>.
- Proposed Regulation on CO<sub>2</sub> from vans<sup>20</sup>.
- Renewable Energy Directive<sup>21</sup>.
- GHG intensity reduction requirement of amended Fuel Quality Directive<sup>22</sup>.

However, to date these measures have not been part of a broad strategy. Given the scale of the challenge faced by the EU in terms of decarbonising transport a **coordinated, strategic approach** should help to ensure that the best measures are undertaken at the most appropriate time. Of course, the definition of "best" and "most appropriate" is open to debate and depends on the perspective taken. However, the fact that most modes of transport emit GHGs means that most modes are likely to be part of the solution, i.e. they will need to contribute to reducing GHG emissions in some way.

Another effect that underlines the importance of a coordinated, strategic approach to reducing transport's GHG emissions is the existence of so-called "**rebound effects**", which will be discussed in more detail in Sections 3 and 5.2.5). Essentially, rebound effects are indirect, second order effects of policy instruments, which are often unintended and have the

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<sup>16</sup> Of course, for biofuels and other energy carriers, it is not strictly accurate to refer to WTW, WTT or TTW emissions, but the terminology is still used in such cases for the purpose of clarity.

<sup>17</sup> Regulation (EC) No 443/2009

<sup>18</sup> Directive 2008/101/EC

<sup>19</sup> Directive 2009/33/EC

<sup>20</sup> COM(2009)593

<sup>21</sup> Directive 2009/28/EC

<sup>22</sup> Directive 2009/30/EC

potential to undermine the ultimate objective of the primary policy instrument, in this case the delivery of reductions in GHG emissions. In order to ensure that the potential GHG reductions of the primary instrument are realised in practice, it may be necessary to implement complementary policy instruments to either reduce, or ideally eliminate, any rebound effects.

## 1.7 Brief overview of the project method and report

The aim of the project was, therefore, to review existing evidence on options and policy instruments for reducing transport's GHG emissions and then to identify the implications of these findings for reducing the EU's transport's GHG emissions between 2020 and 2050.

Within the project, the following definitions were used:

- **Options** deliver GHG emissions reductions in transport, e.g. technical (primarily those that focus on reducing the GHG intensity of the energy used and improving the energy efficiency of vehicles) and non-technical, such as those that improve the efficiency of vehicle use and improve the efficiency of the transport system more generally.
- **Policy instruments** may be implemented to promote the application of these options.

Whilst recognising that these terms can be defined differently, it was decided that these definitions would be used within the project in order to avoid the potential for confusion. An important element of the project was a review of evidence of the GHG reduction potentials, costs, issues, risks and limitations associated with the various options and policy instruments. The findings of the evidence review were brought together in a series of papers, which were presented to and discussed with stakeholders<sup>23</sup>.

Section 2 presents a summary of the findings on technical and non-technical options for reducing transport's GHG emissions, while Section 3 summarises the findings with respect to the potential policy instruments that could be used to stimulate the uptake of these options. Section 4 introduces the concept of alternative policy frameworks that are considered in the remainder of this report to identify the policy instruments that could be introduced to reduce transport's GHG emissions.

As noted in Section 1.2, an illustrative scenarios tool called SULTAN was developed in the course of the project in order to identify a range of potential future scenarios that would deliver GHG reduction in the EU's transport sector. The main results of the scenarios developed for SULTAN are presented in Section 5. These results present the potential GHG reduction from the successive uptake of different GHG reduction options, beginning with technical options and concluding with non-technical options. In each case, relatively ambitious assumptions are made about the potential for the uptake of the various options, the implications of which are also discussed. This section concludes by outlining wider issues that are potentially associated with the level of ambition assumed.

The aim of Section 6 is to present an assessment of the issues associated with the delivery of the reduction potentials outlined in Section 5 under the alternative policy frameworks introduced in Section 4. Section 6 focuses in more detail on the policy instruments required and the issues associated with the implementation of these. Section 7 concludes the report by summarising the findings of the previous sections and presenting the main implications for decarbonising the EU's transport sector.

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<sup>23</sup> See <http://www.eustransportghg2050.eu> for the papers and the details of the meetings with stakeholders; the papers can be found in Appendices 4 to 12 of this report

## 2 Summary findings on technical and non-technical options

The findings of the review of the options for reducing transport's GHG emissions are split by those options that could be considered to be technical, i.e. those that require changes to the technology that vehicles use, and non-technical options. The review of technical options was further divided according to those that directly relate to road modes (see Section 2.1), those that affect non-road modes (Section 2.2) and alternative energy carriers and fuels that could be applied to a range of modes (Section 2.3). The findings from the review of non-technical options are presented in Section 2.4. The findings of the review made it clear that there are a large number of technical and non-technical options that could be taken up to reduce the GHG emissions of vehicles across all of the modes. More details on the GHG reduction potential from these options can be found in the respective appendices, while the assumptions used in SULTAN developed for this project can be found in Section 5.1.

### 2.1 Technical options to reduce GHG emissions from existing road vehicles

With respect to **road transport**<sup>24</sup>, it is expected that internal combustion engines (ICEs) will remain competitive for the foreseeable future and, even in 2050, it is likely that they will still make up a significant share of the transport market. ICEs are relevant not only where conventional and unconventional fossil fuel will be used but also where gaseous fuels and biofuels, including biogases, are expected to be deployed. Improvements in fuel efficiency in vehicles using ICEs will therefore still be highly relevant in reducing transport's absolute GHG emissions (even though the relative importance may be expected to decrease). For many road transport modes, there is also a trend towards the increasing electrification of vehicles, which, in the case of cars in particular, is evident in hybrid vehicles, which use both a conventional engine and an electric battery.

Potential improvements to the fuel efficiency of **light duty vehicles** using ICEs include improvements to the engine and the powertrain, as well as improvements to the vehicle more generally that reduce the energy needed for propulsion. The former category includes options such as variable compression ratios, direct injection, cylinder deactivation, optimizing gearboxes and dual clutches. A number of options can be applied to reduce the energy needed for propulsion, including improvements to a vehicle's aerodynamics and reducing a vehicle's weight by using lightweight materials, as well as recovering waste heat generated, e.g. by braking. It is also possible to reduce the energy used by the additional components fitted to vehicles.

With respect to **new passenger cars**, it can be anticipated that many of the technical options for ICEs that are currently foreseeable will be taken up to some degree in the next 10 years, as EU policy aims to reduce their emissions (as measured according to the existing test cycle<sup>25</sup>) from an average of 158.5gCO<sub>2</sub>/km in 2008 to 95gCO<sub>2</sub>/km by 2020<sup>26</sup>. Similarly, the proposed Regulation to reduce CO<sub>2</sub> emissions from **new vans** may also require the adoption

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<sup>24</sup> See Appendix 4 for more details; also see <http://www.eutransportghg2050.eu/cms/updated-reports/>

<sup>25</sup> It is worth noting that real world GHG CO<sub>2</sub> emissions from these vehicles are likely to be higher than these test cycle emissions.

<sup>26</sup> COM(2009)713; see <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2009:0713:FIN:EN:PDF>



of many of the potential technical options identified for these vehicles, as this proposes that vans' CO<sub>2</sub> emissions be 135g/km in 2020 compared to an average of 203g/km in 2007<sup>27</sup>.

With respect to **heavy trucks**, it is important to note that minimising operational costs is already, and is likely to continue to be, a fundamental consideration in the design of such vehicles. However, some characteristics of heavy goods transport mean that some options for fuel saving are not generic, as in many cases it is optimal to configure a vehicle depending on the characteristics of the goods being transported. Hence, options for fuel saving are tailored to the specific transport demands, although the technological options for fuel saving in heavy goods transport are similar to those for other ICE vehicles. However, in contrast to light duty vehicles, some characteristics of the way in which heavy trucks operate impede fuel efficiency, including the fact that trailers have comparatively long lifetimes, which implies a long penetration time for new technology, and the fact that tractor units are used with different trailers and consequently the combination of the two are not necessarily aerodynamically optimized. In spite of this, manufacturers still anticipate that their fuel efficiency might improve by up to 20% by 2020.

The extent to which the CO<sub>2</sub> emissions from vehicles using ICE engines could be reduced beyond these 2020 figures – without the use of alternative powertrains and energy carriers – is a matter of some debate. Post 2020, there might be the potential for some technologies offering additional savings in CO<sub>2</sub> emissions from new road vehicles using existing conventional petrol and diesel engines from the further optimisation of the options introduced prior to 2020, as well as the use of light-weight materials. It is also likely that the ongoing hybridisation of vehicles will continue, leading to the further developments of hybrid electric vehicles and plug-in electric hybrid vehicles.

Further significant reductions towards the levels potentially required to meet 2050 targets will have to come from the application of alternative propulsion systems and/or the use of alternative, less carbon-intensive energy carriers and fuels. In this respect, electric vehicles or fuel cell electric vehicles using hydrogen are possible alternatives (see Section 2.3). It is important to note that much of the efficiency of an engine is related to the way it is used. A lot of technical effort is directed towards ensuring that the engine is used at its most efficient, which means that it is important to measure fuel efficiency in such a way that it is closely related to fuel efficiency in real world driving. Consequently, it is important that the way in which GHG emissions are measured, and thus the direction in which technical improvements are made, is consistent with their real world emissions, unlike the current test cycle.

At this point, it is also important to highlight that the uptake of options that improve the fuel efficiency of vehicles, such as those noted above, will also reduce the costs of using the vehicles. Any option that improves the fuel efficiency of vehicles will lead to less fuel being required to travel the same distance, which, if everything else remains the same, will make vehicles cheaper to use. The literature shows that, if any good becomes cheaper it is likely to be used more, so it could be expected that options that improve the fuel efficiency could lead to an increase in the amount of travel being undertaken. Such a rebound effect, as noted above, underlines the importance of a coordinated approach to the implementation of complementary policy measures that ensure that the ultimate objective of GHG reductions is achieved.

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<sup>27</sup> Regulation 443/2009

## 2.2 Technical options to reduce GHG emissions from existing non-road vehicles

For the non-road modes<sup>28</sup>, there is the potential to reduce the CO<sub>2</sub> emissions, for comparable vehicles and performance, from new aircraft and maritime ships in 2050 by up to 50% compared to new 2010 vehicles. For inland waterway vessels and trains, potential GHG reductions over the next 40 years are probably not as large. The options for reducing GHG emissions include energy recovery from engines and propellers (for water vessels), measures to reduce friction and improve aerodynamics, the redesign of aircraft and the hulls of water vessels, as well as the use of lighter materials for aircraft in particular.

As noted in Section 1.5, the lifetimes of the vehicles used in the non-road modes tends to be longer than those used on roads. Consequently, existing vehicles could remain in use for much of the next 40 years and would therefore emit comparatively high levels of CO<sub>2</sub> if they were not modified. Hence, for such vehicles, the potential for retrofitting to reduce their respective GHG emissions is potentially important. For example, for water vessels, fitting new engines and propellers to existing vehicles has the potential to deliver improvements in fuel efficiency, and therefore reductions in GHG emissions, as have modifications to existing aircraft, such as the addition of winglets.

## 2.3 The potential for alternative fuels and energy carriers

There is a range of alternative fuels and energy carriers<sup>29</sup> that have the potential to be used in the transport system by 2050 and which have the potential to reduce transport's GHG emissions beyond those that could be achieved through improvements to the conventional ICE alone. These include mixing biofuels with conventional fuels, which can be used in conventional ICEs, and alternative energy carriers, such as electricity and hydrogen, which would require potentially significant modifications to powertrains.

**Biofuels** have the potential to deliver significant reductions in GHG emissions, if certain conditions are fulfilled. Liquid biofuels can be blended with, or potentially used instead of, petrol and diesel, while biogas can be added to, or replace, natural gas (NG) or potentially liquid petroleum gas (LPG). Such fuels have the advantage that they can be used in existing ICEs and vehicles, although in some instances modifications are required, particularly with higher blends or pure biofuels. However, the GHG savings that the use of any biofuel can deliver is very sensitive to the feedstock used and the way in which the biofuel is produced, as well as the method that is used to calculate the savings. In the short-term, the GHG reduction potential from biofuels may be limited, but there is the potential for advanced feedstocks, e.g. woody biomass or algae, and for production processes to develop to produce biofuels with much higher GHG reduction potential.

The use of biogas would clearly depend on their being vehicles available that could use natural gas, either in its compressed (CNG) or liquefied (LNG) form. In road transport, a limited but increasing number of natural gas vehicles are in use, but these are generally seen as a short-term option that has the potential to pave the way for increased use of bio-methane. The use of LNG for shipping appears to offer potentially significant reduction potential, which of course would again improve significantly if low carbon bio-methane was used instead.

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<sup>28</sup> See Appendix 6 for more details; also see <http://www.eurtransportghg2050.eu/cms/updated-reports/>

<sup>29</sup> See Appendix 5 for more details; also see <http://www.eurtransportghg2050.eu/cms/updated-reports/>

For many biofuels there are concerns about availability and wider sustainability impacts. With respect to liquid biofuels, there are concerns about the potential competition with food crops for both land and water resulting from an increased demand for certain feedstocks. There are also concerns about the environmental impacts of indirect and direct land use change that may result from an increased demand for land for the production of feedstocks for biofuels. For all biofuels, there is uncertainty as to whether there will be enough sustainable feedstock available and the transport sector is likely to have to compete with other sectors of the economy for any sustainable biomass that is produced.

**Electricity** is already used as an energy carrier for many railway applications and increasingly, although still very limited, for road transport, particularly cars, as the respective powertrains are electrified. Pure electric powered transport has significant potential to deliver GHG emissions reductions. However, as with biofuels, for such a potential to be realised, the electricity has to be produced from carbon-neutral (and ideally renewable) sources. In this respect, it is important to note that the current electricity supply system in the EU is far from carbon-neutral, although the EU's main electricity generating companies have pledged to reduce their sector's carbon emissions as much as possible by 2050. If electricity could be supplied in a virtually carbon-neutral manner, this would deliver energy at a higher net efficiency compared to hydrogen, except perhaps for hydrogen produced from biological sources. The main potential for increased use of electricity is considered to be light duty road vehicles, although electric trolley buses are an existing technology that potentially in the long-term might be extended further to trolley systems for trucks or even passenger cars on highways. It is considered unlikely that significant electrification would be achieved by 2050 for aircraft, water vessels or long-distance heavy-duty vehicles.

It is important to note that significant challenges remain, principally in the area of electricity storage, in terms of cost, weight, volume, efficiency and power delivery. These limitations mainly impact on the useful range of electric vehicles (EVs) compared to conventional equivalents. Plug-in hybrid electric vehicles (PHEVs) are seen as an intermediate (short- to medium-term) technology on the pathway to electric vehicles in the road transport sector, although they may play a significant role in the longer-term, if the problem of the limited range of battery-only electric vehicles is not overcome.

**Hydrogen fuel cells** offer significant potential to reduce GHG emissions from road transport in the longer term, although, as with other potential alternative fuels and energy carriers, this depends on the way in which the hydrogen is produced. The contribution of fuel cell vehicles (FCVs) will depend on developments in hydrogen and fuel cell technologies, as well as in electrical energy storage for competing pure EVs. FCVs currently have an advantage in range over EVs due to greater energy storage densities for hydrogen relative to electrical energy storage. However, the cost of developing new hydrogen refuelling infrastructure is significant, i.e. it is much higher in comparison to developing a recharging infrastructure for EVs. The possibility to use the existing natural gas infrastructure as a bridging technology for hydrogen distribution is being considered. The use of hydrogen to power aircraft or ships appears to be unlikely, even by 2050, whereas hydrogen fuel cell powered rail vehicles may have the potential to replace diesel rail in the long term in areas where further line electrification is not economic.

The use of renewable energy sources, such as wind power and solar energy, directly in transport is likely to be limited. There is the potential for the increased use of wind power for maritime vessels, probably to supplement other energy sources, potentially in conjunction with other technologies. Solar power has limited potential, although it could be used as a

source of auxiliary power on, for example, road vehicles and inland waterway and maritime vessels.

The technologies discussed above are those that are anticipated to play a role in reducing transport's GHG emissions over the next 40 years. However, there is clearly the potential for a technology that is not yet considered to have potential to be used in transport to emerge that could deliver significant reductions in transport's GHG emissions. It is clearly not possible to identify technologies that are yet to be invented, let alone consider their potential contribution to reducing transport's GHG emissions. However, it is worth considering whether any technologies that already exist could be developed and applied more widely in the transport system<sup>30</sup>. In the road transport sector, some technologies, if further developed, could improve the attractiveness of some of the alternative energy carriers mentioned above, e.g. in-road vehicle charging infrastructure has the potential to overcome some of the range problems associated with EVs, but the technology is still only at a prototype stage. There is the potential for wider application of some existing technologies in public transport, such as Maglev, but the need for specialised infrastructure, which would be relatively expensive, is a major barrier for such technology, as is the higher energy consumption. Personal Rapid Transit systems appear to offer potential for low energy electric mobility within urban areas at relatively low cost. A barrier to deployment appears to be the fear of being the first to deploy such a scheme. Apart from sustainable biofuels and the redesign of existing aircraft, the only other technology that seems potentially feasible for aviation are hybrid airships, but these are still at the prototype stage. For maritime vessels, flettner rotors have the potential to increase the use of wind to power such vehicles, in addition to kites and more traditional sail technology.

For the majority of more radical technologies that could be identified, it was considered that these would be more energy-intensive than existing modes, and so their widespread application would not be beneficial to reducing transport's GHG emissions, even if they proved to be feasible.

Hence, by 2050, there is likely to be a wide range of alternative fuels and energy carriers that are likely to have to complement or replace the use of conventional transport fuels in internal combustion engines in 2050, although it is not anticipated that anything more radical is likely to significantly reduce transport's GHG emissions. While the use of biofuels in modes other than road transport is currently generally immature, it is anticipated that by 2050 biofuels are likely to be an important fuel in aviation and for long-distance heavy duty road vehicles, as well as possibly in inland waterway vessels. This is largely due to the relatively limited number of technical options for reducing GHG emissions from these modes. Such biofuels can be expected to be virtually carbon-neutral and to be produced sustainably. The use of biofuels in other light duty road transport modes will probably have peaked, as other technologies have the potential to reduce GHG emissions from these modes and biomass is unlikely to be available in sufficient quantities for all of its potential uses. Electricity will remain the dominant energy carrier for rail and it can be expected that those main lines that are not already electrified will be by 2050. It can also be anticipated that by 2050, electricity will be used more extensively to power light duty road vehicles, which are likely to include pure EVs, as well as PHEVs. On the road, there are also likely to be some FCVs, while hydrogen fuel cells might also be used in selected rail applications (e.g. shunting) and specialised road applications (e.g. fleets and urban buses). LNG is likely to be used in inland waterway and maritime vessels, while CNG could be used, in short to medium term, in road transport. The direct use of renewable energy sources is likely to be limited to the use of

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<sup>30</sup> See Appendix 18 *Review of potential radical future transport technologies and concepts* for more details; also see <http://www.eurtransportghg2050.eu/cms/additional-reports/>

wind on maritime vessels to supplement other energy sources and the use of solar energy as a source of auxiliary power on vehicles.

## 2.4 The potential of non-technical options to reduce transport's GHG emissions

There are also a range of non-technical options that could be applied across all of the modes to reduce their respective GHG emissions in the course of their operation and from changes in behaviour more widely<sup>31</sup>. Non-technical options include those that improve the efficiency of the use of the vehicle, e.g. by optimising speeds and routes, by optimising vehicles for their intended use and by optimising the utilisation of vehicles, those that use the most appropriate mode for each (part of) the journey and those that increase the efficiency of the transport system as a whole.

There are a number of options with respects to the **optimisation of speeds** that have the potential to reduce transport's GHG emissions. Where there are speed limits on major inter-urban roads in the EU, these are often in excess of the speed at which energy efficiency is optimal for vehicles. Hence, where existing speed limits are exceeded, energy use is even further from being optimal. Consequently, the enforcement of existing speed limits on major inter-urban roads could deliver GHG savings. Additionally, where speed limits do not exist, or where these are higher than the optimal for vehicles, then the imposition, or lowering, of speed limits also have the potential to developed GHG savings. Taking such action would also effectively reduce the capacity of the road network, which would have knock-on effects on demand. However, reducing GHG emissions is clearly not the only reason for setting speed limits, as safety considerations and maximising the efficiency of the transport system as a whole are also important. Speed reduction or optimisation also has the potential to deliver savings for other modes, e.g. lower speeds for maritime vessels can deliver GHG savings, but also enable alternative, more fuel efficient ship designs.

The **optimisation of routes** is also important. For road transport, the use of satellite navigation and potentially more advanced intelligent transport systems (ITS), such as intelligent infrastructure, could ensure that destinations are reached using the best route and that congestion is avoided. Improved fleet management is relevant for many modes, e.g. commercial road vehicles, ships, inland waterways vessels and aircraft, while improved network management is important for trains and inland waterway vessels and improved air traffic management has the potential to deliver GHG savings for aircraft. Such improvements can be facilitated by the development of more sophisticated ITS, which could also improve safety and reliability. However, it is important to appreciate that in optimising routes and the wider use of the transport network, such options effectively increase the capacity of the transport system, which potentially stimulates additional travel. The net GHG impact of optimising the use of the network would depend on the net impact of these two opposing mechanisms. Alternatively, such rebound effects could be overcome by using complementary policy instruments (see Section 5.2.5).

As noted above, there is the potential for improving the efficiency of vehicles using ICEs. In this respect, it is important to note that much of the efficiency of an engine is related to the way it is used. A lot of technical effort is directed towards ensuring that the engine is used at its most efficient, which means that driver behaviour can have a significant effect on fuel economy. In this respect, for all vehicles, energy efficiency can be optimised by adopting the energy efficient driving behaviour, or "eco-driving", as it is sometimes referred to. The adoption of energy-efficient driving behaviour, e.g. optimising acceleration and braking, has the potential to deliver GHG savings for many modes by training drivers and pilots in the

<sup>31</sup> See Appendices 7 and 8 for more details; also see <http://www.eurtransportghg2050.eu/cms/updated-reports/>

relevant techniques. Additionally, the development of vehicle monitoring systems will inform drivers when to take necessary actions to conserve energy, e.g. gear shift indicators.

One of the main issues with attempting to deliver GHG reductions through changing driving behaviour is ensuring that the behaviour is applied and maintained in practice. In the longer-term, any gains delivered by training are likely to be less relevant, as new vehicle technology that automates behavioural changes, for example hybridisation of power trains, gear shift indicators and Intelligent Transport Systems (ITS), may become standard. As with improvements to the energy efficiency of vehicles, as more energy efficient driving has the potential to deliver fuel and, therefore, cost savings, there is the risk of a rebound effect as it has the potential to increase the amount of travel that is undertaken.

Technologies such as road trains, in which cars on major roads could be “led”, self-drive vehicles and intelligent roads also have the potential to improve energy efficiency, as they can optimise speeds, improve the efficiency of the use of the wider transport network and potentially enable lighter vehicles if collisions can be avoided, thus potentially reducing the need for some safety features<sup>32</sup>. However, the extent to which such technologies could deliver GHG savings would depend on their net impacts, as again there is a risk of a rebound effect as the use of transport that apply such technologies could be cheaper, so some additional travel could be generated.

As was noted above, heavy duty road vehicles in particular are often optimised according to the goods that are being carried and the journey that is being undertaken. Similarly for other modes, there is the potential for GHG reductions to be delivered through the optimisation of the design of the vehicle. For maritime vessels, this includes improved maintenance of vehicles and reducing friction by using alternative coatings, which has been identified as having the potential to reduce GHG emissions. For road transport, ensuring that tyres are appropriately inflated also has the potential to deliver GHG reductions, and can be aided by tyre pressure monitoring devices that can be fitted to vehicles.

The **optimisation of vehicle utilisation** is an advantage to any private and many public actors. For those with commercial motivations, optimising the amount of goods or the numbers of passengers that can be moved will clearly be of benefit and many commercial operations already pay a lot of attention to optimising the utilisation of their vehicles. Even public transport operations that are not run on a commercial basis are likely to have an incentive to optimise passenger numbers, although this will depend on the respective arrangements with the appropriate authorities and other stakeholders. The incentive to optimise vehicle utilisation is less clear cut for passenger car drivers, as the financial incentives are nowhere near as significant, if they exist at all. However, there is still scope for improved logistics for some freight applications and for increasing public transport numbers, particularly on off-peak periods and in rural areas. Similarly, options that result in a higher utilisation of passenger cars, such as car sharing and car clubs are also possible. Such improvements could be facilitated by developments in information and communication technologies (ICT).

Maximising the potential for **co-modality**, in terms of maximising the potential for the use of the least carbon intensive modes, also has the potential to deliver GHG emissions reductions from transport. However, the actual GHG benefits that co-modality could deliver depends on the difference in GHG intensity (measured in grams per passenger-kilometre or grams per freight-kilometre) of the modes concerned and the potential volumes of goods and passengers that can be moved between the respective modes. Additionally, it is important to

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<sup>32</sup> See Appendix 18 *Review of potential radical future transport technologies and concepts* for more details; also see <http://www.eurtransportghg2050.eu/cms/additional-reports/>

bear in mind that the various transport modes do not always compete in the same market, e.g. mopeds do not compete with aviation, while city distribution trucks do not compete with maritime shipping. So, for the purposes of stimulating co-modality, it is important to focus on modes that operate in the same markets.

Within these markets, the GHG efficiency of each mode also has the potential to vary significantly from the average, as their respective GHG emissions strongly depend on the load factor, which is directly related to the type of load and type of trip. Therefore GHG reductions can only be estimated by comparing the efficiencies of *specific* transport relations. Comparing averages generally leads to misleading conclusions. Hence, to achieve GHG reductions by stimulating co-modality, it is important to focus on true reduction potentials, rather than aiming at a dogmatic shift for all transport from one mode to another.

For passenger transport, the highest potential for GHG reductions from co-modality exists in dense urban areas, on major inter-urban routes and from aviation to alternative modes. In dense urban areas, there is significant potential by making some GHG-efficient modes, particularly cycling, electric (public) transport and private/public bus transport (as long as the utilisation rates are relatively high) relatively more attractive than other modes. In addition to making some modes relatively more attractive, it is also important to improve intermodal connections, both physical and commercial, e.g. offering various mobility services rather than a company car, integrated payment schemes, etc.

For freight transport, it is also important to focus on true GHG reduction potentials instead of aiming at a dogmatic shift from one mode to another. In this case the highest potential exists outside of urban areas on major inter-urban routes. Electric rail transport and large ships are generally more GHG-efficient than large road trucks, but load factors and trip length are important and should always be considered. There is a potential to improve intermodal connections, to improve the service and interoperability of each mode and to create a level playing field.

While maximising co-modality has the potential to reduce GHG emissions, it will only do so if these reductions are "locked in". Increasing the use of the least GHG intensive modes for each (part of the) journey could be achieved by making these modes more attractive, e.g. through investment in infrastructure. However, if journeys are attracted to the respective more GHG efficient modes from less GHG efficient modes, there is the risk that the capacity that is freed up by the journeys shifted is simply taken up by new journeys that have been induced by the emptier infrastructure. Effectively, therefore, investment in modal shift could lead to increased capacity, more travel and therefore more GHG emissions. This is another example of a potential rebound effect that needs to be addressed through the implementation of complementary measures, thus further underlining the need for a coordinated approach to reduce transport's GHG emissions.

Finally, there is the potential to achieve efficiencies from the use of **larger vehicles** across a range of modes. The relative GHG emissions of large vehicles in use are generally lower than those of smaller vehicles per tonne or passenger kilometre. In addition larger vehicles can have economy of scales advantages in both construction and use leading to lower costs. For land-based modes, there is no agreement on the net effect of allowing larger/heavier lorries due to the competitive situation between different transport modes in inland transport. There is a trade-off between potential efficiency gains for road transport on one hand and an increase in transport demand and unintended modal shift to road transport caused by lower road transport prices on the other hand. The discussion on which of the two effects dominates is polarised. However, in view of this, it is clear that the net GHG reduction of allowing longer and heavier trucks, if any, is likely to be modest.

The non-technical options mentioned so far could all be described as improving the efficiency of vehicle use, as their effect is to reduce the GHG intensity of the travel undertaken, i.e. the GHGs emitted per passenger-kilometre or per freight-kilometre. There are further options that aim to improve the efficiency of the transport system itself by acting directly on reducing passenger-kilometres or freight-kilometres, either generally or in a particular area. One of the key options to improve the efficiency of the transport is to **improve the structure and planning** of the transport system and wider spatial structures. Ensuring that the potential origins and destinations of journeys are as close together as they can be, e.g. by not requiring shoppers to travel to out-of-town shopping centres to buy goods and by optimal location of freight distribution depots, clearly has the potential to reduce the amount of travel required and thus reduce transport's GHG emissions. Where infrastructure capacity is constrained, for example in urban areas, it might be preferable to actively restrict demand through the use of economic instruments, such as road pricing or congestion charging (see Section 3).

## 2.5 The co-benefits of reducing transport's GHG emissions

As set out in this section, there are three broad approaches to reducing transport's GHG emissions, i.e.:

- Improving the **GHG intensity of the energy** that is used by the transport sector (measured in grams of GHGs emitted per mega joule (gCO<sub>2</sub>e/MJ) of energy used). Essentially, this can principally be achieved through the use of alternative fuels and energy carriers (see Section 2.3), although there is some limited potential for reducing the GHG intensity of transport energy using conventional fuel.
- Improving the **efficiency of transport vehicles** by both **technical and operational** means. Essentially, this focuses on reducing the amount of energy used to travel given distances (measured in mega joules per kilometre, MJ/km), e.g. by making vehicles more technically efficient (see Sections 2.1 and 2.2), or on reducing the amount of energy used to undertake given journeys (measured in Joules per journey), e.g. by improving the operational efficiency of vehicle use (see Section 2.4).
- Improving the **efficiency of the transport system**. This essentially focuses on options to reduce the need for or the amount of vehicle kilometres driven, e.g. by improved spatial planning (see Section 2.4) or by internalising the external costs of transport (see Section 3.2).

It is important to note that these approaches have the potential to contribute to the delivery of other policy goals of the European Commission and the EU's Member States, such as improving energy security and improving air quality, in particular. Of the five main ways of improving energy security, two, "increasing the diversity of supply" and "reducing demand for energy" could also be delivered by the main approaches to reducing transport's GHG emissions listed above<sup>33</sup>.

Similarly, reducing the amount of fossil fuels that are used in the transport sector has the potential to reduce the amount of conventional pollutants emitted. This would arise if vehicles used less fuel (and did not make any additional journeys) or if vehicles switched to cleaner energy carriers. In such cases, fewer conventional pollutants would be emitted and thus contribute to improvements in air quality. Given that many EU Member States are currently struggling to reduce their air pollution levels as required by European legislation<sup>34</sup>, then reducing transport's GHG emissions could also help deliver wider air quality objectives.

<sup>33</sup> The others are "establishing long-term supply arrangements", "increasing strategic reserves" and "making greater use of indigenous supplies". See Appendix 13 *Energy security and the transport sector* for more details; also see <http://www.eurtransportghg2050.eu/cms/additional-reports/>

<sup>34</sup> As set out in Directive 2008/50/EC



Additionally, it is important to note that some of the options discussed above could be implemented largely for reasons other than reducing transport's GHG emissions. For example, the stimulation of co-modality in urban areas, which focuses on stimulating the use of the slower modes, such as cycling and walking, as well as the use of public transport, is encouraged for a wider range of social, economic and environmental reasons. In congested urban areas, where the ability to develop infrastructure is constrained, switching to high occupancy public transport has the potential to move people around more efficiently and thus reduce congestion, noise and the emission of air pollutants, as well as improving the overall urban environment.

While many of the options above focus on reducing GHG emissions from transport, it is also important to note that transport delivers significant benefits to its users, both individuals and commercial organisations. As noted in Section 1.3, transport is a derived demand and that there are a wide range of drivers that stimulate the use of transport. Hence, in considering policy instruments to stimulate the uptake of options to reduce transport's GHG emissions, it is important to bear in mind the social and economic impacts.

While the existing benefits of transport, and the co-benefits of reducing transport's GHG emissions, are not the objective of this study, it is always important to remember that these do exist and would be relevant in determining the most appropriate means of reducing transport's GHG emissions.

## 2.6 A simple 2050 vision for the implementation of technical options to reduce transport's GHG emissions

By 2050, it is likely that vehicles, particularly in road transport, will have become more specialised or "fit for purpose". Designing vehicles for a specific application allows weight reduction and optimal performance dimensioning, but will also be necessary to maximise the potential application of the various technical options, particularly alternative propulsion systems and the range of alternative fuels and energy carriers. By 2050, all vehicles will have to be designed and manufactured using the respective best available technologies for that vehicle and its application (see Sections 2.1 and 2.2). These vehicles are likely to be a lot more specialised than those available today, e.g. different cars designed for urban and inter-urban uses, heavy duty vehicles designed differently for short- and long-distance travel with vehicle build-ups that may enable new logistic concepts, and will make use of different energy carriers and alternative fuels in doing so (such as those discussed in Section 2.3).

By mode, the use of the alternative fuels and energy carriers could be differentiated as follows:

- **Biofuels:** Virtually carbon-neutral biofuels are likely to be used in aviation and for long-distance heavy duty road vehicles (due to lack of alternatives), as well as possibly in inland waterway vessels. The use in light duty road transport modes will probably have peaked, as other technologies have the potential to reduce GHG emissions from these modes.
- **Electricity:** All main rail lines are likely to be electrified (the majority are already), while there is likely to be significant use of light duty, electric vehicles on roads.
- **Fuel cells/hydrogen:** These are likely to be used in selected rail applications (e.g. shunting) and specialised road applications (e.g. fleets and urban buses).
- **Natural gas:** Liquefied natural gas (LNG) is likely to be used in inland waterway and maritime vessels, while compressed natural gas (CNG) could be used, in short to medium term, in road transport.

- **Wind:** Wind is likely to be used in maritime vessels to supplement other energy sources, potentially in conjunction with other technologies.
- **Solar:** This has limited potential, although it could be used as a source of auxiliary power on e.g. road vehicles and inland waterway and maritime vessels.

This vision was used to inform the technical scenarios (Scenario 2; see Table 1) in SULTAN.

By 2050, technology will have automated many fuel efficient driving behaviours (in all modes) and will have improved the management of routes, networks and air space, thus reducing the need for users to adopt such behaviours. Technology is also likely to have improved the utilisation of vehicles, particularly freight modes, as well assisting with the maintenance of vehicles through the widespread application of intelligent monitoring systems. However, it is unlikely that technology could ensure that the full GHG reduction potential of the non-technical options is attained. Hence, the optimisation of the non-technical options will need to be assured by the implementation of appropriate policy instruments, as discussed in the following section.

### 3 Summary findings on policy instruments

It is likely that a wide range of policy instruments will need to be applied, not only to ensure that the relevant options have been taken up by 2050, but also to ensure that the most carbon-efficient route was taken to the introduction of these options in the intervening period. Such policy instruments are preferably technology neutral, and may be selected on the basis of their effectiveness, efficiency or cost effectiveness, fairness and acceptance. The review of policy instruments was divided into the following categories of instruments:

- Regulation (see Section 3.1);
- Economic instruments (Section 3.2);
- Infrastructure and spatial policy, speed and traffic management (Section 3.3);
- Information to raise awareness (Section 3.4); and
- Other instruments to stimulate innovation and development (Section 3.5).

The aim of the following sections is to present an overview of the potential policy instruments that could be used to stimulate the uptake of the technical and non-technical options to reduce transport's GHG emissions. A more detailed discussion concerning the instruments that are the most appropriate to put in place to deliver the potential GHG reductions that could be achieved under the scenarios presented in Section 5 can be found in Section 6. This section concludes with a discussion of the way in which policy instruments stimulate the uptake of various options (Section 2).

#### 3.1 Regulation to stimulate the uptake of GHG reduction options for transport

As can be seen from the list of existing, EU-level measures that aim to reduce GHG emissions from transport (see Section 1.6) regulation is already used to reduce transport's GHG emissions. The passenger car CO<sub>2</sub> Regulation already sets emissions performance standards for new passenger cars, while similar standards are proposed for vans. Additionally, activities in support of defining appropriate means for regulating CO<sub>2</sub> emissions from heavy duty vehicles (trucks and buses) have also begun. However, as yet there is not EU policy in place to regulate CO<sub>2</sub> emissions from other modes, although some initiatives are being undertaken in the international context, e.g. the IMO are developing benchmarks for maritime ships<sup>35</sup>.

With respect to road transport, it is likely that there will be a need to continue to regulate and to further tighten regulatory targets for GHG emissions over the whole period until 2050. However, increasingly such regulation is expected to be used to complement the introduction of economic instruments, such as a cap and trade emissions trading systems or CO<sub>2</sub>-based taxation. Additionally, it seems likely that these types of regulations will need to be extended to other modes of transport (in particular if their share of transport GHG emissions increases as foreseen for ships and aviation), as already proposed by ICAO for aircraft.

However, due to changes that can be expected in vehicles and energy use, the nature of GHG emissions regulation for transport may need to change to take better account of WTW energy emissions, i.e. the emissions emitted in the course of extraction, production and transmission, as well as the embedded energy in vehicles, i.e. the emissions emitted in the course of the vehicle's production.

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<sup>35</sup> See Appendix 9 for more details; also see <http://www.eurtransportghg2050.eu/cms/updated-reports/>

However, an important prerequisite for setting emission standards is the availability of appropriate test procedures. These are also relevant for other, complementary instruments, such as labelling and CO<sub>2</sub> differentiation of taxes (see Sections 3.4 and 3.2, respectively). An important issue for further development of these test procedures is to improve the correlation between the reduction measured on the type approval test and effects on emission under real-world driving conditions. In addition to regulating emissions at the vehicle level, it may be useful to introduce efficiency standards for a number of relevant vehicle components. Such standards could replace the provisions for "eco-innovation" in the current legislation for passenger cars.

In the longer term, the present regulatory approach based on setting targets for the sales-averaged CO<sub>2</sub> emissions per manufacturer using a utility-based limit function may need to be replaced by a less flexible approach including, for example:

- Emission limits per vehicle, setting an absolute emissions maximum, either on its own (individual vehicle emission standards) or in combination with fleet averaging (as an upper limit);
- Using utility-based limit curves that penalise high emitters (flattening out for high values of the utility parameter);
- Using utility parameters that more directly relate to the true transport functionality (transport capacity), such as number of seats and trunk space;
- Using bin-based systems requiring increasing shares of vehicles over time to meet more stringent emission limits; or
- Setting absolute restrictions on vehicle parameters (e.g. size, weight, power, power/mass ratio) or limitation of maximum speed or other performance indicators.

When considering modes other than road transport, the regulation of GHG emissions per unit of transport function (e.g. grams per passenger-kilometre or grams per tonne-kilometre) may become relevant.

The list of existing, EU-level measures in Section 1.6) also show recent developments in the regulation of **emissions from the energy chain**. The Renewable Energy Directive sets a minimum target of 10% for the proportion of final energy consumption in transport that should be from renewable sources by 2020, while Article 7a of the amended Fuel Quality Directive (FQD) requires that WTW GHG emissions per unit of energy supplied be reduced by a minimum of 6%, and up to 10%, by 2020. As is clear from the discussion of Section 2.3, mandating the use of renewable energy does not necessarily mean that reductions in GHG emissions are delivered, but such a target may provide a strong stimulus for renewable energy use in transport, which may reduce costs and promote investment in research and development (R&D). As the target was designed flexibly, allowing many different types of renewable energy to count towards the target (as is the case in the current RED), the market will be stimulated to find the most cost effective renewable energy solution for transport. Together with the CO<sub>2</sub> regulation of the fuels, this is designed to result in a drive for low carbon renewable energy.

As was noted in Section 2.3, there are concerns about the net GHG impacts and wider sustainability impacts of some alternative fuels and energy carriers, such as biofuels. The EU legislation contains sustainability criteria for the biofuels that can contribute to meeting its targets. The aim of developing such criteria is to counter concerns that biofuels could be produced that either do not result in a net carbon benefit, e.g. as a result of indirect land use effects, or adversely impact on biodiversity or compete with food crops for land and water. Given that the range of fuels in transport is likely to come from an ever more diverse range of

sources, including unconventional fossil fuels, then the development of sustainability criteria for all transport energy sources is important.

If electric transport increases in the future, including potentially the development of hydrogen as an energy carrier for transport, the policies of the power sector also come into play, such as the EU ETS, which sets a cap on CO<sub>2</sub> emissions from the sector and the renewable energy policies implemented by various Member States. Further greening of the power sector, no doubt an important part of climate policy in the next decades, will then also reduce GHG emissions of those parts of the transport sector that can use it.

In terms of GHG emissions reduction, the regulation of the GHG intensity of fuels seems to be the best way forward. It leaves the choice of CO<sub>2</sub> reduction measure and energy carrier up to the market, where the most cost effective measures (in terms of cost per tonne CO<sub>2</sub> reduction) are likely to be taken. Further reducing the CO<sub>2</sub> emissions target in future regulation could thus provide an effective means to promote low-carbon fuels in the future. The start that has been made on regulating WTW emissions from transport energy is likely to need to continue to ensure that appropriate signals are given to suppliers and users of transport energy in view of the fact that different actors only face and are able to impact on part of the emissions.

Consequently, it can be concluded that an integrated set of policy instruments is necessary to regulate WTT and TTW emissions in such a way that the introduction of clean technologies, which are relevant for realising ambitious long term GHG emission reduction targets, are stimulated without creating loopholes or even adverse impacts on WTW GHG emissions in the intermediate timeframe. In the long term a level playing field needs to be created in which improved conventional technologies and new options compete on the basis of cost effectiveness towards meeting environmental targets on the one hand and market attractiveness on the other hand. Combining an energy efficiency target at the vehicle level (rather than a CO<sub>2</sub> emissions target) with a WTW GHG emissions target at the level of (fossil and non fossil) energy carriers appears to be an option, but this would require more research to investigate whether it provides better safeguards for realising net WTW emission reductions and against loopholes.

In the longer term other emissions which cause radiative forcing may need to be taken into account. These include black carbon and N<sub>2</sub>O emissions from combustion engines in general, as well as impacts of emissions of water vapour and other substances by aircraft and at high altitudes. It seems quite likely that some overarching measures, such as those discussed above, will increasingly need to be deployed to reinforce the effects of other policy instruments. A combination of vehicle regulation and measures targeting in-use parameters incentivises application of fuel efficient vehicles and optimal use of the vehicles. Therefore, not only efforts in setting vehicle standards, but also in in-use standards for logistics, public transport, etc. may be useful.

### **3.2 Economic instruments to stimulate the uptake of GHG reduction options**

Economic instruments can contribute to GHG emissions reduction in various ways. When considering economic instruments it is important to realise that they also serve many other aims. Three main motives for pricing policies in transport can be distinguished:

- **Influencing behaviour** to improve the efficiency of the transport system and/or to reduce the environmental burden;
- **Generating revenues**; and

- **Increasing fairness**, e.g. the 'polluter pays principle', which is a key principle for EU policy stated in the EU Treaty.

In line with these various aims, various approaches to transport pricing exist. A first approach is called *internalisation of external cost*, also called *marginal social cost pricing*. The primary motivation for marginal social cost pricing is to achieve a more efficient economy by ensuring that prices equal marginal social costs. A second approach for pricing policy is the introduction of so-called Baumol taxes, which are set at a level which is estimated to be sufficient to achieve a given environmental objective. A third approach is Ramsey pricing, which is primarily aimed at generating revenues for governments with the smallest distortions on the economy. In a perfect market, the first best and most efficient approach — based on theoretical economic considerations — is *marginal social cost pricing*. However, deviating from pure *marginal social cost pricing* is usually considered to be appropriate for various reasons, including:

- If first best pricing is not applied throughout the network for all competing modes.
- If pure marginal social cost pricing requires an expensive or complex system, which leads to high administrative or transaction costs.
- If revenues from marginal social cost pricing are insufficient to cover infrastructure costs<sup>36</sup>.

Regarding GHG policy for transport, the main cost drivers for the marginal climate cost of transport are fuel consumption and the GHG intensity of the fuel. Therefore a purely marginal social cost based tax or charge would be a fuel tax or charge at the level of the marginal external cost of CO<sub>2</sub>, based on the GHG intensity of the fuel. Inclusion in an emissions trading scheme is an alternative way to give the same type of incentive, although in this case the price would be based on abatement costs rather than damage costs.

For all transport modes, either a fuel tax or emissions trading is therefore a potentially key element in an effective and efficient GHG reduction policy. However, it should be noted that it is very difficult, if not impossible, in these instruments to take account of variations in the GHG intensity of fuel based upon the way in which it is produced. It also needs to be noted that there are a range of impacts on society which it is desirable to reduce, not just GHG emissions. It is desirable for these other costs to also be internalised, however this will be difficult when using a solely carbon pricing instrument for internalisation.

Consequently, applying pure *marginal social cost pricing* to transport would imply that, in addition to fuel taxes for internalising the costs of climate change, differentiated kilometre charges should be introduced for internalising the marginal cost of infrastructure construction, maintenance and management, air pollution, noise, accidents and congestion. Depending on the mode, fuel taxes or emissions trading and differentiated infrastructure charges could be accompanied by other economic instruments, e.g. vehicle taxes to provide specific incentives for buying fuel efficient vehicles and to correct for consumer myopia<sup>37</sup>.

As is clear from the above discussion, the cost of a tonne of CO<sub>2</sub> is an important element in marginal social cost pricing. These costs can be estimated by using either damage costs or mitigation costs. A problem with both approaches is that estimates of both have very high uncertainties. For 2010, the mid-range estimates for the whole economy are in the order of

<sup>36</sup> See Appendix 10 for more details; also see <http://www.eustransportghg2050.eu/cms/updated-reports/>

<sup>37</sup> It is increasingly recognised that, when buying a new vehicle, consumers often do not pay attention to the full lifetime costs that they might face. This is referred to as consumer myopia, i.e. consumers are shortsighted with respect to costs, only taking account of the potential costs incurred in first three or four years of ownership.

€25 per tonne of CO<sub>2</sub> while in 2050 the CO<sub>2</sub> costs are expected to increase to roughly €85 per tonne, but with a very high range of uncertainty of at least €20 to €180 per tonne. Long term damage cost estimates do not yet include all possible long term risks, such as the feedback mechanisms that may occur in the world climate system that could lead to much more rapid and dramatic climate changes. These risks are the main arguments behind the overall aim of keeping temperature rise within 2° Centigrade, so long term climate costs may even be much higher than the figures mentioned above.

Both fuel taxes and a cap and trade emissions trading scheme can be regarded as a first best approach. They both provide incentives for all types of GHG reduction options and leave the actual choice of how to reduce CO<sub>2</sub> emissions to the market, which may deploy many different reduction options, both technical and non-technical, such as those set out in Section 2. These instruments also have an impact on transport demand, as they cause an increase in the price of fuel. For fuel consumers, emissions trading works in a similar way to including a carbon price in fuel taxes, with the main difference being that under emissions trading the price can vary more frequently over time. For governments, the main difference is that a CO<sub>2</sub> emissions target has to be set under emissions trading, instead of a CO<sub>2</sub> price.

There are two potential options for a cap and trade emissions trading system:

- Upstream trading: A cap is put on companies that sell transport fuels. The CO<sub>2</sub> price may become volatile due to the very indirect impact of energy companies on the behaviour of consumers;
- Downstream trading: Fuel consumers, that actually use the fuels and thus emit the CO<sub>2</sub>, are the trading parties. A disadvantage of this approach is that it is complex and costly due to the large number of trading entities.

Were transport to be included in the existing EU emissions trading system (ETS), which is a downstream system, a potential drawback is that the EU ETS also contains companies that compete with industry outside the EU; a high CO<sub>2</sub> (and energy) price (resulting from a restrictive cap) may harm their competitive position<sup>38</sup>. Strongly reducing the CO<sub>2</sub> cap in the ETS or otherwise increasing the CO<sub>2</sub> price may therefore have negative impact on EU economy and employment, and on the effectiveness of the CO<sub>2</sub> policy (due to carbon leakage). Moreover, this option does not allow for the minimisation of the sum of mitigation costs and carbon leakage and therefore does not reduce GHG emissions at the lowest overall cost for the EU economy. Note that this drawback would disappear once it were possible to put a stringent global climate policy in place, but it would still not guarantee that the price was high enough for early enough action in transport. The inclusion of a growing sector, such as transport, in the EU ETS will more rapidly lead to allowance price increases and stimulate reduction efforts, primarily in non-transport sectors. However it is likely to have a limited impact on transport due to the problems previously identified. Conversely, if other policy instruments, such as energy efficiency standards for vehicles, are used to restrict the growth in transport's GHG emissions, the inclusion of transport in the EU ETS would not provide such pressure for emissions savings in other sectors.

This problem could be avoided by introducing a separate emissions trading system for the transport sector. However, such a system would be similar to introducing an equivalent similar CO<sub>2</sub> tax on fuels in all EU Member States, but is likely to be much more complex and still does not address the problem of split incentives. However, a separate emissions trading

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<sup>38</sup> Note that it is possible to take action to address such potential carbon leakage, as the Commission has under the existing EU ETS by giving the sectors that are potentially at risk from carbon leakage 100% of their benchmark allowances for free. It is not clear what additional action would be needed, or indeed could be taken, if transport were included in the EU ETS.

for transport would lack the flexibility of enabling abatement options to be taken up across various sectors, thereby failing to deliver one of the principal advantage of an ETS.

As is evident from the respective price elasticities (see, for example, Table 2 in Section 5.1.1), economic instruments can have a significant impact on the overall volume of transport undertaken, as well as on the modal split. The effects of pricing measures depend a lot on the presence of alternative modes. In a city with good public transport and cycling facilities, the impact of parking fees will be larger than in other cities. Therefore, also for these reduction options, economic instruments should preferably be combined with other type of instruments, e.g. spatial planning, infrastructure policy, etc. in order to be effective.

The main barriers for the introduction of economic instruments that could effectively reduce GHG emissions of transport have to do with the lack of public support and the fear for adverse economic effects. Increasing the cost of freight transport has an impact on the costs of production and therefore also on the competitive position of the EU economy. The size of the impact is largely dependent on the share of transport costs in the overall production costs. For around 70% of products, this share is less than 3%, although for some it may represent up to 8% of the total costs<sup>39</sup>. Consequently, increasing transport costs has an impact on production costs, but in most cases this impact is only modest.

Economic instruments can be combined well with other instruments. They are complementary to vehicle regulation in improving fuel efficiency of the fleet since they can help to avoid the rebound effects from improved efficiency (see Section 3.6, for example). Various types of economic instruments (e.g. fuel taxes, emission trading and differentiated vehicle taxes or parking fees) create market conditions which help to increase the market share of fuel efficient vehicles.

Various economic instruments could contribute to GHG reduction in **road transport**. The inclusion of road transport in the EU ETS is theoretically possible, but risks being suboptimal, as long as it lacks a global climate policy, for the reasons mentioned above. Consequently, for road transport a separate trading scheme or carbon taxes on fuel, which would probably be less complex, would be alternatives. Additionally, given consumer myopia, i.e. that consumers tend not to consider the life-time costs of car use, instruments in addition to fuel taxes or emissions trading are also important in changing consumer behaviour, for example differentiated registration (or purchase) taxes, circulation taxes and parking fees.

The removal of hidden subsidies, such as the way in which some countries tax company cars and the fiscal treatment of commuting and business travel, is also important in ensuring that users are faced with the full consequences of their choices and thus in reducing transport's GHG emissions. Kilometre charges and congestion charges can be effective instruments for reducing many other types of external effects, particularly road congestion. Therefore they are effective instruments in a policy that aims at both congestion reduction and GHG reduction, because they can reduce traffic congestion without generating extra traffic.

Financial instruments in **rail transport** have a relatively small GHG reduction potential. From the perspective of fair and efficient pricing, rail pricing becomes important as soon as economic instruments are further developed in other modes. Since electricity is already included in the EU ETS, fuel taxes on rail diesel could than be harmonised at a higher level.

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<sup>39</sup> Based on work undertaken in support of the European Commission's proposal for the Eurovignette Directive in 1996 (COM(96) 331); see Annex 2 of COM(96) 331. The 8% figure is for the cement and lime industries. Of course, for transport industries the proportion of transport costs in their total costs will be significantly higher.



However, improving the competitive position of rail transport by increasing the efficiency, interoperability and quality of service seem currently higher priorities.

A fuel tax on the use of **inland navigation** would be an efficient instrument to influence the CO<sub>2</sub> emissions if it were implemented at the European level. However, this would require an amendment of the Mannheim Convention, otherwise the effectiveness of the instrument would be significantly reduced. Only when this restriction could be overcome it would be a reasonable instrument. The same holds for environmentally differentiated infrastructure charges.

The inclusion of **maritime shipping** in the EU ETS is one of the policy instruments being discussed for GHG reduction for maritime shipping. A fuel tax would only be environmentally effective if it were implemented on a global scale, which would also be the optimal level for the implementation of an EU ETS for ships. However, such a global implementation is certainly not easy to achieve. Environmentally differentiated port charges are also the most effective when implemented on a global scale, but implementation at a regional scale could deliver some GHG reductions. Here the voluntary participation of ports is conceivable too. A disadvantage of such port charges could be that, depending on the design of the instrument, it might only provide a small incentive for operators to take abatement measures, as port dues seem to constitute only a small part of the total costs for ships while at berth.

From 2012, CO<sub>2</sub> emissions from **aviation** for flights from, to and within the EU, will be included in the EU emissions trading scheme and will receive up to 85% of allowances corresponding to the sector's historic emissions free of charge, depending on the growth of emissions. A ticket tax and/or environmentally differentiated airport charges, which could be voluntarily implemented by Member States, could accompany the trading scheme. The equal regulation of the different modes with regards to fuel taxation and VAT would also contribute to the development of a level playing field in transport.

A fuel tax could be environmentally effective when implemented at a European scale. However, to achieve this many Bilateral Air Service Agreements will have to be adjusted. While this will take time, it is clearly feasible within the time frame under consideration. For both a ticket tax and the imposition of VAT on flight tickets, it holds that they target the external costs indirectly by aiming at reducing the transport demand of passengers. Both instruments do not give an incentive for airlines to invest in abatement measures. A ticket tax is easier to differentiate environmentally.

Finally, it is worth noting that the emissions of oxides of nitrogen (NO<sub>x</sub>) of aircraft, if emitted above a certain altitude, also seem to contribute to the GHG effect. Depending on the scientific consensus reached, the regulation of CO<sub>2</sub> emissions of aviation should be accompanied by policies targeting NO<sub>x</sub> emissions.

The scenarios developed in SULTAN cover a number of the economic instruments discussed in this section (see Table 1 in Section 5). The potential GHG emissions reduction that could be achieved by the introduction of various CO<sub>2</sub> prices is the subject of scenario 12, while the costs associated with NO<sub>x</sub> and particulate matter (PM), both conventional air pollutants, are included in scenario 11. Scenario 10 assesses the potential impact of reforming Member States' company car taxes, while scenario 13 assumes that all modes are subject to equivalent levels of fuel duty and VAT on fuel.

### 3.3 Infrastructure and spatial policy, speed and traffic management

In infrastructure and spatial planning processes various instruments are used to assess the **environmental implications of decisions**: Environmental Impact Assessments (EIA); Cost Benefit Analyses (CBA); and Strategic Environmental Assessments (SEA). These instruments can help decision makers make choices that take into account the environmental impacts of a project or a plan, e.g. for new transport infrastructure or spatial development.

Further integration and improvement of GHG impacts in environmental assessments could have a significant impact on the GHG emissions of transport in the long term. The policies for doing this are:

- Ensure that all (very) long term impacts on GHG emissions are included in these assessments.
- Apply higher shadow prices for the long term emissions of CO<sub>2</sub> in CBAs, in order to better reflect the risks for possible long term dramatic climate changes.
- Introduce specific conditions or requirements to the overall impact on GHG emissions.

There are a number of **urban planning and infrastructure policies** that affect the GHG emissions of transport, e.g. urban planning, investments in public transport, cycling and walking infrastructure, parking policy and policies for advanced distribution concepts. These policy instruments could help to reduce GHG emissions. However, they need to be combined with other measures such as pricing policies, otherwise the reduction is expected to be limited (or even negative). There is limited concrete, quantitative evidence on GHG reduction potential of these instruments, partly because of the complexity of effects induced by these policies, but also because of the lack of assessments: most of these instruments are not specifically applied with the goal of reducing GHG emissions.

These instruments could also have a positive impact on the liveability and accessibility of cities. Effects on GHG emission reductions are more limited and may even be negative in certain cases because of second order effects: some of these policies may also increase overall transport volume if no policies to prevent that are implemented.

Outside of urban areas, most transport GHG emissions are from cars and trucks (for the shorter distances) and by airplanes and trucks (for the longer distances). To reduce GHG emissions from these trips, the main policy instruments are those that reduce the need for journeys or those that achieve a shift from high-carbon kilometres towards lower-carbon kilometres for transport. Investments in the less GHG intense modes have the potential to lead to better developed and more efficient transport networks. However, provision of new transport possibilities and/or infrastructure alone cannot be expected to lead to a GHG emission reduction, as it is effectively increasing the capacity of the transport system, which in turn is likely to stimulate additional travel. Consequently, such investments need to be part of a wider set of complementary policy instruments, such as regulation of vehicle emissions or pricing policy, if it is to play a role in reducing transport's GHG emissions.

**Traffic management policy** could also be used to minimise fuel consumption and GHG emissions. For the purposes of CO<sub>2</sub> reduction, this would be achieved by reducing the number of kilometres driven, by favouring less GHG intensive transport modes and by enabling vehicles to operate at favourable, constant speeds. Significant reductions in GHG emissions could then be achieved. However, traffic management measures could also increase the capacity of the road network and thus the attractiveness of (certain routes in) the transport network. This could in turn lead to extra kilometres being driven and thus additional GHG emissions, unless this policy is part of a larger set of measures as described

above. Lowering **speed limits** can be very effective in reducing GHG emissions, without generating this rebound effect of increasing transport volume. Enhanced speed limit enforcement can have a comparable effect as has been illustrated where concerted efforts have been made in this respect.

The most important barriers to these policy instruments are the economic consequences of longer travel times and user acceptance and compliance with speed limits. Most of the measures discussed have (significant) co-benefits, for safety, air quality, reduced noise and energy security.

In conclusion, there is a strong relationship between the provision of infrastructure, spatial planning and transport speed on the one hand, and transport demand and modal split on the other hand. Both within and outside of urban areas, GHG reduction could be delivered by spatial planning policies and investments in public transport, cycling and walking. Lower speed limits or traffic management may also be effective instruments to reduce the GHG emissions of transport. In order to achieve GHG reduction, an important prerequisite is that the policies aim to reduce transport volume or to cause a shift towards less GHG intensive modes of transport. If successfully implemented, many of these instruments, especially spatial policies, will usually only be effective in the long run, since the impacts of urban planning take some time.

However, drivers of these policies are currently typically economical and social aims rather than environmental. Many of these policies could then lead to an increase in transport demand and thus GHG emissions if no other policies (such as pricing policies) are implemented to prevent this<sup>40</sup>.

The scenarios developed in SULTAN cover a number of the instruments discussed in this section (see Table 1 in Section 5). Scenario 3 assesses the impact of a number of measures to stimulate cycling and walking, while scenarios 5 and 6 assess the potential GHG reduction that could be achieved through a package of mobility management measures and improved freight inter-modality, respectively. Finally, scenarios 7 and 8 assess the potential impact of speed policies, i.e. improved speed enforcement and the introduction of a harmonised motorway speed limit in the EU.

### **3.4 Information to raise awareness and encourage behavioural change**

Information will be important to increase awareness of not just the options that could be adopted to reduce GHG emissions, but also to raise awareness of the importance of taking action to address climate change more generally as part of a wider shift to lower GHG intensity lifestyles, as well as to overcome informational barriers associated with new technologies or modes of travel.

However, it is important to remember that the provision of information, information campaigns and raising awareness can only go so far in terms of reducing the GHG emissions of personal and business travel choices. Instruments such as the introduction of eco-driving for individuals and organisations are likely to have a positive effect on the reduction of GHG emissions. It is likely to be an important part of the learning package for new drivers, but is also relevant to experienced drivers. However, there will come a point where awareness and understanding of the benefits of eco-driving will reach a peak, after which further improvements are unlikely. This will be coupled with technological

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<sup>40</sup> See Appendix 11 for more details of the potential GHG reduction of the instruments discussed in this section; also see <http://www.eurtransportghg2050.eu/cms/updated-reports/>

developments in the transport field, with vehicles becoming continually more fuel efficient, likewise with the introduction of hybrid and electric technology (see Section 2.4).

Schemes and initiatives could become widespread across Europe, constantly raising awareness, although there will rapidly come a point where information will have to be supported by a range of other instruments and measures to ensure benefits (in terms of GHG emission reduction) into the longer term (post 2020), including those relating to demand management, the provision of attractive and accessible infrastructure (footways, cycleways, public transport etc.) so people are able to make practical changes in the way they travel. Land use and spatial planning is also an important instrument in terms of reducing the need to travel and enabling the use of more sustainable modes (see Section 3.3).

Whilst energy and CO<sub>2</sub> labelling of vehicles at the point of sale can help to increase awareness of the potential environmental implications of a new purchase, the evidence suggests that this measure is unlikely to have any direct impact on reducing emissions of GHGs, particularly when implemented in isolation, as car buyers base their purchasing decisions on many other criteria. Supporting measures include those already beginning to be implemented in EU Member States, such as vehicle taxation, which can be used to further encourage the purchase of vehicles with lower GHG emissions. However, as mandatory CO<sub>2</sub> emission targets come into force for passenger cars, energy and CO<sub>2</sub> labelling will play less of a role in encouraging the purchasing of lower polluting vehicles, but would still have a role in complementing the legislation through raising awareness and ensuring comparable and independent information for consumers.

The responsibility for the provision of information, information campaigns and raising awareness is likely to be at a variety of levels of government, from European to the local level depending on the key messages. In any case, support from the Commission and national governments in terms of best practice is required. Implementation is often more likely to be at a local or regional level. With regards to labelling, the responsibility for stimulating best practice should largely lie at the European level in order to overcome some of the inconsistency issues that currently arise with existing legislation between countries. Implementation of legislation is the responsibility of vehicle manufacturers, vehicle dealers and national governments.

With regards to driver training, the overall long-term (post 2020) reduction potential is hard to estimate especially due to the fact that the distribution of technologies in the vehicle fleet by 2050 is unknown. Vehicle technology is expected to automate more and more of the eco-driving techniques, thus reducing the potential benefits of these operational measures. The current generation of hybrids already automates gear changes, recovers brake energy and prevents unnecessary idling. Additionally, tyre pressure monitoring that will automatically warn drivers if tyres need to be inflated (or inflate them automatically) will be fitted as standard in the near future. It is also likely that different vehicle technologies will require different efficient driving rules. For instance, a hybrid drive might benefit from driving methods that are based on the optimal utilisation of the electric buffer, and electric cars might require other techniques than cars running on hydrogen-fuel cells or hybrids. Depending on the distribution of technologies in the fleet, single eco-driving training might no longer have the desired effect. The responsibility for the promotion of eco-driving activities (i.e. through sharing of good practice) and the implementation of appropriate legislation could lie with the Commission and national governments. They will be supported by vehicle operators in ensuring that training is provided to drivers working in the transport industry.

Ultimately it should be recognised that there are strong interlinkages between information instruments and other policy instruments. However, whilst these instruments provide context

and information, they will mostly rely on the implementation of other instruments to stimulate change. Assessing the impact on GHG emissions of information instruments is not straightforward, but the impact of training to deliver fuel efficient driving was assessed by scenario 9 of SULTAN (see Table 1 in Section 5).

### 3.5 Other instruments to stimulate innovation and development

Many of the instruments discussed in the previous sections have the potential to contribute to stimulating technical innovation and development, although often this stimulation is indirect. Instruments such as regulation to tighten emissions standards or improve GHG-intensity targets have the potential to stimulate innovation, although the effect is more likely to be felt for those technologies that are already near to being placed onto the market. The instruments considered in this section directly target technologies that are struggling to increase their market share or which are at earlier stages of development, i.e.:

- Green public procurement;
- Fleet tests and demonstration programmes; and
- Research and development.

The use of **green public procurement (GPP) policies** and practices targets those technologies that have been tested and demonstrated and so are ready for the market, but which are not currently commercially viable to move into mainstream markets. Previously there had been concerns that GPP contravened the EU's single market legislation, but the 2004 public procurement Directive<sup>41</sup> clearly allows GPP, so this is no longer a concern. GPP may lead to a shift in the distribution of energy efficiency in the procured fleet, but may also accelerate the introduction and availability of more fuel-efficient vehicle types. As other policy instruments become tighter, e.g. vehicle emissions performance standards and GHG energy intensity targets, these revised instruments are likely to achieve impacts similar to those being sought after through the use of GPP (through fleet turnover in the procured fleet and developments in fuel efficient vehicle types). Therefore in the longer term, the impact of GPP and associated legislation will diminish unless its requirements are continually revised in light of technical and policy developments. The introduction and implementation of GPP legislation and uptake is ultimately the responsibility of the Commission and national governments, such as the clean road vehicles Directive (see Section 1.6). Its uptake should be supported by various levels of government and the public sector, but also to the private sector in terms of ensuring that the appropriate fuel-efficient technology is being developed. The introduction of GPP also has the potential to stimulate the development of less developed technologies.

**Fleet tests, demonstration and pilot programmes** can be used to help develop those technologies that have not yet been fully tested or demonstrated in relevant operational environments. Public sector support for such tests and programmes provide a clear signal to the operators, manufacturers and developers that the government is committed to the development of low carbon technologies. Grants could be provided from public sector funds for demonstration projects or tax credits or tax incentives could be used to stimulate fleet tests and demonstration projects. Such tests and programmes enable manufacturers to learn from the operation of prototypes and enable operators to learn from the operations of the vehicles, as well as from consumer reactions. Hence, such instruments could accelerate the introduction of technologies that are currently further away from market introduction and enable more efficient design, particularly in conjunction with R&D.

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<sup>41</sup> Directive 2004/17/EC

**R&D**, which could be funded by either the private or the public sector, is essential in delivering technical improvements in the transport sector by assisting the development of technologies that are not yet ready even to be tested or demonstrated. Hence, R&D is important to assist those technologies that are furthest from being commercially viable. Mandatory requirements and the implementation of new legislation, such as that discussed relating to GPP, are likely to be key drivers of future R&D, as will be ever-tightening emissions standards (see Section 3.1). R&D can be a way of advancing technology and ensuring that energy/fuel efficiency (and other desired goals) can be achieved, but also as a mechanism to deliver the desired goal at a lower cost. However, it should be ensured that R&D is actively focused on the right technologies, e.g. aiding the achievement of targets, but taking account of any subsequent implications for transport or other sectors (e.g. economic or societal impacts etc). The responsibility for the undertaking of R&D activities is likely to fall to vehicle manufacturers and industry, with support from national governments or the EC.

The use of policies to stimulate innovation is also a potentially useful tool, but these should not become subsidies or be used to promote developments that were already taking place. Hence, the design and application of such instruments need to be continually monitored and evaluated to ensure that they are targeting the most appropriate technologies for appropriate lengths of time.

### **3.6 The complementary nature of regulation and economic instruments**

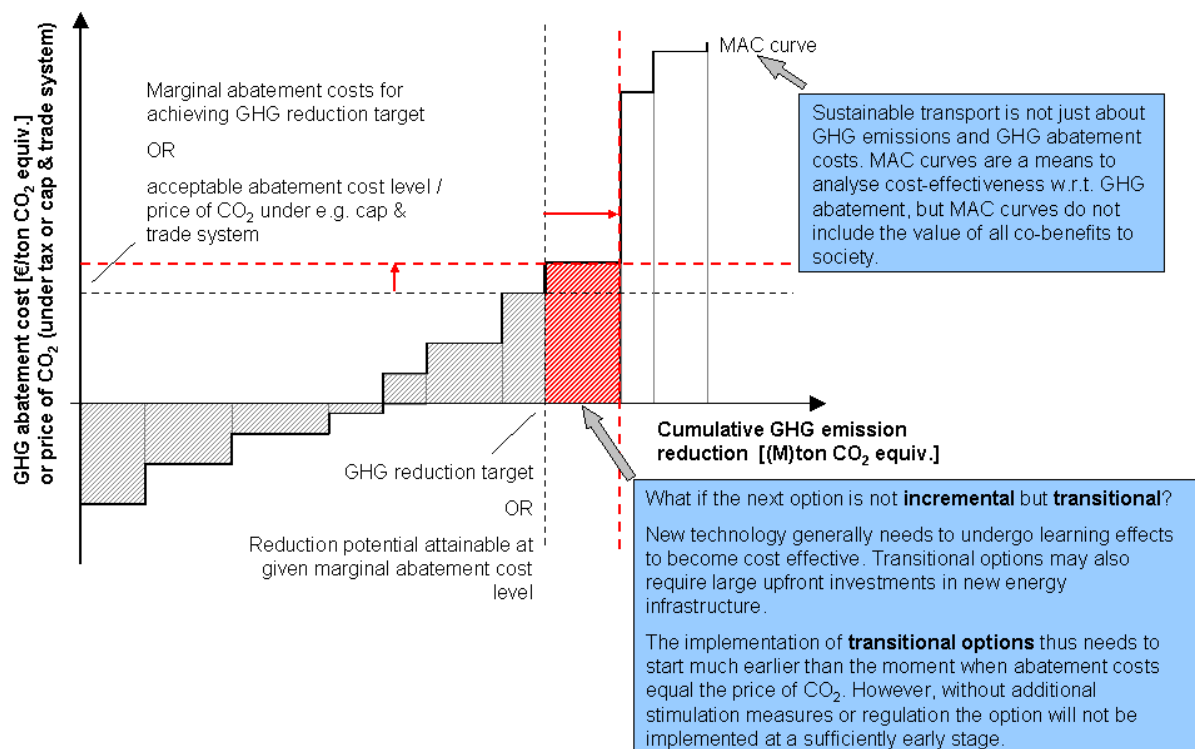
A general challenge with respect to using economic instruments for promoting low carbon transport is the issue of split incentives. In other words, while manufacturers are required to invest in (initially expensive) technology, the users benefit from reduced fuel consumption but have limited incentives to invest in (initially expensive) technology. This is further amplified by the acknowledged myopia of consumers with respect to future cost savings and by risk aversion. Particularly for more transitional technologies, such as vehicles using electricity or hydrogen, the initial costs of vehicles and infrastructure will be high and most consumers will need time to accept and become accustomed to the new technologies. For these technologies early market formation is necessary to stimulate investment in infrastructure and to push the options down the learning curve (cost reduction and product innovation) so that they are available at mature costs when necessary (see Figure 7).

To solve this problem it will be necessary to apply both **push** (supply side) and **pull** (demand side) instruments. In view of this, regulation and economic instruments may not need to be alternatives but can act as complementary elements of an integrated approach to virtually carbon-neutral mobility. This can be supported by demand measures such as time-limited support mechanisms (see Section 3.5), labelling and other information instruments (Section 3.6), as well as tax differentiation which in part should be arranged at a European level, but can mostly be implemented at the national level.

### **3.7 Mapping policy instruments to options**

The previous sections have discussed various policy instruments that have a potential role to play in stimulating the uptake of both technical and non-technical options that could reduce transport's GHG emissions. The discussion with respect to regulation highlighted that such instruments are appropriate for decreasing the GHG intensity of energy used in the transport system and for setting standards to improve the energy efficiency of new vehicles.

**Figure 7: Illustration of how economic instruments may fail to create early stimuli for market formation for transitional technologies that are required to meet more ambitious GHG reduction targets**



For their part economic instruments are also important, both for addressing the potential rebound effects from using less GHG intensive and more energy efficient vehicles, but also from the perspective of economic efficiency. In this respect, both emissions trading and the integration of CO<sub>2</sub> costs into fuel taxes have the potential to be an efficient mechanism, but other market failures and regulatory failures exist, such as incomplete information and split incentives, which mean that the use of other policy instruments are also important. In this respect, targeted economic instruments could be used to stimulate different behaviour with respect to vehicle purchasing and use, while various instruments could be used to assist the development of new technologies, which are as yet not commercially viable, e.g. green procurement policies and funding of fleet tests, demonstration programmes and wider R&D. The provision of information is also important at a number of levels to inform travel choices, to educate with respect to new technologies and to increase the understanding of climate change and the role of individuals in mitigating this.

It is important to note that it is not possible to map a particular policy instrument to the uptake of a particular option<sup>42</sup>. Most policy instruments have the potential to stimulate the uptake of a range of options. For example, the inclusion of a CO<sub>2</sub> price in fuel taxes impacts directly on the demand for travel, but will also help to stimulate the development of more efficient vehicles and more efficient transport systems.

<sup>42</sup> In Appendices 9 to 12, policy instruments are mapped to options. It can be seen that from these tables, that there is not a direct one to one mapping for any combination of option and policy instrument.

## 4 Policy frameworks for reducing transport's GHG emissions

As was noted in Section 1.6, the EU's current approach to reducing transport's GHG emissions has been targeted at specific areas, e.g. vehicles or fuels, whereas a coordinated, more strategic approach is important to address the long term challenge of reducing transport's GHG emissions. In order to provide such an approach, the project developed alternative policy frameworks, which aim to set out the potential strategic approaches, and issues associated with the implementation of these, that might be adopted to address the challenge of reducing transport's GHG emissions. The potential policy frameworks were defined on the basis of the means of reducing transport's GHG emissions that each particularly targeted (i.e. those set out in Section 2.5). For each of the subsequent figures, the dotted lines representing 60%, 80% and 95% reductions are with respect to transport's 1990 emission level.

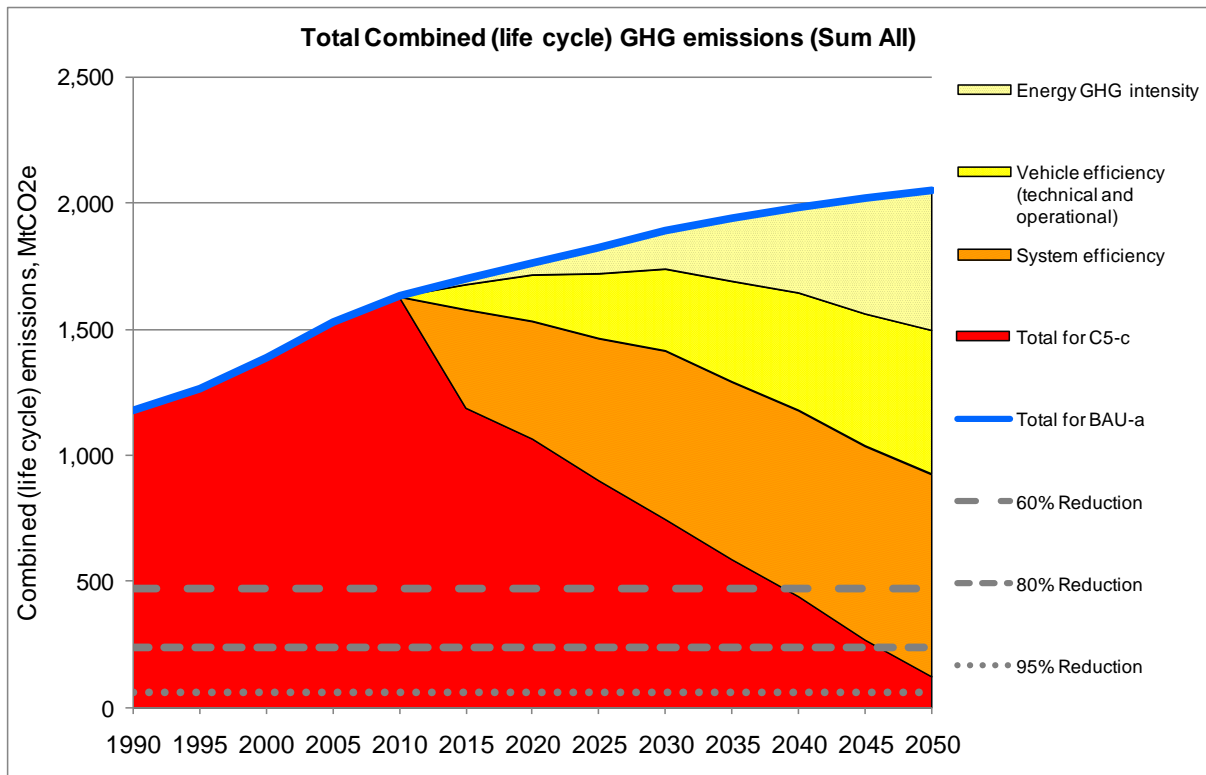
Figure 8 illustrates, for the most demanding policy package considered within the project, the GHG reductions delivered by category. Broadly, *GHG intensity of energy* and *efficiency of vehicles (technical)* could be considered to be stimulated predominantly by the technical options, while *efficiency of vehicles (operational)* and *system efficiency* is a result primarily of the action of the non-technical options (see Section 2). In the figure, the technical and operational efficiency of vehicles are presented together, as these both act on the energy used by a vehicle for a particular distance travelled, as measured in mega joules per kilometre (MJ/km). For their part, the "GHG intensity of energy" affects the amount of GHGs emitted per mega joule (MJ) of energy used, while "system efficiency" acts to reduce the amount of vehicle kilometres travelled by, for example, improving the structural efficiency of the transport system through improved spatial planning and improving the economic efficiency of transport by internalising its external costs.

Figure 9 and Figure 10 illustrate separately the breakdown of these categories for technical and non-technical options respectively. The scenarios in SULTAN assume that non-technical options impact both on transport volume and the efficiency of vehicles (e.g. increased fuel costs resulting in purchase of more efficient new vehicles) and their use (e.g. lower speed limits or eco-driving). Similarly technical options have impacts on transport volume (e.g. via increased fuel prices).

The approach taken for the alternative policy scenarios was to begin by identifying the potential GHG reductions that could be achieved by the technical options, i.e. improving the GHG intensity of the energy used by transport and improving the technical efficiency of the vehicles. The GHG reductions identified would identify whether the uptake of the technical options could deliver GHG reductions of the order that might be required. Subsequently, scenarios focusing on the non-technical options **were added**, thus integrating improvements to the efficiency of the transport system to the improvements in GHG energy intensity and the technical energy efficiency of vehicles. The potential GHG reductions resulting from this approach is presented in Section 5.3, while the policy frameworks themselves are presented in Section 6.1 for technical options and Section 6.2 for non-technical options.

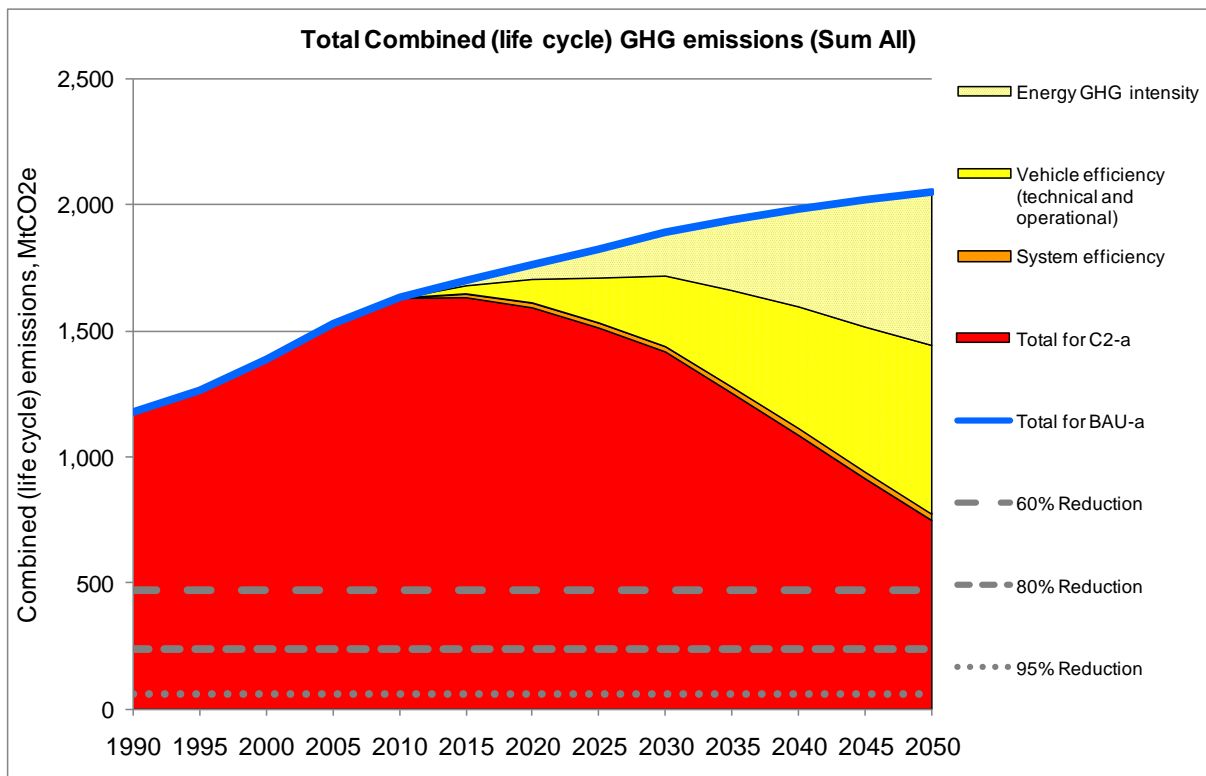


**Figure 8: Potential means of reducing transport's GHG emissions – All Options**



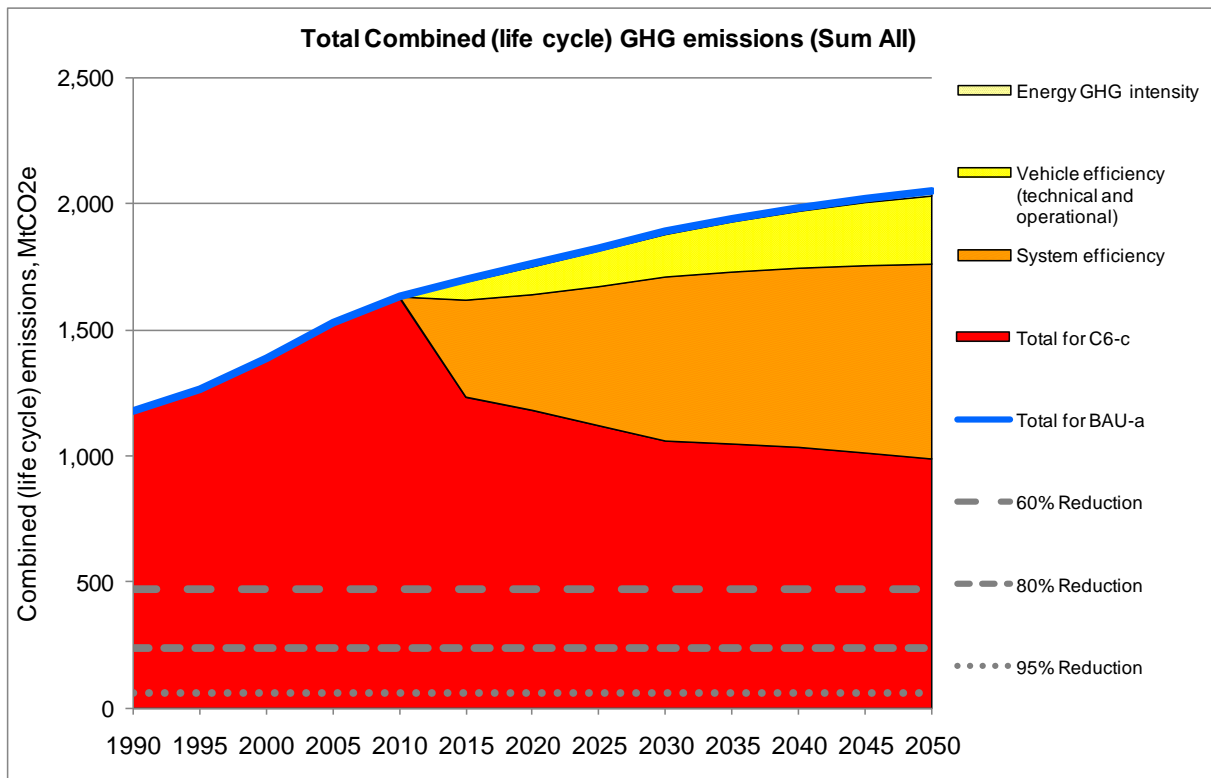
Source: SULTAN Illustrative Scenarios Tool, Scenario C5-c

**Figure 9: Potential means of reducing transport's GHG emissions – Technical Options**



Source: SULTAN Illustrative Scenarios Tool, Scenario C2-a

**Figure 10: Potential means of reducing transport's GHG emissions – Non-Technical Options**



Source: SULTAN Illustrative Scenarios Tool, Scenario C6-c

## 5 Delivering GHG emissions in the transport sector by 2050

This section presents the potential GHG reductions that might be possible in the EU transport sector by 2050 using a back-casting approach to help identify the policies/options that might be needed to reach desired GHG reduction levels. The analysis has been based predominantly on the GHG reduction potentials identified in the course of the evidence review and stakeholder engagement undertaken as part of the project (see Section 1.2). Additional elements were based on supplementary external analysis and data sources such as the potential electricity decarbonisation rate (from EURELECTRIC, 2010) and EU biofuels potential (from BIOFRAC, 2006). Due to the complexity of assessing all of the information that was obtained in the evidence review, an illustrative scenarios tool (SULTAN) was developed to estimate the potential GHG reductions resulting from the uptake of the various options. The aim of this tool was not to attempt to predict what will happen in the EU transport sector; rather it was to identify what GHG reductions might be possible if the uptake of the various options identified in Section 2 were stimulated by sufficiently ambitious policy instruments, such as those discussed in Section 3.

To interpret the results from SULTAN it is also important to note the following key points:

- The list of options considered focused on the main technical and non-technical options identified that could be suitably defined. The list is therefore not fully comprehensive as there are other options not included that also could make important contributions to reducing transport GHG emissions. However, most of the main options have been covered in the tool.
- The tool covers both direct (TTW) and indirect (WTT) emissions of CO<sub>2</sub>, N<sub>2</sub>O and CH<sub>4</sub>. The tool does not include climate impacts of other pollutants, such as radiative forcing caused by high altitude emissions of NO<sub>x</sub> and water vapour from aircraft.
- International (i.e. to non-EU countries) aviation and maritime shipping are included.

Section 5.1 introduces the illustrative scenarios used in the project by first presenting the scenarios, along with the most important assumptions that underlie the tool, followed by a summary of the most important assumptions that were used when developing the combined scenarios. Clearly, a large number of assumptions had to be made in developing the tool. Some of the risks and uncertainties associated with these assumptions are discussed in Section 5.2.

Section 5.3 presents the results of the scenarios, focusing on the combined scenarios. The potential GHG reductions that might be delivered by stimulating the uptake of various categories of options in turn are discussed, i.e.:

- Reducing the **GHG intensity of transport energy**;
- Improving the **technical energy efficiency of new vehicles**;
- Improving the **operational efficiency of vehicles**, i.e. how they are used, and improving the **structural efficiency of the transport system**; and
- Improving the economic **efficiency of transport**, by internalising selected external costs, removing subsidies and creating a level playing field.

The final combined scenario presents the maximum potential that the scenarios defined in the tool could deliver. The implications of this final scenario for key transport indicators are discussed in Section 5.4.

## 5.1 Introduction to the Illustrative Scenarios

### 5.1.1 The scenarios and the most important underlying assumptions

As was noted at various points in Sections 2 and 3, various scenarios have been defined and their potential impacts on transport's GHG emissions assessed using SULTAN. Table 1 provides a summary of these scenarios, together with the category of option and type of option that each scenario stimulates.

**Table 1: Summary list of the illustrative scenarios defined in SULTAN**

Scenarios defined in SULTAN	Area	Type	
<b>Single Scenarios</b>			
1. Reduce GHG intensity of fuel (all modes)	A	Technical	
2. Mandatory new vehicle emission limits (all modes, with/without biofuels)	A, B		
3. Package of cycling and walking improvement measures (walk/cycle)	C	Non-Technical	
4. Improved spatial planning (road and rail)			
5. Package of mobility management measures incl. improved public transport			
6. Improved freight intermodality (road, rail and inland shipping)			
7. Improved speed enforcement (road)	D, (E)	Non-Technical	
8. Harmonised EU motorway speed limit (road)			
9. Fuel-efficient driver (FED) training (road, rail)			
10. Company car tax reform (cars)	(A, B, C, D,) E		
11. CO <sub>2</sub> price tax (all modes, based on central/low/high CO <sub>2</sub> costs))			
12. Non-CO <sub>2</sub> price tax (road, internalise cost of NO <sub>x</sub> , PM and energy security)			
13. Equivalent duty and VAT rates for fuels (all modes)			
<b>Combination Scenarios</b>			
C1. Technical Measures: Reduce energy GHG intensity (biofuels)	A		Technical
C2. (All) Technical Measures: Mandatory new vehicle limits + biofuels	A, B		
C3. Scenario C2 + Spatial planning and modal shift measures	A, B, C		Technical and Non-Technical
C4. Scenario C3 + Speed and driver training measures	A, B, C, D		
C5. Scenario C4 + Taxes (with central/low/high CO <sub>2</sub> prices), i.e. All Technical and Non-Technical Measures Scenario	A, B, C, D, E		
C6. Non-Technical Measures: Planning +modal shift +speed +FED training +Tax (central/low/high CO <sub>2</sub> prices)	C, D, E		

**Notes:**

Many of the scenario options will affect more than one category to a greater or lesser extent, however they have been grouped in the above table into their primary category area of action, as follows:

- (A) Decarbonising energy carriers (i.e. reducing the GHG intensity of transport energy).
- (B) Improving vehicle efficiency (i.e. improving the technical energy efficiency of new vehicles).
- (C) Efficient organisation of transport system (i.e. improving the structural efficiency of the transport system via modal shift, co-modality and spatial planning).
- (D) Improving vehicle use (i.e. using vehicles more efficiently by improving operational efficiency).
- (E) System efficiency (e.g. improving the economic efficiency of transport via economic instruments, by internalising selected external costs, removing subsidies and creating a level playing field).

The elasticities used to define the impact of changing **fuel prices** in the illustrative scenarios are summarised in Table 2. For example, an elasticity of -0.54 means that for every 1% increase in final fuel price there is an equivalent demand response of -0.54%. The elasticity linking **demand response to speed reduction** measures is assumed to be 1:1 for passenger modes (i.e. a 1% reduction in passenger kilometres for every 1% reduction in

speed) and 1:4 for freight modes (i.e. a 0.25% reduction in tonne kilometres for every 1% speed reduction).

**Table 2: Fuel Price-Demand response elasticities used in the definition of the illustrative scenarios modelled in SULTAN Illustrative Scenarios Tool**

Mode	Elasticity
Car	-0.54
Bus	-0.38
Passenger Rail	-0.24
Motorcycle	-0.41
Van	-0.30
Medium Truck	-0.30
Heavy Truck	-0.30
Inland Shipping	-0.18
Maritime Shipping	-0.18
Freight Rail	-0.24
Intra EU Aviation	-0.38
Other International Aviation	-0.38

Source: UK MARKAL ED model (2008)<sup>43</sup>

The assumptions on the **external costs** of CO<sub>2</sub>, NO<sub>x</sub> and PM emissions are based on information from the EC's IMPACT project and are summarised in Table 3 and Table 4. In addition an indicative figure for energy security from the IMPACT handbook of approximately 5 €/cent/litre has also been used.

**Table 3: External costs of climate change from IMPACT project (in €/tonne CO<sub>2</sub>), expressed as single values for a central estimate and lower and upper values**

Year of application	2010	2015*	2020	2030	2040	2050
Lower value	7	12	17	22	22	20
Central value	25	32.5	40	55	70	85
Upper value	45	57.5	70	100	135	180

Notes: \* interpolated from IMPACT study values for 2010 and 2010

**Table 4: External costs of NO<sub>x</sub> and PM used in defining illustrative scenarios**

		2000	2010	2015	2020	2030	2040	2050
EU27 NO <sub>x</sub>	All	4,400	7,424	8,642	9,261	9,650	10,102	10,228
EU27 PM	Non-urban	57,355	89,571	98,629	96,427	92,328	86,539	75,267
EU27 PM	Urban	158,568	251,282	279,002	275,397	262,014	236,852	180,868

Source: Based on weighted average of figures from IMPACT project (in 2000€/tonne pollutant), corrected for GDP growth in future years with elasticity of 0.5.

### 5.1.2 Summary of the most important assumptions for the combination scenarios

A summary of the main additional assumptions used in the definition of the combination illustrative scenarios are provided below.

<sup>43</sup> AEA (2008) *MARKAL-MED model runs of long term carbon reduction targets in the UK*, report by AEA for the UK Committee on Climate Change, 2008. Available from CCC's website at: <http://www.theccc.org.uk/reports/building-a-low-carbon-economy/supporting-research>

Energy efficiency of vehicles

- Vehicle efficiency and the reduction in GHG intensity of transport's energy – see Figure 24, Figure 25 and Figure 26 in Section 5.4.
- Aircraft improvement assumed to increase from 1 to 1.5% per year.
- Ships improvement assumed to increase from 0.5 to 1.5% per year.

Vehicle powertrain technology

- See Table 5.

**Table 5: The assumed proportion of new vehicles using different powertrain technology**

	<b>2020</b>	<b>2030</b>	<b>2050</b>
<b>Cars</b>	52% Petrol/diesel 2% LPG/CNG 32% HEV 12% PHEV 2% EV 0% FCEV	29% Petrol/diesel 3% LPG/CNG 42% HEV 19% PHEV 5% EV 2% FCEV	2% Petrol/diesel 4% LPG/CNG 24% HEV 50% PHEV 10% EV 10% FCEV
<b>Buses</b>	46% Diesel 8% CNG 40% HEV 5% EV 1% FCEV	20% Diesel 5% CNG 50% HEV 10% EV 15% FCEV	0% Diesel 0% CNG 25% HEV 35% EV 40% FCEV
<b>Motorcycles</b>	99% Petrol 1% EV 0% FCEV	84% Petrol 8% EV 8% FCEV	15% Petrol 35% EV 50% FCEV
<b>Vans/Light Trucks</b>	67% Diesel/petrol 20% HEV 8% PHEV 5% EV 0% FCEV	45% Diesel/petrol 30% HEV 15% PHEV 8% EV 2% FCEV	3% Diesel/petrol 12% HEV 50% PHEV 25% EV 10% FCEV
<b>Medium Trucks</b>	72% Diesel 1% CNG 20% HEV 5% PHEV 2% EV 0% FCEV	41% Diesel 2% CNG 35% HEV 15% PHEV 5% EV 2% FCEV	1% Diesel 4% CNG 10% HEV 35% PHEV 25% EV 25% FCEV
<b>Heavy Trucks</b>	84% Diesel 1% CNG 15% HEV 0% FCEV	50% Diesel 2% CNG 40% HEV 8% FCEV	0% Diesel 5% CNG 60% HEV 35% FCEV
<b>Inland Ships</b>	97% Diesel 3% LNG	94% Diesel 6% LNG	90% Diesel 10% LNG
<b>Maritime Ships</b>	90% Conventional 4% LNG 6% Wind assisted	82% Conventional 6% LNG 12% Wind assisted	65% Conventional 10% LNG 25% Wind assisted

Electricity and Hydrogen

- EURELECTRIC assumption to essentially decarbonise electricity by 2050.
- Hydrogen production assumed to also essentially decarbonise by 2050.

Biofuels

- Liquid hydrocarbon fuels needed where other fuels not feasible.
- Assumption that up to 174 Mtoe possible by 2050 (17 times current consumption), resulting in biofuels replacing almost 100% of supply of combustion fuel by 2050.
- Average GHG saving reaches 60% in 2020, 75% in 2030, 85% in 2050

Spatial planning

- 5% less demand from road transport by 2020 rising to 10% less by 2050.
- Additional impacts on co-modality/modal shift integrated into assumptions below.

Co-modality/modal shift in 2050

- 30% urban car traffic shifted to other modes.
- 10% non-urban car traffic shifted to other modes.
- 20% intra-EU aviation shifted to rail (accompanied by an increase to high-speed rail).
- 15% from heavy trucks to other modes.

Eco-driving

- Virtually 100% of drivers trained by 2050 (for road and rail).
- Long-term impacts of eco-driving training around 50% of short-term savings.
- Savings from training decline to 2050 due to technology effects.

Speed limits

- Motorway limits harmonised and lowered to 100kph for LDVs and 80kph for HDVs.
- Better enforcement of speed limits across all roads.

Taxes

- Fuel tax assumed equivalent to current road petrol tax rate per unit of energy across all modes including VAT.
- Fuel tax in addition includes up to €180 (high) carbon price in 2050 (see Table 3).
- NO<sub>x</sub>, PM pollutant emission costs (see Table 4) and energy security costs (see Section 5.1.1) internalised for road modes.
- Company car tax reformed to eliminate subsidy.

## 5.2 Risks and uncertainties associated with the main assumptions underlying the illustrative scenarios

As clearly stated above, a number of important assumptions had to be assumed in order to be able to develop the tool to identify the GHG emissions reduction that various scenarios could deliver. In this section, the risks and uncertainties associated with a number of the main assumptions are discussed, as follows:

- The potential role of biofuels.
- The potential for the use of electricity and hydrogen in transport.
- The potential roles of non-technical options.
- The role of economic instruments.
- Rebound effects.
- The business as usual baseline for transport demand.

### 5.2.1 The potential role of biofuels

As noted in Section 2.3, biofuels have a potentially significant role in decarbonising existing transport fuels, especially for aviation and heavy duty road transport, and therefore in reducing the GHG intensity of the energy used by transport between now and 2050. However, in the illustrative scenario tool it was decided to limit the amount of biofuels that could be used in the transport sector to the maximum EU production potential of 174 Mtoe that was estimated by BIOFRAC.

While biofuels could theoretically save significant levels of GHG emissions, there are a number of important issues that need to be understood better or resolved before biofuels can be used with complete confidence. The potential GHG reductions resulting from the use of biofuels is very sensitive to the feedstock and production methods used, as well as fundamental assumptions in the calculation of savings. Hence, from the perspective of delivering GHG savings, it might be preferable to limit the use of biofuels to certain feedstocks and production methods. However, in an increasingly global market, governed by the principle of free trade, both within the EU and internationally via the World Trade Organisation, ensuring that the biofuels used deliver the potential GHG reductions is a challenge.

While in the short-term, current biofuels are likely to offer only a small or limited GHG reduction potential, there is an expectation of potential for larger reductions in the medium to long term, as advanced feedstocks (e.g. lignocellulosic biomass, algae) and production processes are developed and mature. However, the extent of these developments is uncertain.

There are also wider questions about the net GHG balance of certain feedstocks and production methods. The potential for both direct and indirect Land Use Change (LUC) resulting, for example, from the conversion of natural habitats to the production of biofuels feedstocks, and the resulting impacts on the net GHG balance of the biofuels produced has not yet been resolved. Additionally, there are concerns with respect to the amount of land and water that extensive production of biofuels might require. Given that both of these resources are increasingly scarce in a world where demand for food is expected to increase significantly, the amount of biomass available for fuels may be constrained by competition for land and water to feed an increasing global population and replace petrochemical derived products (e.g. textiles, plastics and chemicals) with those produced from biomass. Numerous studies have been undertaken on these issues and a consensus is yet to emerge on many of these issues.

Clearly, if some of the issues associated with biofuels can be resolved, this would reduce the uncertainty and potential risk in relying on biofuels as a means of significantly reducing GHG emissions from transport. Potentially a larger amount of biofuel might then be used for transport in this case. Alternatively, demand for biomass (i.e. for other forms of bioenergy, fibres, chemicals or food) from other sectors might constrain the use of biofuels in transport even if these wider issues are resolved.

## **5.2.2 The potential for the use of electricity and hydrogen in transport**

As noted in Section 2.3, the vehicles used in 2050, particularly cars, are likely to be of a range of vehicle types with drivetrains that are significantly more electrified than currently, and use alternative energy carriers such as electricity and hydrogen. As can be seen in Table 5, the tool assumed significant uptakes of HEVs, EVs, PHEVs and FCEVs, particularly by 2050. Pure electric powered transport holds the greatest potential for GHG emissions reductions, since the electricity can be produced from essentially carbon-neutral sources and utilised directly at higher net efficiency compared to hydrogen fuel (except perhaps for biological H<sub>2</sub> production pathways, which are much more efficient in terms of primary energy use than other pathways). However, significant challenges remain principally in the area of electrical energy storage, particularly in terms of cost, weight, volume, efficiency and power delivery. These limitations also impact on the useful range of electric vehicles compared to conventional equivalents. These and other barriers mean the significant use of pure battery electric vehicles is still seen as a long-term option, although smaller scale penetration is already progressing in the short-term. Hence, a relatively low proportion of such vehicles was assumed in the most ambitious scenario, although if electrical energy storage technology (i.e.



batteries, super-capacitors, etc) develops more quickly than anticipated, such vehicles may have a larger role to play. Overall reduction potential would increase (and further reduce reliance on biofuels for light duty vehicles).

The tool adopts the assumption by EURELECTRIC that the electricity supply sector could be producing its electricity from virtually-carbon free sources by 2050. Additionally, the tool assumes that any hydrogen produced for and used by the transport sector would also be essentially carbon-neutral by 2050. Clearly, these assumptions are ambitious and rely on the successful implementation of carbon-reduction strategies in sectors other than the transport sector. If these assumptions prove to be over-ambitious, then comparative reductions in the transport sector would need to be delivered through the uptake of other options, potentially including non-technical options.

However, the electrification of existing vehicles is already underway. Conventional cars have more and more electric features, thus blurring the line between a conventional car and a hybrid car, which combines the use of an internal combustion engine and electric motor. Plug-in hybrid electric vehicles are a further potential step to the full electrification of cars, as they have performance characteristics and ranges similar towards their conventional equivalents. A range of electric vehicles are developing, which means that the distinction between what is a conventional vehicle and what is an electric vehicle will become increasingly difficult to determine, thus leading to a continuum of technologies rather a set of technologies with distinct differences.

In the longer-term, hydrogen fuel cells offer significant potential to reduce GHGs from road transport, although this depends on the way in which the hydrogen is produced. The contribution of fuel cell vehicles (FCVs) will depend on developments in hydrogen production and storage and fuel cell technologies, as well as in electrical energy storage for competing electric vehicles. FCVs currently have an advantage in range over EVs due to greater energy storage densities for hydrogen relative to electrical energy storage.

However, the costs associated with these alternative vehicles are likely to be a barrier to significant market penetration. The vehicles are likely to remain more expensive than existing conventional vehicles, even though in many cases the vehicles might be cheaper to operate. Additionally, the cost of developing new hydrogen refuelling infrastructure is significant and likely to be much higher than developing a recharging infrastructure for pure EVs. The possibility to use the existing natural gas infrastructure as a bridge for hydrogen distribution might alleviate this if it is feasible.

### 5.2.3 The potential role of non-technical options

As discussed in the previous sections, the assumptions associated with the technical options are relatively ambitious and consequently the GHG reductions assumed might not actually be realised. In this case, further reductions would have to be delivered from non-technical options in order to achieve similar levels of emissions reduction. However, as was clear in the review of the options for reducing GHG emissions from transport, the reduction potentials associated with the technical options have been more frequently estimated and so probably have a larger degree of confidence associated with them<sup>44</sup>. As with the technical options, the assumptions that were made in relation to non-technical modes were based on findings from the literature reviews and stakeholder engagement. However, as many of these options are often encouraged for reasons other than reducing transport's GHG emissions, it was often difficult to identify relevant estimates of GHG reduction potential.

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<sup>44</sup> See the respective Appendices 4 to 8 for more details; also see <http://www.eurtransportghg2050.eu/cms/updated-reports/>

Additionally, the potential GHG reduction from many non-technical options will be dependent on local circumstances, including the range of transport modes available. For many of the non-technical options, the delivery of the assumed GHG reductions is also dependent on the enforcement of the policy instrument, e.g. speed limits, how an option is maintained in practice, e.g. fuel efficient driving, and the complementary measures that have been put in place, e.g. co-modality. Hence, the assumptions of GHG reductions associated with the non-technical options are problematic. Having said that, it could be argued that the assumptions that are used are reasonably ambitious, e.g. assuming that improved spatial planning policies reduces demand for road transport by 10% by 2050.

#### **5.2.4 The role of economic instruments**

The rationale for the use of economic instruments to stimulate the uptake of GHG reduction options was discussed in detail in Section 3.2. As was noted there, the first best and most efficient approach is to adopt a marginal cost pricing approach in which the external costs of transport are internalised, i.e. included in the price of transport. Hence, there is a clear economic and environmental justification for the scenarios that include a price for CO<sub>2</sub> in the prices faced by transport users (i.e. scenario 12) and the costs associated with conventional air pollutants (in scenario 11). These external costs were taken from the IMPACT study, which was undertaken for the European Commission (see Table 3 and Table 4). However, as noted in Section 3.2, there are currently significant levels of uncertainty associated with long-term CO<sub>2</sub> prices, in particular. Consequently, the high estimate of the carbon price in 2050 was used, but it is possible that this cost might be even higher. Scenario 10 can also be justified economically as this scenario is based on a reform of Member States' company car tax systems, so as to remove any subsidies that currently exist.

The final taxation scenario (number 13) was included to take account of the existing discrepancies between the taxation of various modes, particularly the discrepancy between the fuel duties and VAT paid by the road sector and the treatment of the aviation and maritime sectors. In scenario 13, it was assumed that fuel duties and VAT were harmonised across all of the modes at the level of the duties and taxes currently paid by private road transport. Clearly, any level of taxation could be chosen for this scenario, but it was assumed that it would be politically more likely that taxation was increased to the highest level experienced by any of the modes rather than reducing taxation to a lower level. If lower levels of harmonisation were assumed, then the potential GHG reductions delivered by this scenario would clearly be reduced. Given that the adoption of these harmonised rates would significantly increase the costs faced by international aviation and maritime in particular, it would be extremely challenging to achieve this as it would require global agreement and cooperation.

#### **5.2.5 Rebound effects**

As was mentioned in Section 3, rebound effects have the potential to undermine the GHG reduction potential of many policy instruments. For example, any option that potentially makes transport cheaper could stimulate travel and thus undermine the GHG emissions reductions from the uptake of the respective options. For minor improvements in the energy efficiency of vehicles, e.g. through minor improvements to existing engines, such an effect is not likely to be significant at the level of the individual vehicle, although the net impact could be significant. However, within the existing policy framework, some technologies, particularly electric vehicles, would be significantly cheaper to use, which could exacerbate other adverse impacts of transport, e.g. congestion. In order to avoid such rebound effects, complementary policy instruments would need to be put in place, e.g. increasing the direct costs associated with use by increasing the taxation in electricity used for transport.

Complementary policy instruments might also be needed to ensure that the potential GHG reduction of co-modality, for example, is also achieved. Stimulating co-modality is not on its own a sufficient condition for delivering GHG reductions. For example, if the stimulation of co-modality led to an increase in the use of public transport for (parts of) some journeys, road space would then be freed up. If this space was then used for journeys that, for example, had previously been suppressed due to the level of congestion on the road, then the net impact of the co-modality option would not necessarily be positive; rather it would depend on the net impact of the GHG saved on the (parts of) journeys for which an alternative mode is now being used, and the GHG emitted by the additional journeys stimulated by the freed up road space. In order to ensure that GHG reductions are delivered, instruments to constrain demand could also be introduced, e.g. road pricing.

The existence of rebound effects underlines the importance of introducing complementary policy instruments to reduce and ideally eliminate any rebound effects in order to ensure that the potential GHG reductions of the primary instrument are delivered in practice. Within the tool, it was not possible to build in the impact of rebound effects, so the GHG reduction potentials delivered by some of the scenarios might be over-estimated when taken individually.

### **5.2.6 The business as usual baseline for transport demand**

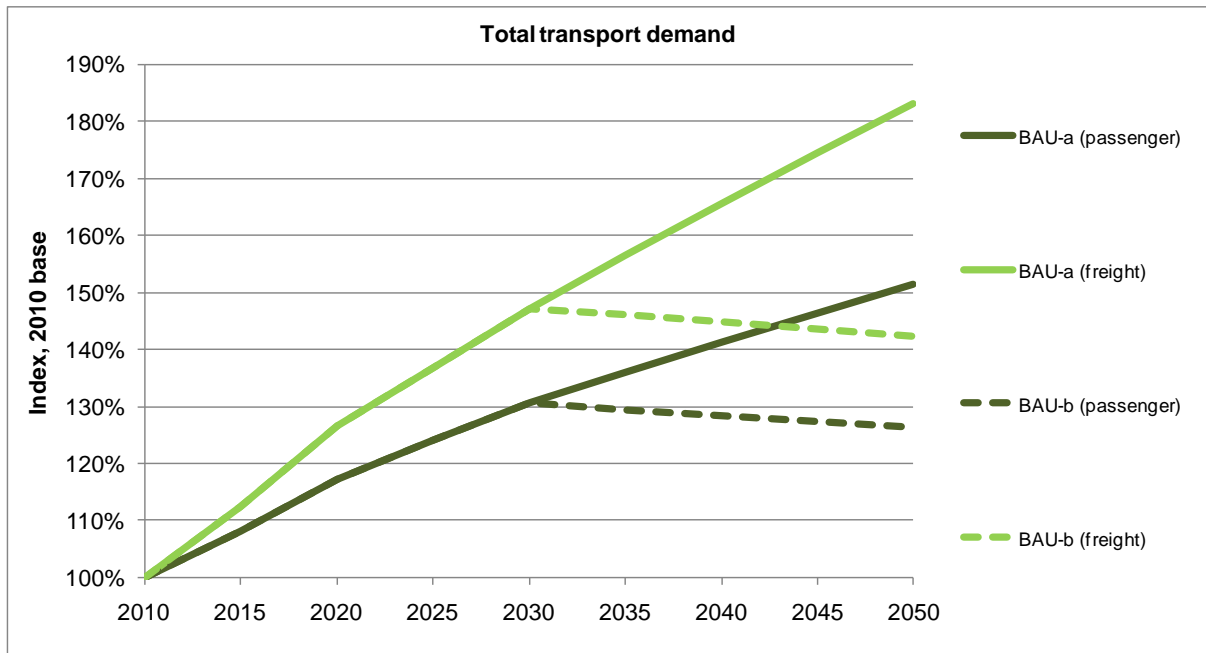
As noted in Section 1.2, it is challenging to attempt to identify the policy implications of GHG reduction objectives set for 40 years time given the uncertainties with respect to how society might develop and how relevant technologies will develop. The future form of society will have implications for the level and type of transport it needs, as transport is largely a derived demand, as noted in Section 1.3. However, in determining how future GHG emissions might need to be reduced it is important to be able to understand how recent trends in GHG emissions might continue into the future. In this respect the baseline of transport demand assumed is of particular importance.

The baseline of transport demand used in SULTAN was developed in two parts. From 2010 to 2030, it was developed using datasets consistent with the projections (in stock, demand, etc) from the EC's TREMOVE model (version 2.7b), which is the primary EU transport model used in environmental analysis of transport policies. Between 2030 and 2050, there are no comparable projections of potential business as usual trends, so it was necessary to extrapolate in particular changes in demand and stock.

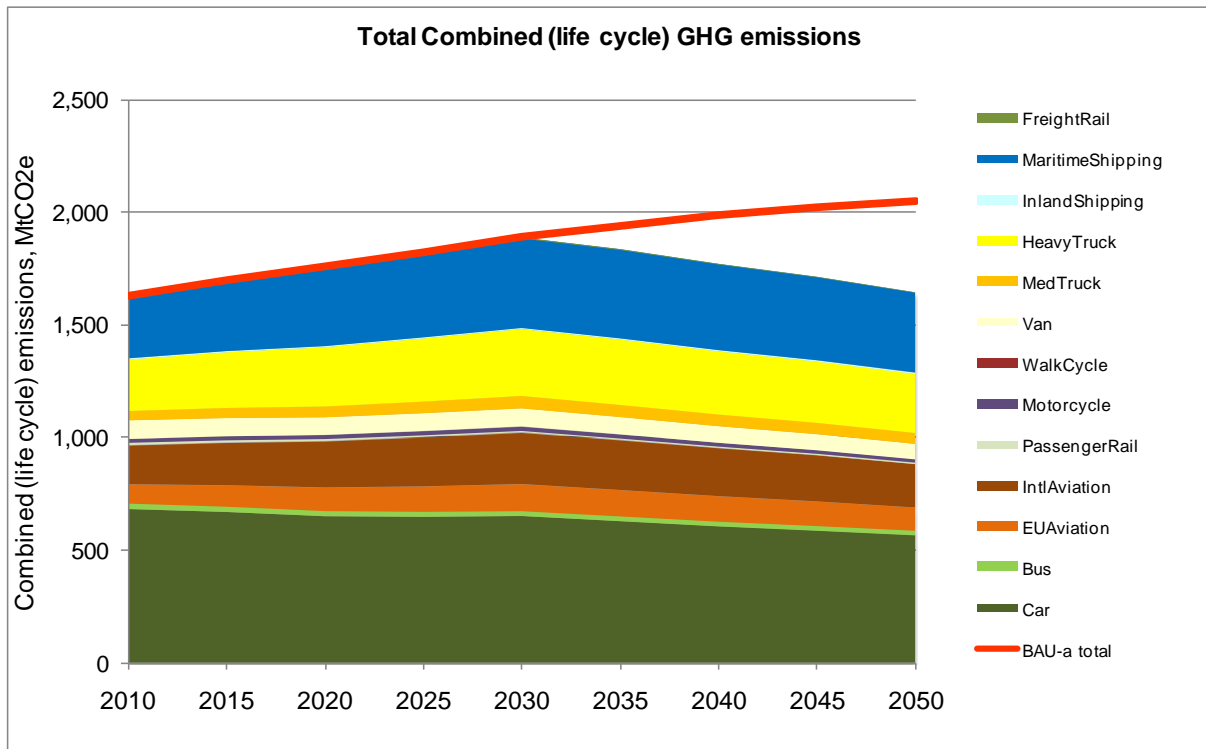
Within the project, the assumption that transport demand might continue to increase at projected rates was questioned. First, it was noted that population growth is one of the drivers of transport growth, even though the rate of population growth has been much lower than the growth in either freight or passenger transport in recent years (see Figure 6). In this context it was noted that over the next 40 years, the population of some EU countries is expected to decline, which could have an impact on demand for transport and therefore projections of potential future increases in demand. In order to address this concern, first the default demand and stock projections were extrapolated on the basis of stock/1000 population and demand/1000 population to create a revised BAU-a (default) baseline. In addition, an alternative baseline (BAU-b, low) was developed as a low-case sensitivity, which assumed that these ratios remained constant from 2030. This sensitivity for demand and stock growth is illustrated in Figure 11, with the implications for business as usual growth in GHG emissions resulting from these alternative assumptions presented in Figure 12. Comparing this growth to the original baseline, as also presented in the figure, it can be seen that under business as usual GHG emissions in 2050 would be 403MtCO<sub>2</sub> (or 20%) less under the alternative assumptions than under the original assumptions. It should be noted

that this is best viewed as an extreme case, as the historic trend has been for continued growth in transport demand intensity.

**Figure 11: Index of total transport demand for the BAU-a (default) and BAU-b (low) scenarios**



**Figure 12: Alternate business as usual (BAU-b, low) projected growth in transport's GHG emissions by mode**

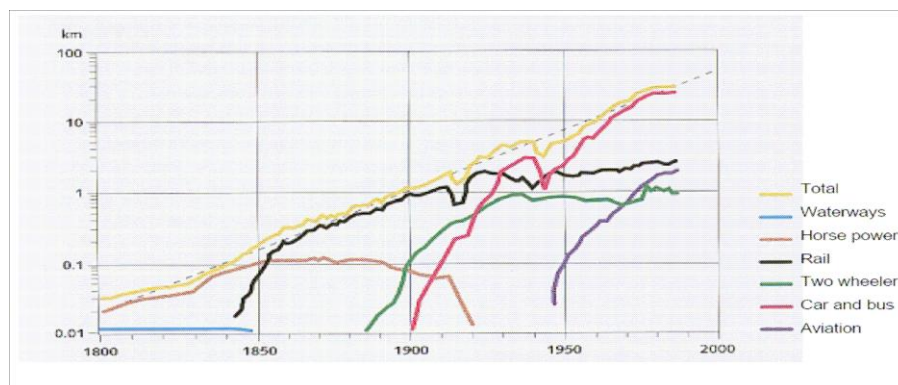


A second reason for potentially questioning current projections of future transport demand was that some elements of passenger transport demand could be reaching a saturation

point<sup>45</sup>. Analysis for the UK suggests that over the last 10 to 15 years, the demand for daily passenger travel in the UK has been relatively constant. It has been proposed that this was due to people being able to access sufficient choice of services without travelling any further and thus the value of additional choice would be subject to diminishing returns. It is important to note that the analysis was only undertaken for passenger demand for daily travel, hence excludes passenger travel by air, as well as freight transport. However, if the saturation point hypothesis is correct, this would have implications for projections of GHG emissions from at least some transport modes.

Also relevant to this discussion is the link between travel speed and transport volume<sup>46</sup>. According to a number of studies, the average time a person spends travelling each day ranges from 60 to 70 minutes. This effect has been identified in a number of countries and seems to be indifferent to increasing transport possibilities and has been constant for a number of decades. The implication of this finding is that as transport modes become faster, demand for travel (measured in terms of distances) will increase, as people will be able to cover greater distances in the same amount of time. This effect is illustrated in Figure 13, which presents the increase in average travelling distances in France between 1800 and 2000. As can be seen, the average distance covered by passenger transport per person per day increased from a few kilometres in 1800 to 40 kilometres in 2000.

**Figure 13 Travelling distance per person per full day 1800-2000 (excluding walking; France)**



Source: ECMT, 2002

It is not clear whether the analyses for the UK and France are contradictory or consistent. One reason to argue for consistency is that the French figure includes aviation, whereas the figures underlying the UK analysis did not. Hence, the assumption that travel demand will continue to increase into the future is potentially questionable, although there is not yet sufficient evidence to suggest what an alternative projection might be.

### 5.3 Potential GHG emissions reductions that might be delivered respectively by additional alternative policy frameworks

The approach taken to estimating the GHG reduction potential for transport in 2050 consisted of taking each of the categories of option presented at the beginning of this chapter in turn, i.e. reducing the GHG intensity of transport energy, improving the technical energy efficiency of new vehicles, improving the operational efficiency of vehicles, improving the structural efficiency of transport and finally using economic instruments to improve its economic efficiency. The potential of different technical and non-technical options identified

<sup>45</sup> Metz, D. (2009) "Sustainable Travel Behaviour" A paper presented at the UK UTSG conference, January 2009; see [www.limitstotravel.org.uk/documents/](http://www.limitstotravel.org.uk/documents/)

<sup>46</sup> See Appendix 8 for more details; also see <http://www.eurtransportghg2050.eu/cms/updated-reports/>

in the course of the evidence review and stakeholder engagement were used to define scenarios in SULTAN in order to estimate the total GHG reduction potential from these different elements in turn.

**Figure 14: Reductions in transport's GHG emissions by mode resulting from reducing the GHG intensity of existing fuels through the increased use of biofuels (scenario C1a)**

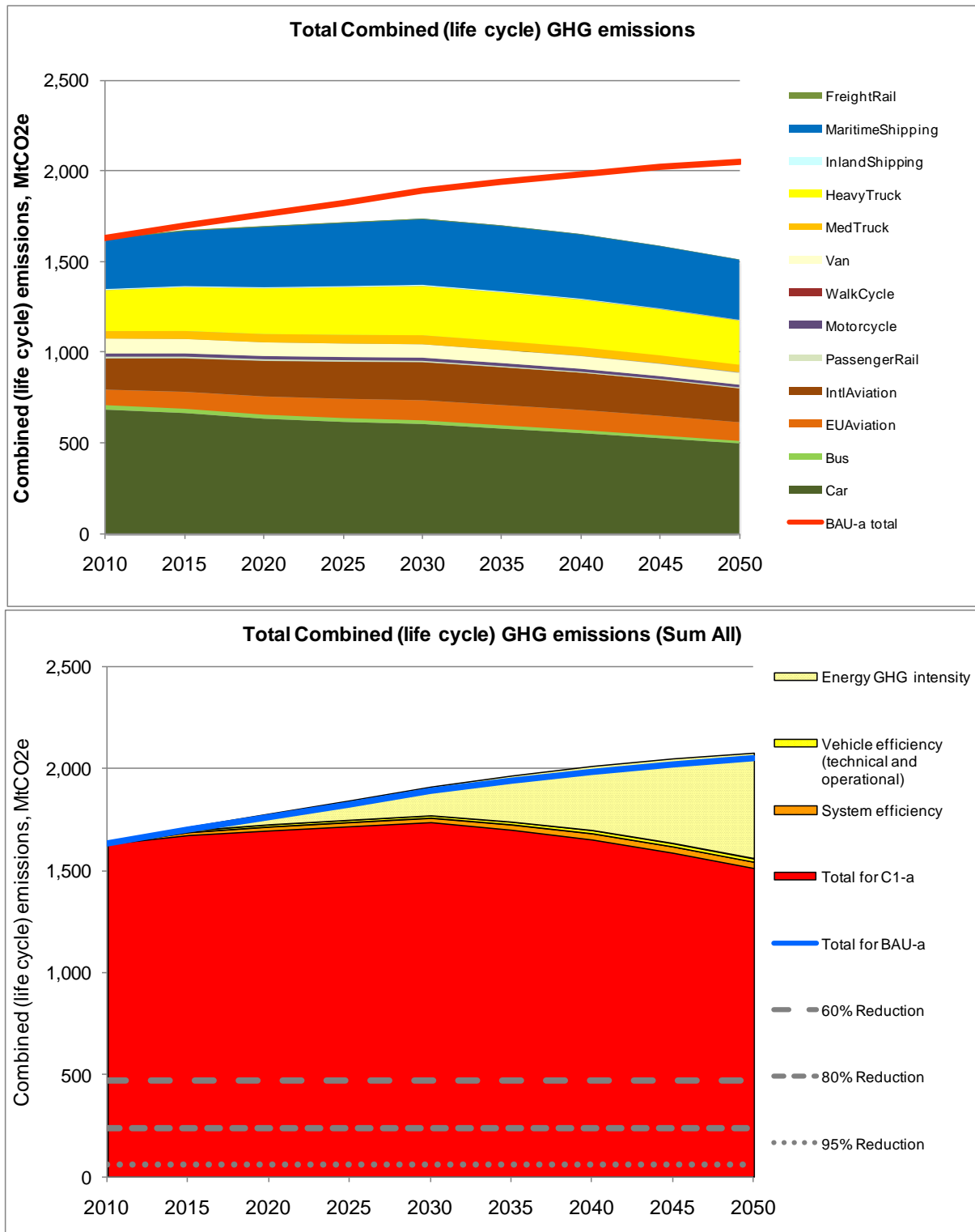


Figure 14 shows the estimated reductions in GHG emissions that could be achieved by 2050 resulting from **improving the GHG intensity of transport energy** by introducing significant amounts of biofuels. The estimates assume that the average WTW GHG reductions that biofuels could achieve compared to conventional fuels more than double from around 40% in 2010 to around 85% in 2050<sup>47</sup>.

The amount of biofuels that could be used was limited to ensure that no more biofuels are used in transport than the maximum EU potential of 174 Mtoe of biofuel (equivalent to approximately 30% of total BAU fuel consumption), as estimated by BIOFRAC (2006)<sup>48</sup>. The implications of adopting this figure as the maximum potential for the use of biofuels in transport are discussed in Section 5.2.1. Using this amount of biofuels would lead to a small decrease in transport's GHG emissions in 2050 compared to 2010, although these would still be 29% higher than transport's GHG emissions in 1990. Hence, reducing the GHG intensity of existing fuels by adding biofuels is unlikely to be sufficient in returning transport's GHG emissions to 1990 levels, let alone to reduce these significantly below 1990 levels.

As noted in Section 2, the findings of the evidence review concluded that there was significant **potential to improve the technical fuel or energy efficiency**<sup>49</sup> of new vehicles. Additionally, in the longer-term, there is the potential for further GHG reductions to be delivered across most of the modes from changing the underlying powertrains used by vehicles to facilitate the use of alternative energy carriers, particularly electricity but also hydrogen used in fuel cells. However, it is important to note that if alternative energy carriers are to contribute to decarbonising transport these also have to be less GHG intensive ways (see Section 5.2.2 for a further discussion of this). In general there appears to be a consensus on the likely progressive electrification of drivetrains amongst manufacturers of light duty vehicles. However, it is uncertain as to whether the primary energy carrier/storage utilised will be liquid fuels (i.e. in plug-in hybrids), hydrogen (i.e. via fuel cell vehicles) or electrical storage (i.e. in batteries of pure electric vehicles).

Figure 15 shows the potential for GHG reductions in the EU transport sector resulting from significant improvements in the technical energy efficiency of new vehicles, including the increased use of alternative energy carriers. Figure 16 shows these reductions **in addition to** the potential reductions delivered from an increased use of biofuels (as shown in Figure 14). This reduction potential assumes an ambitious uptake of various alternative technologies, e.g. in 2050, 50% of new car sales would be plug-in hybrid electric vehicles (PHEVs), with hybrid electric vehicles (HEVs) accounting for one quarter of new car sales and electric vehicles (EVs) and fuel cell electric vehicles (FCEVs) accounting for a further 20% in total (equally distributed; see Table 5)<sup>50</sup>. Similar levels of reduction in total GHG emissions could also be achieved via a range of variations on the relative proportions of PHEVs, EVs and FCEVs. This suggests that it is possible to achieve a 36% reduction of transport's GHG emissions on 1990 levels through technical options, i.e. from reducing the GHG intensity of existing fuels and improving the technical energy efficiency of vehicles, including a significant amount of switching to alternative powertrains using lower GHG

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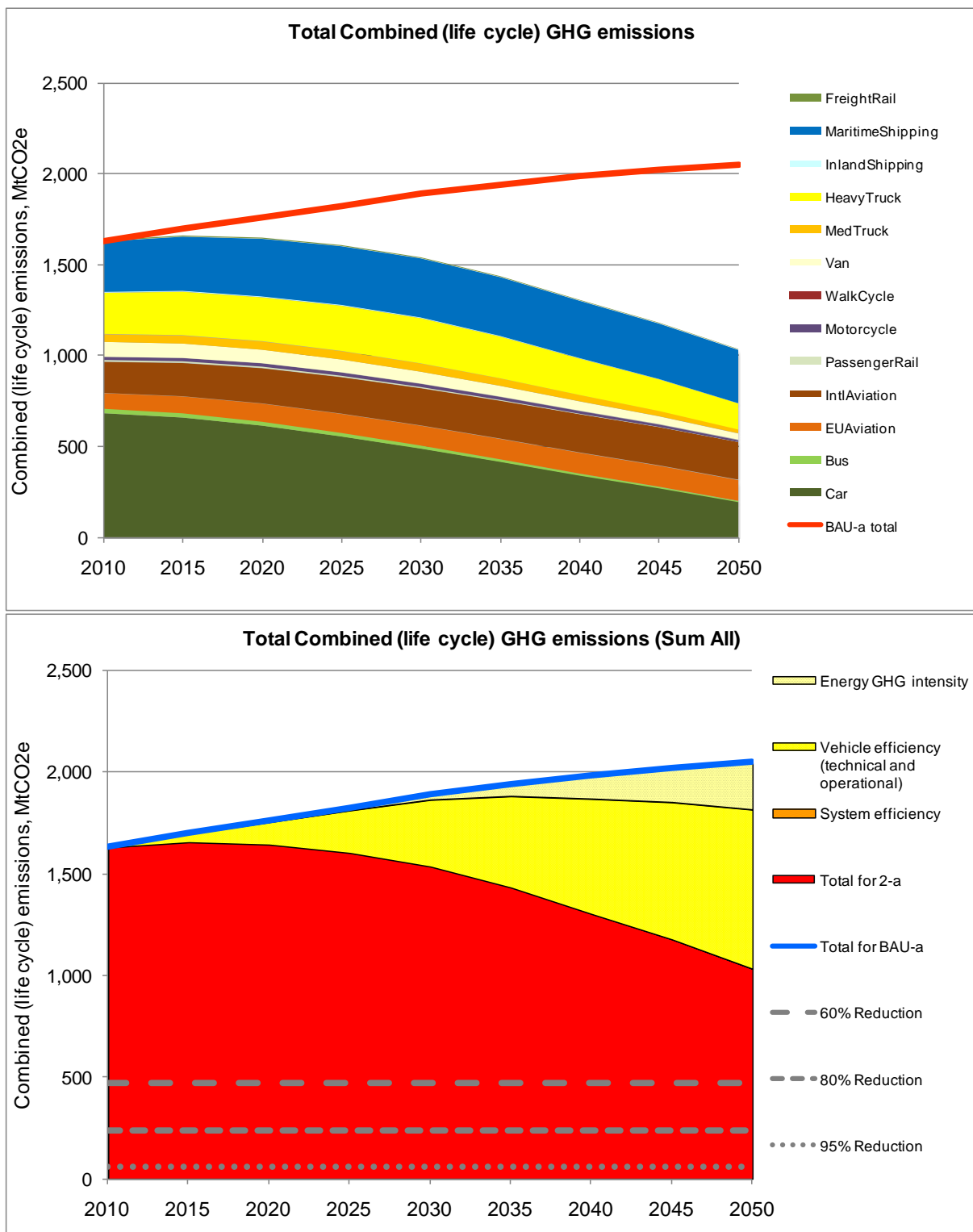
<sup>47</sup> This assumption applies for bioethanol and biodiesel for road transport, bioLPG, biocrude for ships and biokerosene for aviation. Biomethane is assumed to deliver 100% reductions from 2010 to 2050.

<sup>48</sup> Biofuels in the European Union - A Vision for 2030 and beyond, Final draft report of the Biofuels Research Advisory Council, March 2006. Available at: [http://ec.europa.eu/research/energy/pdf/draft\\_vision\\_report\\_en.pdf](http://ec.europa.eu/research/energy/pdf/draft_vision_report_en.pdf)

<sup>49</sup> Currently, improvements in the efficiency of vehicles are often referred to as improvements in their respective "fuel efficiency". However, such future fuels such as electricity and hydrogen are more accurately referred to as energy carriers rather than fuels. Hence, once such energy carriers are used in the transport system, it is more accurate to use the term "energy efficiency" rather than "fuel efficiency". We take this approach in the remainder of this report.

<sup>50</sup> The remaining new car sales would consist of 4% of cars operating on compressed natural gas, and some remnant traditional ICE cars using gasoline and diesel.

**Figure 15: Potential reduction in transport's GHG emissions by mode resulting from improving the technical energy efficiency of vehicles (all modes), including reductions resulting from the increased use of alternative energy carriers (scenario 2a)**

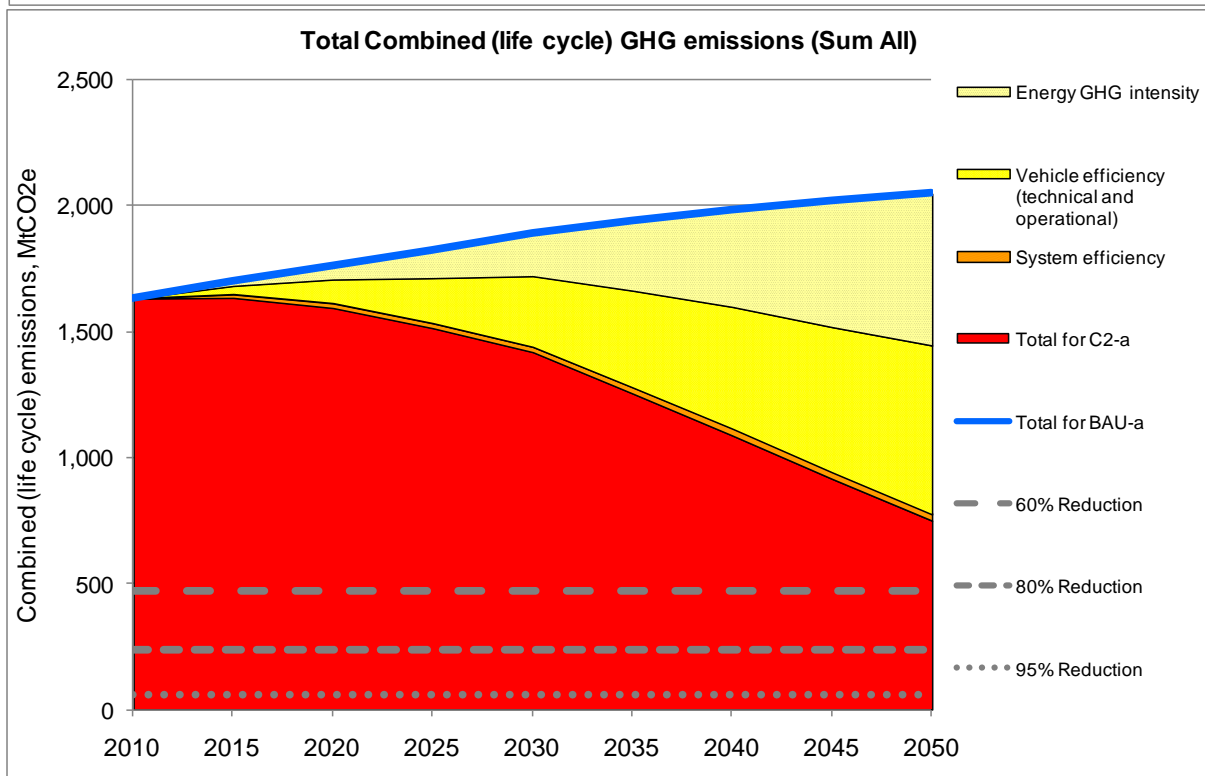
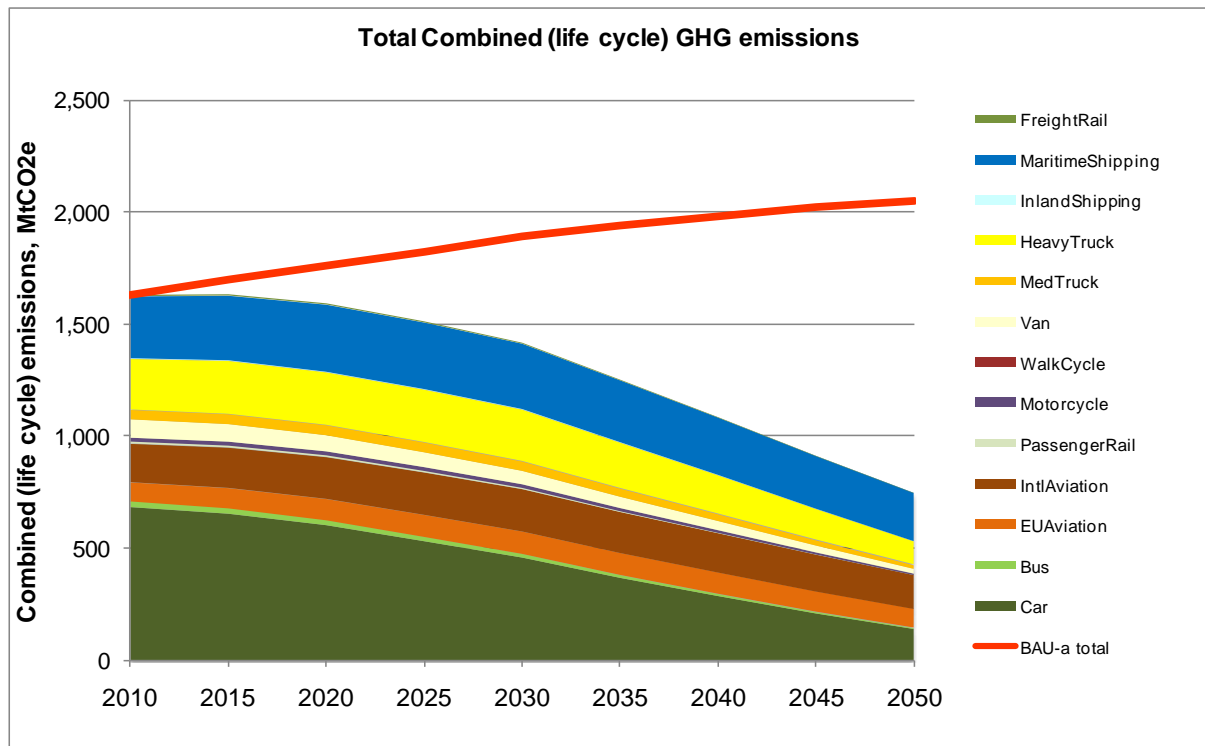


energy carriers. This compares with a corresponding reduction of 12% due to improving the technical energy efficiency of vehicles alone. However, if a significant breakthrough in the short to medium term were made in either the hydrogen fuel cell or electrical energy storage



areas, there might be significantly greater potential for GHG emissions reductions from the use of these technologies.

**Figure 16: Potential reduction in transport's GHG emissions by mode resulting from improving the technical energy efficiency of vehicles (all modes), including reductions resulting from the increased use of alternative energy carriers, *in addition to* reducing the GHG intensity of existing fuels by increasing the proportion of biofuels used (scenario C2a)**

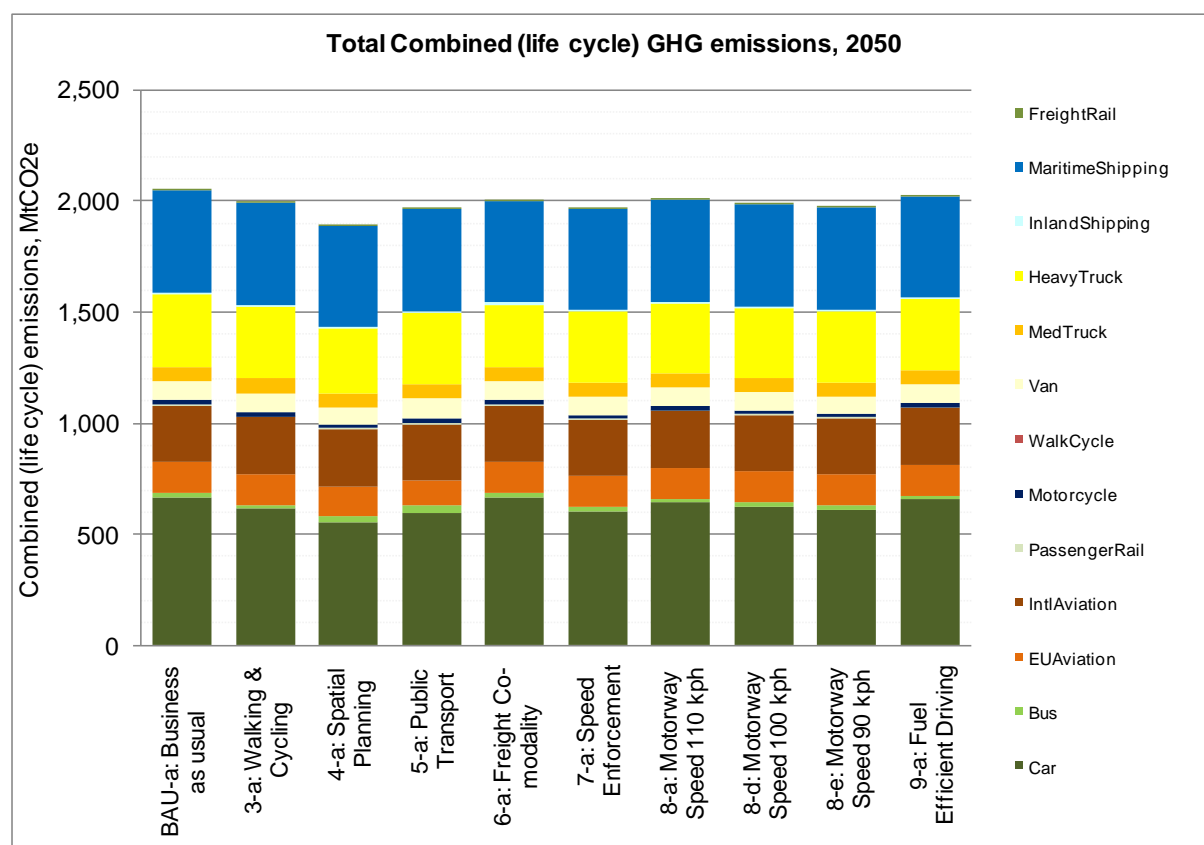


As noted in Section 2, there are a number of non-technical options that have the potential to reduce transport's GHG emissions and the evidence review identified GHG reduction potentials that could be delivered by these options. Figure 18 presents the GHG reductions that could be delivered through the uptake of selected non-technical options, **in addition to** the reductions that could be achieved by technical options (as presented in Figure 16). The reduction potentials presented here are from those options that that could improve the operational efficiency of vehicles and the structural efficiency of the transport system, i.e.:

- Measures supporting walking and cycling (Individual Scenario 3).
- Improved spatial planning policies (Individual Scenario 4).
- The active development encouragement of public transport (Individual Scenario 5).
- Improved freight co-modality (Individual Scenario 6).
- Speed enforcement on all roads (Individual Scenario 7).
- Lower harmonised motorway speeds (Individual Scenarios 8a-e).
- More fuel-efficient driving (Individual Scenario 9).

The separate GHG reduction potentials from each of these individual scenarios are shown in Figure 17.

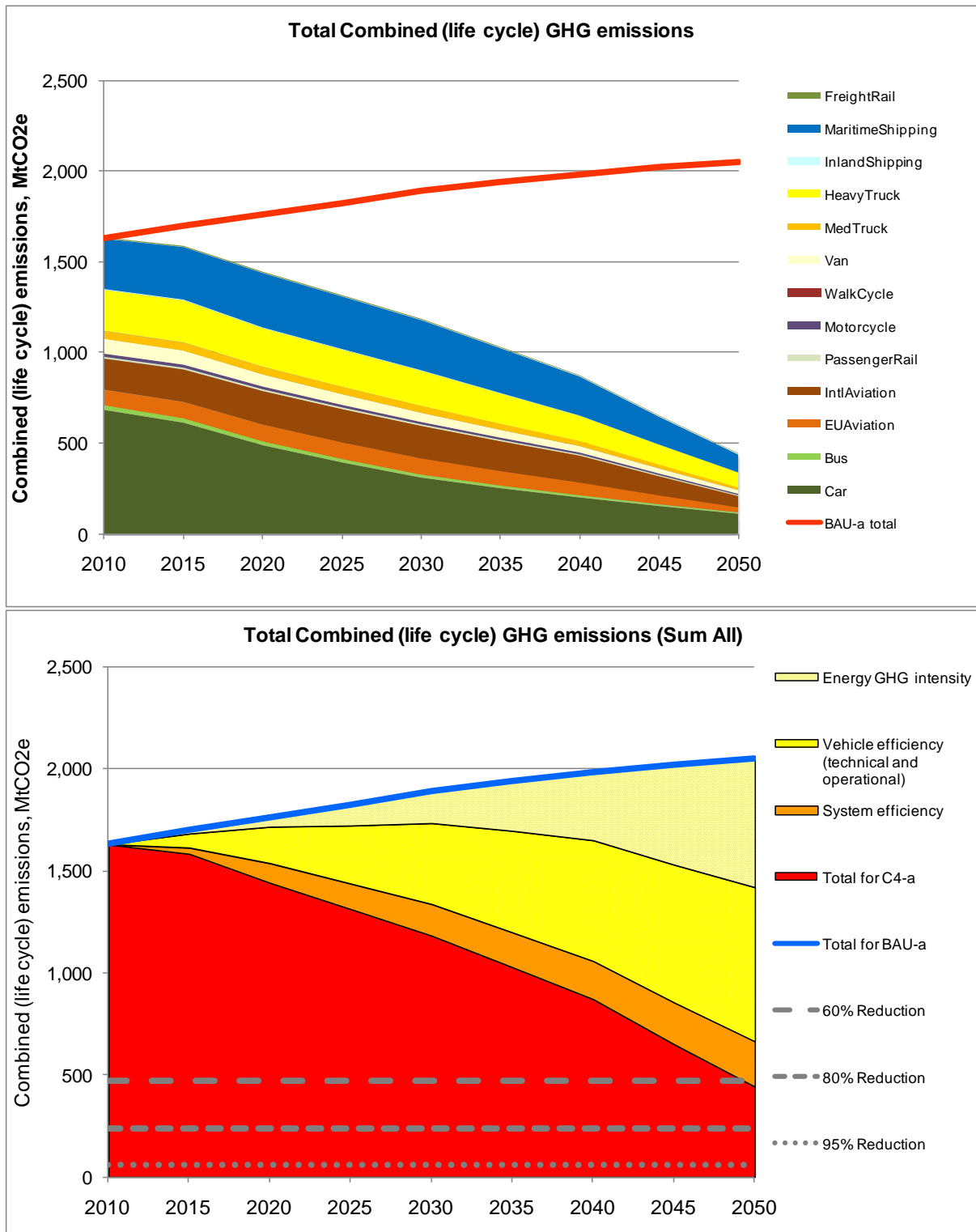
**Figure 17: Potential reduction in transport's GHG emissions by mode from scenarios focusing on selected non-technical options (scenarios BAU, 3-7, 8a, d, e and 9)**



The GHG reduction potentials shown in Figure 18 do not yet include the use of economic instruments to increase the economic efficiency of the transport system or to create a level playing field in terms of taxation. Hence, without such economic instruments, the technical and non-technical options considered so far have the potential to reduce transport's GHG emissions to 62% below 1990 levels by 2050. This is equivalent to a 78% reduction on BAU

in 2050, compared to the individual performance of scenarios 3 to 9, presented in Figure 17, which range from a 1.1% to a 7.6% reduction on BAU for 2050.

**Figure 18: Potential reductions in transport's GHG emissions by mode resulting from improving the efficiency of vehicle use and improving the structural efficiency of the transport system, in addition to reducing the GHG intensity of existing fuels and improving the technical efficiency of vehicles (all modes) (scenario C4a)**

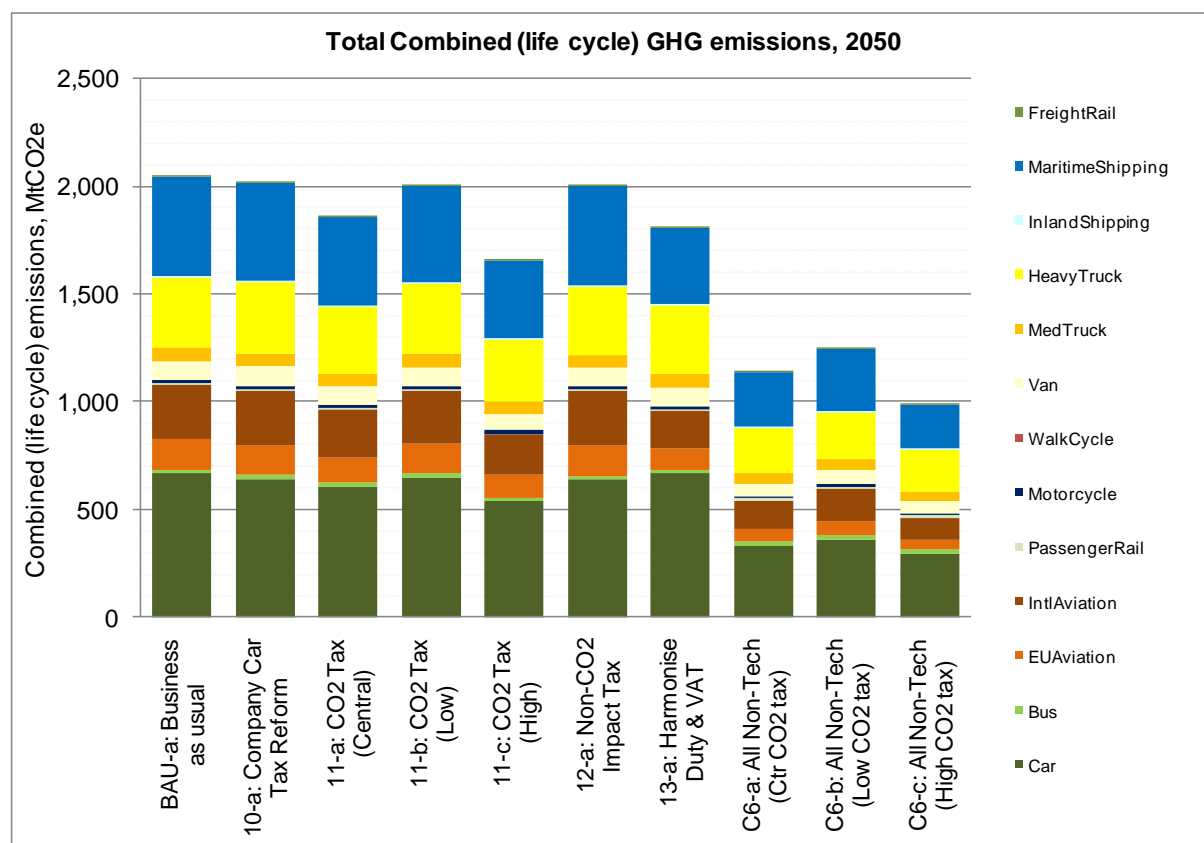


The implications of the assumptions used for the non-technical options included here are discussed in Section 5.2.3. It is worth noting that the level of reduction shown in Figure 18 is lower than figures from some other studies. However, most other comparable assessments do not include emissions from international aviation and maritime, which is an important omission, since these sectors are expected to increase the most under BAU scenarios and have lower potential for technical improvements and a relatively slow stock turnover (see Section 1.5).

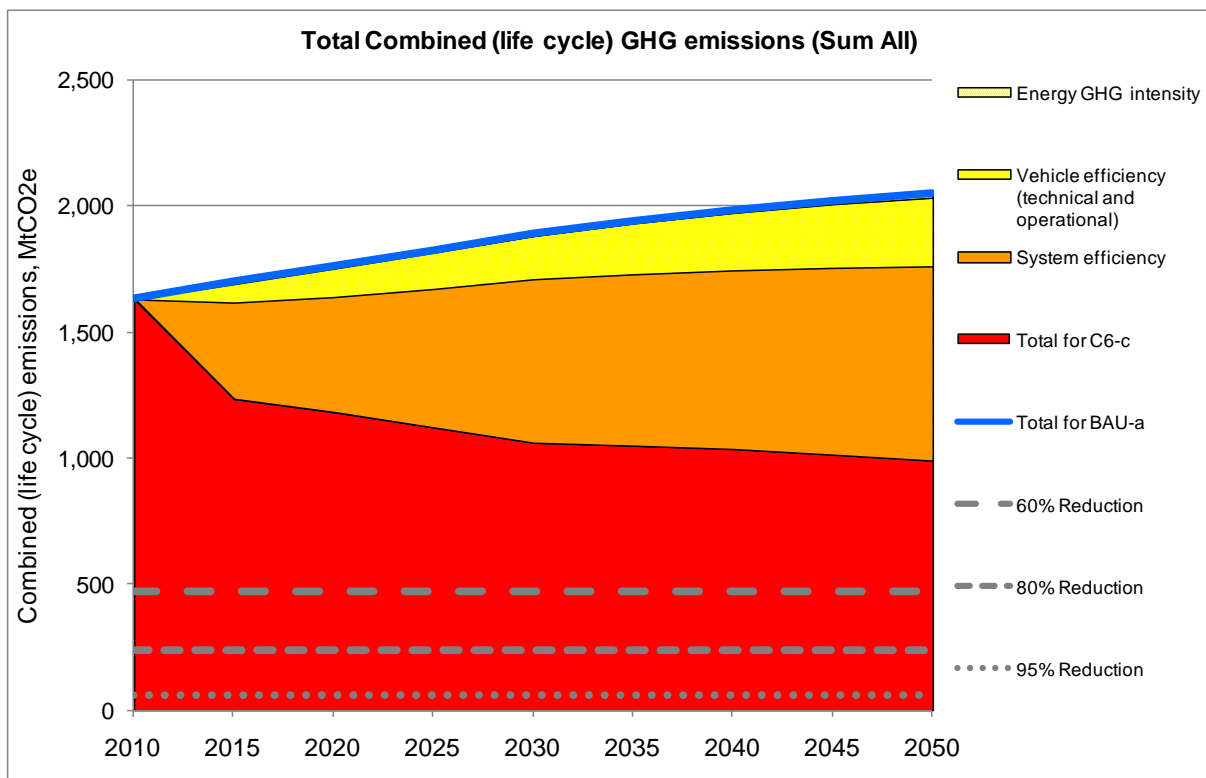
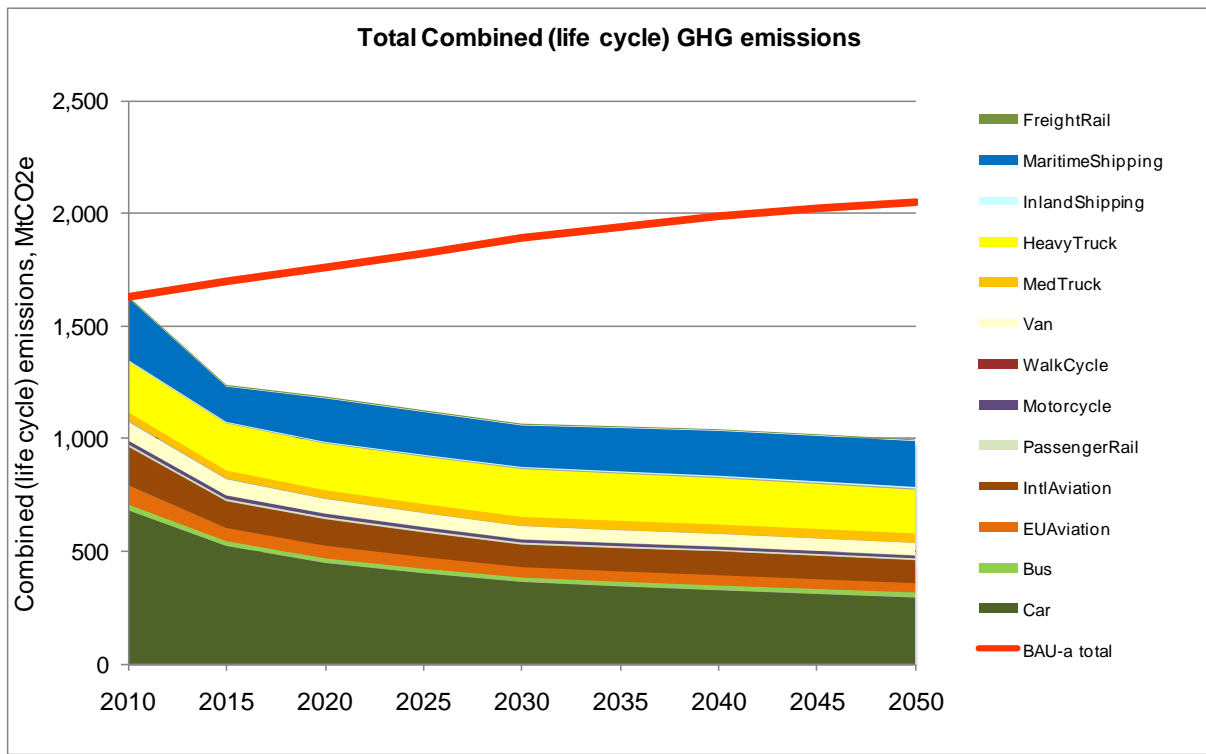
The final set of scenarios assessed by the tool was a series of scenarios using economic instruments to improve the economic efficiency of transport, as follows:

- Reform of company car taxation in the EU to remove perverse incentives for larger vehicles and increased car use (Individual Scenario 10).
- Inclusion of a CO<sub>2</sub> charge on top of other taxes and charges, reflecting the IMPACT study upper CO<sub>2</sub> prices (Individual Scenario 11c).
- Inclusion of charges to cover the external costs associated with emissions of NO<sub>x</sub>, PM and with energy security (Individual Scenario 12).
- Harmonisation of fuel duty levels and VAT across all transport modes (including international ones) in order to produce a level playing field from the perspective of fuel taxation (Individual Scenario 13).

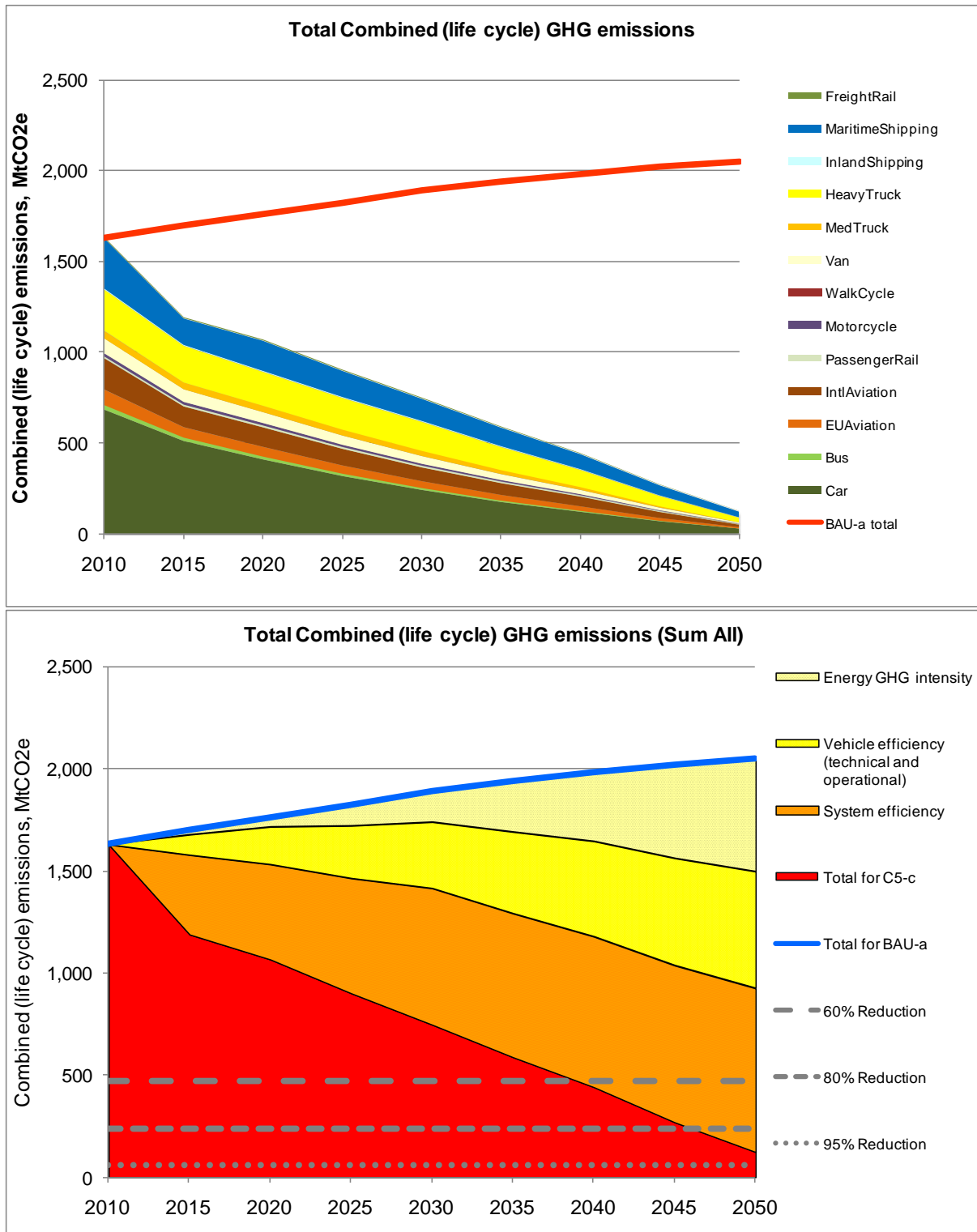
**Figure 19: Potential reductions in transport’s GHG emissions by mode in 2050 from the introduction of selected economic instruments (scenarios BAU, 10, 11a-c, 12, 13)**



**Figure 20: Potential reductions in transport's GHG emissions by mode resulting from improving the efficiency of vehicle use, improving the structural efficiency of the transport system and the introduction of economic instruments to improve the economic efficiency of transport and to create a level playing (scenario C6c)**



**Figure 21: Potential reductions in transport's GHG emissions by mode resulting from the introduction of economic instruments to improve the economic efficiency of transport and the creation of a level playing field, *in addition to* the stimulation of other technical and non-technical options for all modes (scenario C5c)**



As was noted in Section 5.2.4, there are economic and environmental reasons for introducing economic instruments, which would in effect reduce demand for transport by

improving the economic efficiency of transport. Figure 20 shows the reduction potential of the introduction of these economic instruments, while Figure 21 shows the reduction potential of these instruments **in addition to** the reduction potential from the uptake of the technical and non-technical options presented in Figure 18. The separate GHG reduction potentials from each of these individual scenarios are shown in Figure 19.

The addition of the scenarios that involve economic instruments has the potential to deliver an 89% decrease in transport's GHG emissions compared to 1990 levels (a reduction of 94% on BAU in 2050). Individually, illustrative scenarios 10 to 13, which include these economic instruments, achieve GHG reductions of 1.4%, 2.3 to 19.2% (low to high CO<sub>2</sub> price), 2.2% and 11.7%, respectively, compared to business as usual in 2050 (see Figure 19). In particular, the harmonisation of taxes has particularly significant implications for international aviation and maritime shipping, due to the current comparatively favourable treatment of these modes. The inclusion of increased rates of fuel duty and VAT in SULTAN results in significant reduction in the demand for these modes due to the demand elasticities assumed. The challenges associated with the implementation of these scenarios are discussed in Section 5.2.4.

## 5.4 Implications for the key indicators

Figure 21 suggests, subject to the risks and uncertainties described in Section 5.2, that it may be possible to achieve around an 89% reduction in GHG emissions on 1990 levels from the EU's transport sector by 2050. This assumes that ambitious policy instruments are put in place that stimulate the uptake of a range of technical and non-technical options and that economic instruments are applied to improve the economic efficiency of the transport sector. Clearly, the assumptions underlying this scenario have a number of important implications, which are discussed in more detail in the next section. The aim of this section is to present what the GHG emissions reductions presented in Figure 21 mean for a number of key transport indicators.

Figure 8, Figure 9 and Figure 10 (in Section 4) summarise the contribution that reducing the GHG intensity of transport energy, improving vehicle efficiency (both technical and operational) and improving the efficiency of the transport system, respectively, make to the most ambitious reduction scenario (C5-c) shown in Figure 21. This scenario results in reductions of 89% in total GHG versus 1990 levels (and reductions of around 94% compared to business as usual) for 2050. Improving the efficiency of the transport system delivers nearly 40% of this reduction compared to business as usual. However, it is important to understand what this means in practice. As noted in Section 4, improvements in transport efficiency result directly from reductions in the amount of travel undertaken. However, this is not the same as reductions resulting from policy instruments that actively target demand. On the contrary, some (albeit as small proportion) of these GHG reductions will be the indirect result of improving the technical fuel efficiency of vehicles (see Figure 16). Further GHG reductions resulting from lower transport volumes arise from using vehicles more efficiently (e.g. driving behaviour and increased utilisation) and improving the structural efficiency of the transport sector through improved spatial planning and co-modality (see Figure 18). Neither do the economic instruments applied under scenarios 10 to 13 directly target transport demand, rather they aim to improve the economic efficiency of transport through the internalisation of external costs, the removal of subsidies and the creation of a level playing field (in terms of fuel taxation) between the modes.

The remaining 60% of GHG reductions presented in Figure 21 arises directly from the introduction of technical options resulting almost equally from improving the GHG intensity of energy carriers (i.e. on GHGs emitted per mega joule (MJ) of energy used), which includes

biofuels and other energy carriers, such as electricity and hydrogen, and improving the technical and operational efficiency of vehicles (i.e. on mega joules per kilometre, MJ/km).

Figure 22 further underlines the importance of non-technical options in delivering the scenario in Figure 21. This shows cumulative GHG emissions between 2010 and 2050, which are arguably even more important for climate change than the actual 2050 emissions, as these reveal the amount of GHGs that transport has emitted in the intervening period. This shows that under the most ambitious scenario (C5-c, as presented in Figure 21), the cumulative GHG emissions from the EU transport sector between 2010 and 2050 would be a 60% reduction on business-as-usual cumulative GHG emissions, whereas under the purely technical scenario (C2-a, presented in Figure 16), the equivalent figure would be around a 30% reduction. This reflects the fact that the uptake of the technical options takes time, as existing vehicle designs need to be developed and fuels need to be developed, whereas the GHG reduction potential of non-technical options can be delivered much more quickly.

**Figure 22: Total cumulative GHG emissions resulting from the illustrative scenarios presented in Figure 9 to Figure 21**

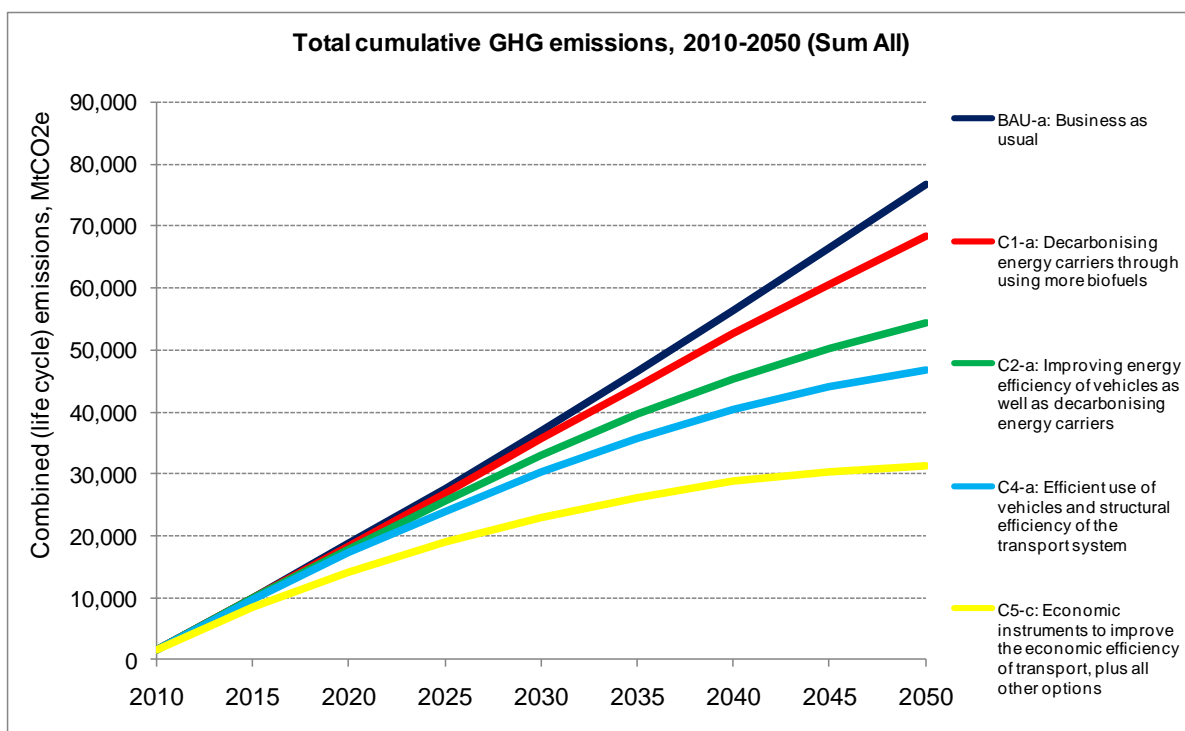
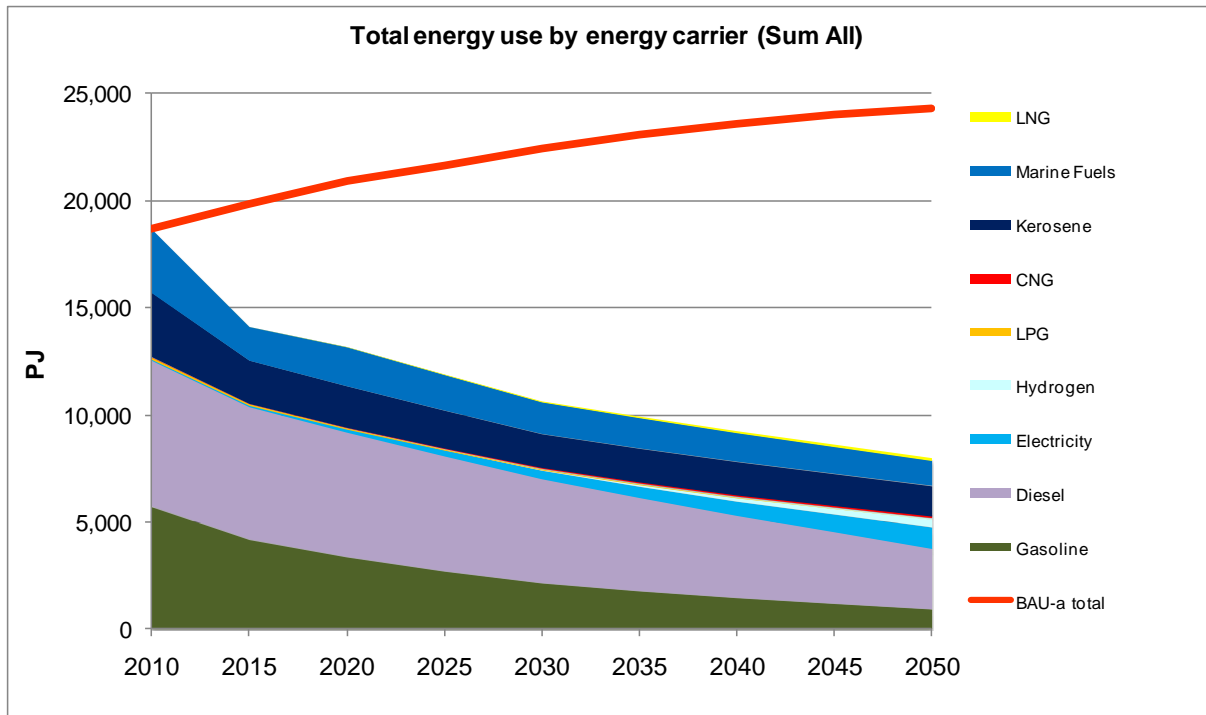


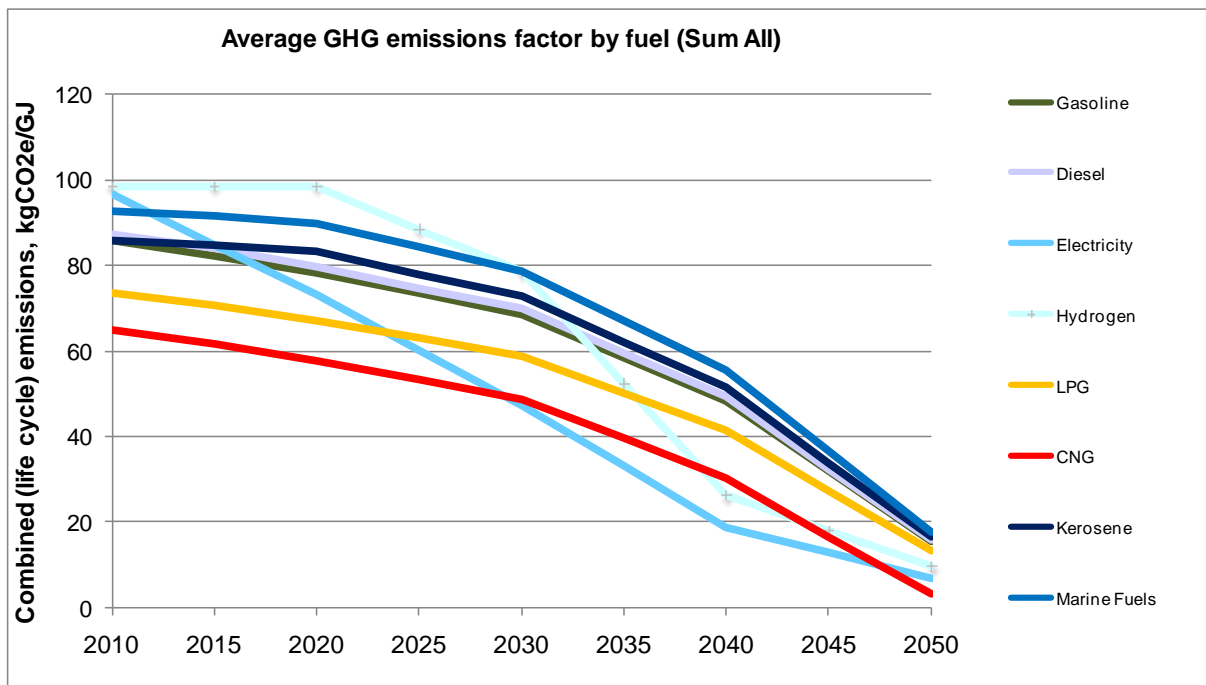
Figure 23 shows the energy carriers that would be used in 2050 under the ambitious scenario shown in Figure 21, while Figure 24 shows the scale of the ambition of this scenario with respect to the decarbonisation of various transport fuels and energy carriers. It is worth noting that the significance of vehicles using electricity and hydrogen is somewhat greater than the corresponding proportion of the total energy consumption of these energy carriers. This is because vehicles using these fuels could be up to 2 to 3.5 times more energy efficient than equivalents powered by conventional fuels alone. However, from these figures, it is clear that conventional fuels could still have a significant role to play in the 2050 transport system, although these fuels would have to have a GHG intensity of less than 20% their 2010 equivalents. This underlines the importance of blending-in virtually carbon-neutral, sustainable biofuels. The production of electricity and hydrogen would also have to be significantly less carbon intensive than it was in 2010.



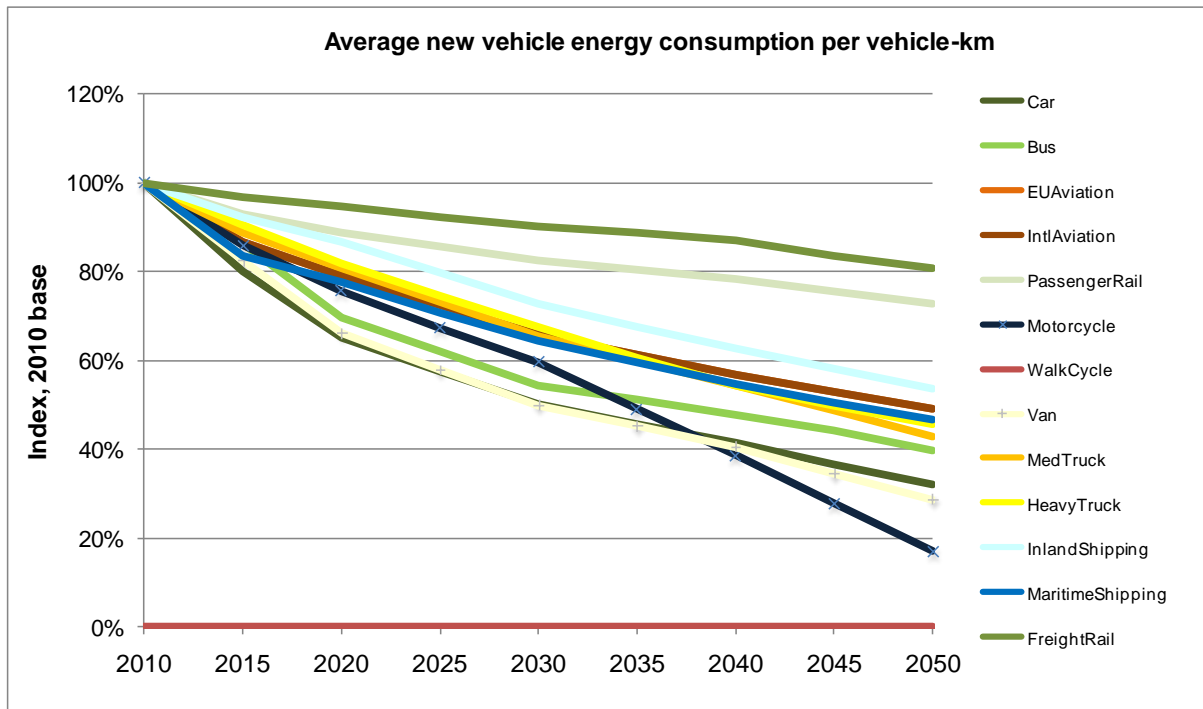
**Figure 23: Total energy use by energy carrier resulting from the illustrative scenario presented in Figure 21 (for liquid fuels, the labels refer to fuel type, but assume the blending of biofuels in these)**



**Figure 24: Extent of decarbonisation required by energy carrier under the illustrative scenario presented in Figure 21**



**Figure 25: Extent of improvements in average new vehicle efficiency required under the illustrative scenario presented in Figure 21**



**Figure 26: Extent of decarbonisation required per new vehicle under the illustrative scenario presented in Figure 21**

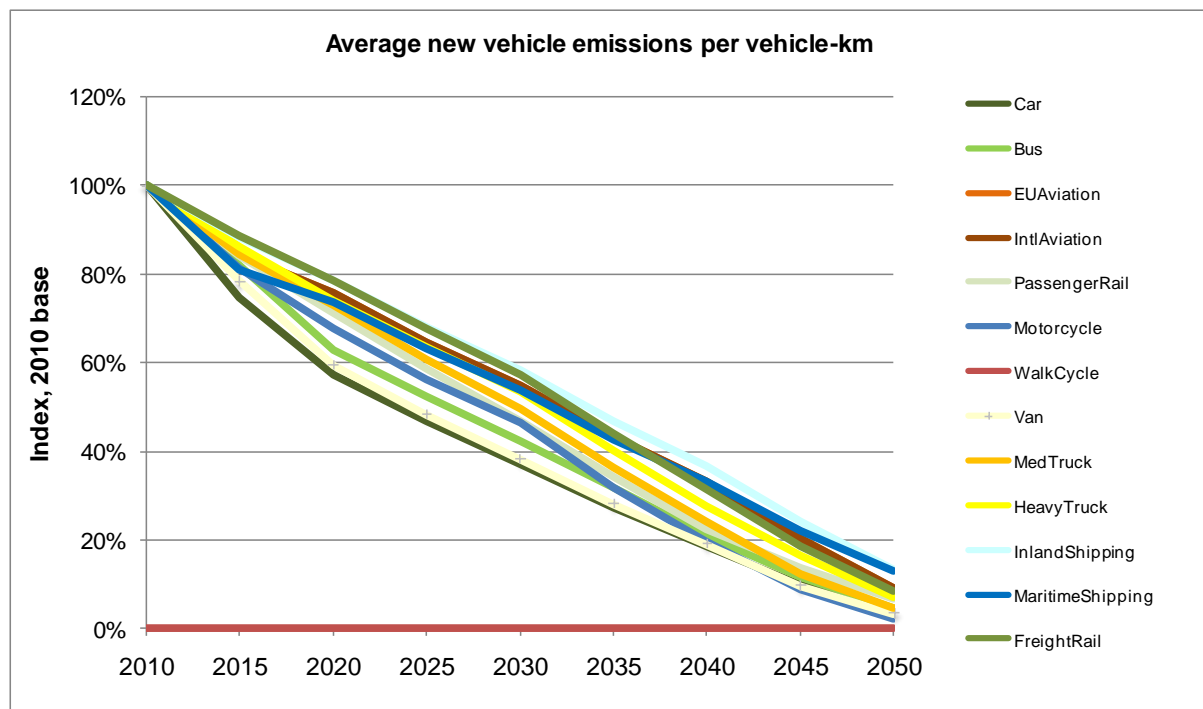
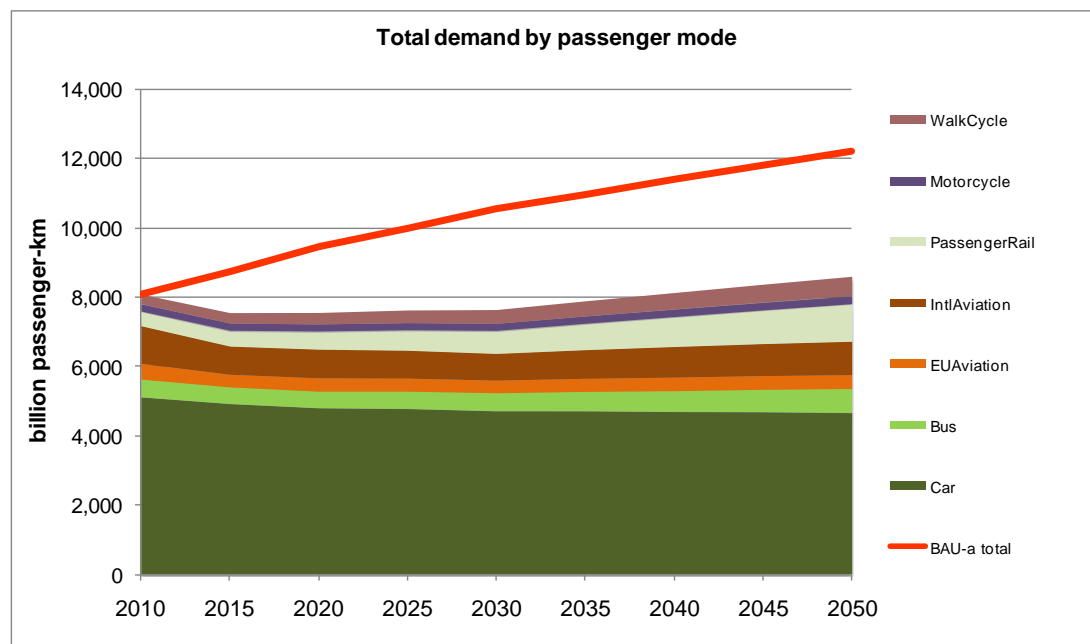


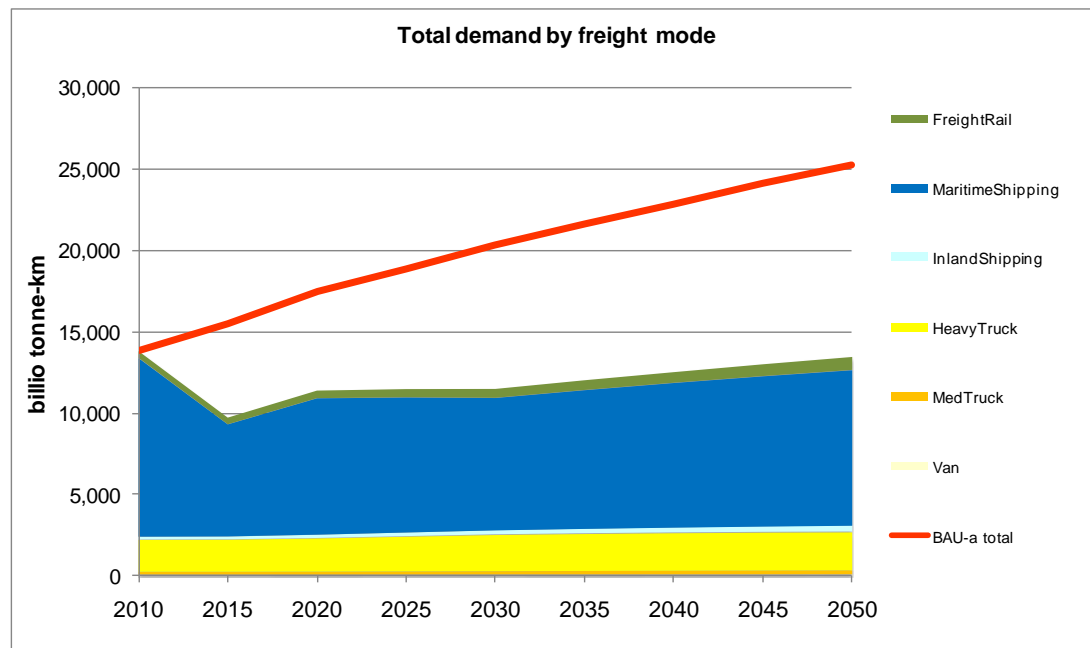
Figure 25 and Figure 26 shows the extent of the ambition in terms of improving vehicle efficiency and reducing overall WTW GHG emissions per vehicle kilometre required under the most ambitious scenario (i.e. that shown in Figure 21). This shows that the average WTW GHG emissions of new vehicles in 2050 would need to be less than 10% of the value of their equivalent 2010 vehicles. Due to changes to powertrains and the decarbonisation of

energy carriers, the corresponding required improvement in vehicle efficiencies is somewhat less – ranging from 20% to 80% depending on the mode. This is achieved through a combination of improving vehicle efficiency and introducing less GHG intensive energy carriers.

Figure 27 and Figure 28 show the implications for demand for passenger and freight transport, respectively, of scenario C5-c illustrated in Figure 21. The initial declines in all modes result from the use of economic instruments to internalise selected external costs, remove some subsidies and create a level playing field between the modes (from the perspective of the fuel taxes that they face). These have a more significant impact on aviation and maritime transport, as is clearly evident from the initial dip in demand for maritime shipping in Figure 28 (in spite of a gradual introduction of the harmonised taxes from 2010 through to 2030). Whereas under business as usual, the demand for passenger travel is expected to increase by 50% and that for freight transport would nearly double, under the ambitious scenario, the demand for both in 2050 would not be that different from the respective demands in 2010. However, the modal shares have changed. For passenger transport, demand for travel by bus, rail and walking and cycling would have grown, while demand for aviation and travel by car would be around 10% lower than 2010 levels. For freight, the demand for maritime transport would be lower in 2050 than in 2010, while the demand for all of the other modes would increase, with larger relative increases in the rail and inland waterway sectors. The reduction in demand for aviation and maritime travel is primarily due a demand-response to significantly higher fuel price increases (since they are currently duty and VAT free) compared to other modes.

**Figure 27: Demand for passenger travel implied under the illustrative scenario presented in Figure 21**



**Figure 28: Demand for freight travel implied under the illustrative scenario presented in Figure 21**

## 5.5 Potential for reducing transport's GHG emissions

The scenarios developed under the project illustrate that, under the assumptions made, GHG reductions of up to 89% from transport could be possible, although this requires the uptake of a range of ambitious technical and non-technical options in addition to directly influencing the demand for travel through economic instruments. This ambitious scenario requires a reduction of the GHG intensity of all transport energy carriers of at least 80% compared to 2010 levels, while new transport vehicles in 2050 would need to have more than a 90% reduction in net GHG emissions (and potentially be up to 80% more energy efficient) than new vehicles of 2010. Demand for travel, both passenger and freight, would be similar to levels in 2010.

Reasonably ambitious assumptions underlie these GHG reductions with respect to the uptake of both technical and non-technical options. Of course, technical developments may occur faster than anticipated in which case lower levels of reduction would be needed from non-technical options to achieve a similar overall level of GHG reductions. On the other hand, the existing barriers to the assumed uptake of the technical options may not be overcome as much as assumed, thus requiring more reductions from non-technical options and further reductions in demand.

Issues associated with the delivery of the required levels of uptake of the options are discussed in the next sections.

## 6 Policy frameworks for reducing transport's GHG emissions

This chapter focuses on the alternative policy frameworks that may be utilised to stimulate the uptake of first the technical options and then the non-technical options for reducing GHG emissions from transport (as noted in Section 4). As was clear from the findings of SULTAN presented in Section 5.3, long term policy frameworks for virtually carbon-neutral transport will require a mix of supply- and demand-oriented policy instruments. The complementary nature of various policy instruments, particularly economic instruments and regulation, was noted in Section 3.6 in order to overcome the split incentives associated with the options for reducing transport's GHG emissions.

Consequently, the aim of this chapter is to set out the issues with respect to the introduction of policy instruments that have the potential to achieve the GHG reductions set out in Section 5.3. To this end, Section 6.1 sets out the issues associated with stimulating the uptake of the technical options, focusing on the regulation of the GHG intensity of transport energy and the technical efficiency of vehicles, while Section 6.2 set outs the issues associated with the introduction of policy instruments that are aimed primarily at stimulating the uptake of non-technical options. The complementary nature of the various policy instruments, particularly regulation and pricing is underlined throughout these sections and is further underlined in Section 6.3, which also prioritises the policy instruments and discusses the respective administrative responsibilities.

### 6.1 Policy framework for decarbonising fuels and improving vehicles

A general overview of policy instruments that may be used to promote CO<sub>2</sub> emissions reduction by stimulating the uptake of technical options is presented in Figure 29. While the stimulation of R&D and the introduction of regulations trigger developments on the supply side, specific market stimulation instruments and more generic economic instruments may be used to promote demand for sustainable vehicles.

As was clear from the discussion of Section 3.1, the development of alternative, virtually carbon-neutral energy carriers and the development of highly energy efficient vehicles are complementary. Consequently, Section 6.1.2 discusses issues concerned with the potential future regulation of vehicles and their components, while Section 6.1.3 covers the regulation of energy carriers. Prior to these, Section 6.1.1 sets out some high level issues associated with the transition to decarbonised fuels and vehicles.

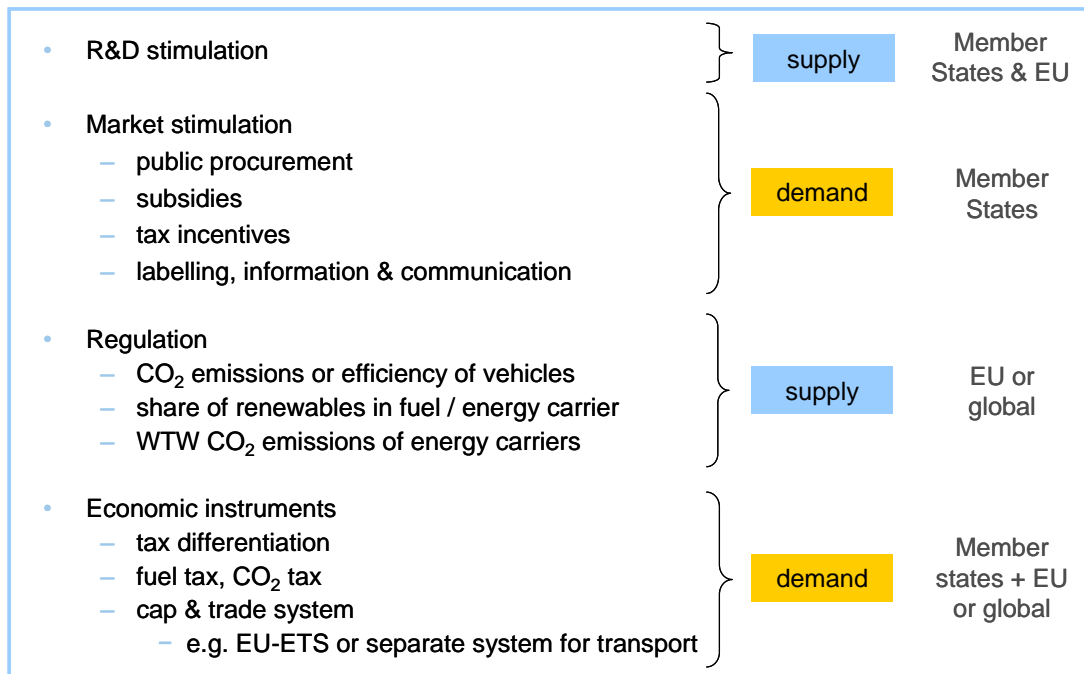
#### 6.1.1 Transition to decarbonised fuels and vehicles

As discussed above, within a given structure of the transport system, i.e. without making changes to the way in which vehicles are used, the GHG emissions of vehicles can be reduced either by making the vehicles more energy efficient and/or by reducing the GHG intensity of the fuels and energy carriers used in the vehicles (also, see Figure 30).

In the short-term, applying “**incremental**” **improvements** to make vehicles that run on conventional fuels more efficient will be the main option for achieving significant GHG emission reductions. In the longer-term, the need for the introduction of significantly more energy efficient vehicles and energy carriers that are capable of much lower GHG intensity

will require within the next four decades a “**transition**” that involves structural changes in the transport system as well as the energy system.

**Figure 29: General overview of policy instruments that promote the development and application of technical options for reducing GHG emissions from transport**



**Figure 30: Pathways for creating virtually carbon-neutral vehicles**

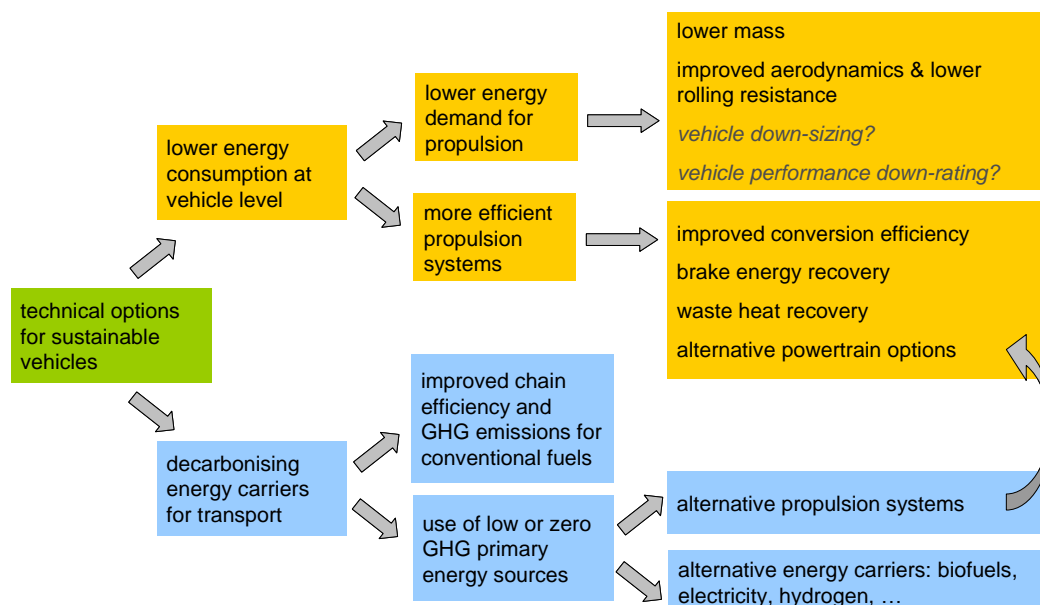
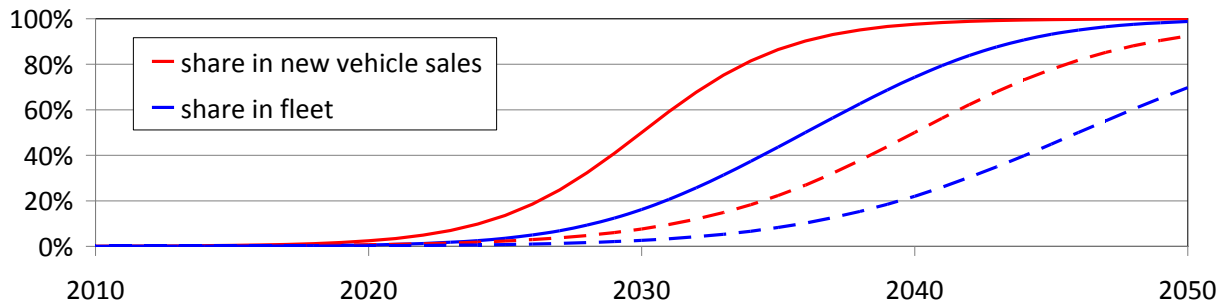


Figure 31 presents a scenario for the introduction of vehicles that have the potential to use energy carriers that have the potential to deliver virtually carbon-neutral energy for road transport. Given the general dynamics of introducing new technologies (that are usually represented by S-curves) and the dynamics of fleet turn-over, the first vehicles using alternative powertrains that are potentially carbon-neutral need to come to the market by 2020 or 2025 to ensure a sufficient share in the fleet by 2050. (For other modes, these dates will have to be even earlier due to the longer life-times of these vehicles, e.g. ships and

aircraft.) It is important to note that lines in Figure 31 represent the total number of vehicles that have the potential to use virtually carbon-neutral energy carriers; it should not be taken to imply that a particular alternative energy carrier would necessarily achieve 100% penetration into the vehicle market.

**Figure 31: Indicative representation of the evolution of the share of potentially virtually carbon-neutral vehicles in the new vehicle sales (red lines) respectively the overall fleet (blue lines) for meeting the EU's ambition for GHG emission reduction in 2050**



In general two phases can be discerned for light duty road transport vehicles for the coming decades: pre 2030; and post 2030. Between 2010 and 2030 conventional vehicles need to continue to be made more efficient. At the same time experimentation needs to be undertaken with vehicles using alternative powertrains that are potentially carbon-neutral. Before 2030 the most viable options among these low carbon alternatives need to be developed to technological and economical maturity. This must be achieved in part by creating first markets for such alternatives using low GHG energy. This in turn will generate production volumes and lead to cost reductions through learning effects. It will also create a basis for industry to invest further in the development of optimised products and production methods. By 2030 alternatives must be ready for large scale uptake. Between 2030 and 2050 the market share of sustainable alternatives needs to be increased significantly in order to achieve a significant fleet share by 2050, e.g. to the levels mentioned in Table 5 in Section 5.1. Policy instruments need to be tailored to this phasing.

Whilst the timeframe of the example in Figure 31 is specifically valid for road transport, similar arguments can be made for vehicles used by other modes. The possible speed and timing of the transition in rail, shipping and aviation may be slower than in road transport due to longer vehicle lifetimes, and thus slower fleet renewal, as well as longer lead times for innovation (as discussed in Section 1.5). On the other hand, the fact that such vehicles have longer lifetimes argues for the urgent introduction of cleaner vehicles for these modes, in order to ensure that cleaner vehicles have a significant market share by 2050.

In parallel, of course, action needs to be undertaken to ensure that GHG reductions are also achieved over the whole lifecycle of the preferred energy carriers, otherwise it will not be possible to achieve virtually carbon-neutral transport when measured over the life-time of the energy used. Hence, in this respect, attention needs to be paid to the way in which the potential alternative energy carriers for transport are developing, particularly their developing potential to reduce their respective GHG emissions. The transport policy framework would need to be amended appropriately if the potential GHG reductions of any energy carrier were not being achieved in practice.

### 6.1.2 Regulation of vehicles and components

One of the main benefits of regulating GHG emissions from new vehicles is that it is potentially very effective, as it targets all new vehicles and is potentially applicable for all

modes. In this respect, current regulation is aimed directly at TTW emissions, which is important as these are the emissions that can be influenced by a vehicle's manufacturer. In order to be clear and transparent, regulation requires test procedures that ensure that the emissions measured correlate to real-world emissions. As noted in Section 3.1, fuel efficiency and CO<sub>2</sub> targets already exist for cars and have been proposed for light commercial vehicles. Similar regulations could be developed for other modes, and indeed are being considered<sup>51</sup>. Once these have been set, regulatory targets should be successively tightened in order to stimulate innovation. The regulation of CO<sub>2</sub> emissions from vehicles can be implemented in a number of different ways, for example:

- Emission targets for the sales-averaged CO<sub>2</sub> emission per manufacturer determined using a linear utility-based limit function, as is the case for the present approach for cars and light commercial vehicles;
- Emission limits per vehicle, also using a linear utility-based limit function, setting an absolute emission maximum, either on its own (individual vehicle emission limits) or in combination with fleet averaging (as an upper limit for individual vehicles falling under a sales averaged overall target);
- One of the above options but using non-linear utility-based limit curves that e.g. penalise high emitters (curve flattening out for high values of the utility parameter);
- Using bin-based systems requiring increasing shares of vehicles over time to meet more stringent emission limits.

In the future it may be necessary to develop a more sophisticated approach in view of the changes in the potential energy carriers used for propulsion and the differences in the location of GHG emissions associated with them.

In addition to the regulation of the energy efficiency of vehicles, the energy efficiency of particular components may also be regulated. Over time, regulation is likely to become more sophisticated and integrated as the need to ensure GHG reductions intensifies. Some interesting examples of regulatory options that have been identified with the project<sup>52</sup>, which may be considered for future EU policy, include:

- Regulation of **CO<sub>2</sub> emissions per unit of transport function**, i.e. in gCO<sub>2</sub> per passenger kilometre or g/CO<sub>2</sub> per ton kilometre: This option would mean a more integral approach to sustainability of transport and would allow emission standards to be applied across different modes. Transport performance, however, is difficult to measure in a legally watertight way, and it might be necessary to define different targets for different categories of transported goods or persons.
- Setting **absolute restrictions on vehicle parameters**, e.g. on size, weight, power, or power/mass ratio. Similarly a limitation of maximum speed or other performance indicators could be considered.
- **Mandatory application of technologies**, e.g. retrofitting existing vehicles with low rolling resistance tyres.
- Promoting **application of "eco-innovations"**, i.e. technologies that do not yield (large) benefits on the type approval test but that do significantly improve real world CO<sub>2</sub> emissions: This is already a (temporary) part of the present regulation, but could be explored further. Ideally an improvement of the type approval test procedure would reduce the number of technologies that would fall under this definition. This type of regulation may have to be combined with regulation setting minimum performance requirements at the component level.

<sup>51</sup> See Appendix 9 for more details; also see <http://www.eurtransportghg2050.eu/cms/updated-reports/>

<sup>52</sup> See Appendix 9 for more details; also see <http://www.eurtransportghg2050.eu/cms/updated-reports/>



- Mandatory **externally controlled limitation of speed and acceleration**, dependent on location and condition of driving, with possible additional benefits for air quality, noise and safety.

### 6.1.3 Regulation of energy carriers

An integral element of the approach towards the introduction of vehicles that have the potential to be virtually carbon-neutral could be based on a combination of the TTW GHG emissions or energy efficiency of vehicles and the regulation of the WTT or WTW GHG emissions of energy carriers. The latter would target fuel and energy producing companies while meeting vehicle legislation would remain the responsibility of vehicle manufacturers. Appropriate co-ordination of the two regulatory pathways is a prerequisite for a successful stimulation of the transition to potentially carbon-neutral vehicles.

As noted in Section 3.1, the reliance on alternative energy carriers, and the need to lower the GHG intensity of these alternative energy supplies, means that the interaction with wider energy policies becomes important for policy instruments that aim to decarbonise transport. Article 7a of the Fuel Quality Directive (see Section 3.1) contains a provision for identifying and monitoring electricity used for electric vehicles, but it is not yet clear whether this would, for example, require smart metering to identify the electricity used by EVs. Further uncertainties exist over how the GHG intensity of that electricity is to be identified and on the relationship and interaction between electricity used for EVs and that used by households more generally. These developments suggest that the regulation of energy carriers is likely to become more sophisticated and also be increasingly linked to developments in wider energy policy, which will be fundamentally important if transport is to virtually decarbonise by 2050. Regulation targeting the GHG intensity of potential transport energy carriers will need to be closely monitored in order to ensure that it is complementary to other mechanisms and subsequently developed if it needs to address a particular market failure or be used to overcome a particular barrier<sup>53</sup>.

## 6.2 Policy framework for improving the efficiency of the transport system

As was discussed in Section 2.4, there are a number of non-technical options available for reducing transport's GHG emissions, and there are a number of policy instruments that could be put in place to stimulate the uptake of these options, either directly or indirectly (see Section 3). As was noted in Section 4, non-technical options directly affect the operational efficiency of the vehicle, i.e. the way in which the vehicle is used, and the efficiency of the wider transport system itself. Examples of options that directly affect the operational efficiency of a vehicle are:

- Maximising the potential of co-modality.
- Optimising the structure of the transport system.
- Optimisation of speeds.
- Fuel efficient driving behaviour.
- Optimisation of traffic flows and routes (for all modes) and improving vehicle utilisation.
- Larger vehicles.

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<sup>53</sup> In parallel, standards on fuel quality and compatibility need to be in place, as well as dedicated safety regulations for new fuels and their applications, in order to ensure that the absence of such standards does not act as a barrier to the introduction of a potentially promising (from the perspective of GHG emissions reduction) energy carrier.

As noted in Section 3.6, other policy instruments, such as regulation and economic instruments also have the potential to influence indirectly the uptake of such options. The potential application of regulation to reduce transport's GHG emissions was discussed in Section 6.1. In addition to influencing the uptake of non-technical options indirectly, economic instruments also have the potential to improve the economic efficiency of the transport system directly, and can also be used directly to reduce demand.

There are a range of issues associated with introducing policy instruments to stimulate the uptake of each of these options, as well as in using economic instruments to reduce transport's GHG emissions, which are set out below. The section concludes with the ultimate option for reducing transport's GHG emissions – that of implementing policy with the direct aim of managing the demand for travel.

### **6.2.1 Maximising the potential of co-modality**

Maximising the potential of co-modality for GHG reduction is not simply a case of always preferring one mode over another; rather it is concerned with choosing the least-GHG intensive mode that is appropriate for each (part of a) journey (see the discussion in Section 2.4). Important policy instruments that could contribute to maximising the potential for co-modality are:

- Spatial planning, particularly that which focuses on enabling the least GHG-intensive modes to be used. In urban areas, this means enabling walking, cycling and public transport, while on major inter-urban passenger and freight routes, rail is often a more appropriate option for medium distances.
- Infrastructure policy, including the provision and improvement of infrastructure for the most GHG efficient mode in different locations.
- Economic instruments, particularly to reduce potential rebound effects (see Section 6.2.7).
- Communication policy, i.e. communicating to potential users about the least GHG intensive modes.
- Stimulation of innovation in technology, as some ICT developments can assist in improving the quality of other modes and enable improved communication.
- Stimulation of new business models, as these are likely to be needed to maximise the potential for co-modality.

As noted in Section 2.5, the stimulation of co-modality for passenger transport, particularly in urban areas, is important for a wide range of reasons, not just from a GHG perspective, including the social function of public transport and various co-benefits such as congestion reduction, solving parking problems, and reducing noise and air pollution.

The maximisation of co-modality is relevant for a range of different types of journey, so different policies and administrations will be responsible for these policies depending on the location concerned. Hence, while co-modality is often spoken about with respect to passenger transport in urban areas, it is also important for passenger transport for inter-urban travel and shorter international journeys, particularly within the EU, as well as for local, inter-urban and international freight transport. The extent to which co-modality is possible will depend on a wide range of factors, including the goods that are transported in the case of freight transport. Consequently, maximising the potential of co-modality for GHG reduction will require a wide range of policies and the involvement of a large number of actors.

## 6.2.2 Optimising the structure of the transport system

One of the principal policy instruments for optimising the structure of the transport system is spatial planning. As was noted above, spatial planning, both within urban areas, but also on inter-urban routes, in rural areas and at the international level, is an important element in maximising co-modality. However, spatial planning also has the potential to improve the efficiency of the transport system through the optimal location of services, employment and residential areas.

However, there are significant challenges in using spatial planning to reduce transport's GHG emissions. One of the important issues is that each location is different and while lessons can be learnt from the experience of other (similar) locations, it is often not possible to transpose approaches directly from one location to another. In this respect, it is important for a large degree of local autonomy in spatial planning. However, in the absence of higher level guidance or frameworks, wider issues, such as climate change, may be overlooked. Hence, the use of spatial planning to reduce GHG emissions from transport requires that different administrative levels work together. However, as with public transport, there are potential co-benefits to be delivered if spatial planning is able to deliver GHG emissions.

## 6.2.3 Optimisation of speeds

The potential benefits to GHG emissions of enforcing existing speed limits and the imposition, or lowering, of speed limits on inter-urban roads was discussed in Section 2.4. Speed limits can be enforced or imposed technically, as well as through the clear indication of speed limits on relevant transport infrastructure, coupled with the threat of sanctions. They have a significant potential to reduce GHG emissions from transport and very easy to implement and have short lead times.

Speed limitation devices can be applied to vehicles, which ensure that vehicles are not able to travel above a particular chosen speed. Currently, such devices are used on road-based freight transport, but not on other modes. From the perspective of GHG reduction, a case could be made to limit the speed of all road vehicles by technical means and the relevant limiters could be required by and specified by European legislation. However, requiring the fitting of speed limiting devices for all road transport is likely to be controversial.

Limiting speeds on major inter-urban roads generally, even through the imposition of speed limits and the threat of sanctions, is difficult particularly where no speed limits currently exist on motorways. In other countries, there are calls for existing speed limits to be increased, particularly on major inter-urban roads, to take account of improved vehicles. Consequently, enforcing existing speed limits on inter-urban roads and reducing speed limits, may not be popular.

For non-road modes, the main restrictions on the speeds at which vehicles travel is likely to be technical, in so far as what a vehicle (and in the case of trains and inland waterway vessels, the infrastructure) and its cargo of goods or passengers can withstand. Safety concerns are also an important consideration, particularly in urban areas (for rail) and near ports for maritime vessels. Reducing speeds on such modes has the potential to increase costs, as fewer goods and passengers are able to be transported in a given period (assuming that the capacity of infrastructure does not increase). Hence, speed limitations on such modes are likely to be met with resistance from operators, and also passengers and freight customers. However, in the light of GHG constraints, these costs might be preferable to the alternatives.

Consequently, using speed reduction as an option to reduce transport's GHG emissions may not be easy, although it should be possible in the short term to at least to improve the enforcement of existing measures. If speed limitation is to play a more significant role in GHG reduction from transport, in the longer-term, the wider culture would need to change to accept this option. In implementing such a policy it would be important to recognise the trade-offs as well as the wide range of benefits it would bring.

#### **6.2.4 Fuel efficient driving behaviour**

As noted in Section 2.4, fuel efficient driving behaviour could be directly delivered by training drivers and pilots; economic instruments also have a potential (indirect) role to play if increased costs lead to the greater adoption of more fuel efficient driving behaviour (see Section 6.2.7). For some vehicles, particularly road transport, concerns regarding the extent to which the behaviour is maintained after training are likely to be addressed in the medium-term by developments in intelligent transport systems and technical developments of vehicles, which have the potential to automate much of the necessary driving style.

#### **6.2.5 Optimisation of routes and improved vehicle utilisation**

As noted in Section 2.4, the optimisation of routes has the potential to reduce GHG emissions. Given that such an option is generally financially beneficial to users and operators of both freight and passenger transport, the barriers to route optimisation need to be overcome. These generally include a lack of information that either enables the optimal route to be taken or enables the right decision to be made, e.g. due to the amount of data that has to be processed. As also noted previously, the development of ITS have the potential to contribute to the optimisation of routes, as it potentially makes such decisions easier.

With respect to vehicle utilisation, there are also potential financial benefits from improving the uptake of this option, as freight companies and public transport operators both potentially stand to gain financially from transporting more goods and passengers. Having said that, whether increasing utilisation is worthwhile depends on the net effect of the effort that the optimisation of utilisation takes, and the subsequent costs incurred, and the potential benefits. The latter, of course, are associated with the cost of travel, and therefore the costs that can be saved from higher rates of utilisation.

There are many factors that constrain improvements in vehicle utilisation, varying from market-related, regulatory, inter-functional, infrastructural and equipment related constraints. Some of these constraints could be addressed by targeted policy instruments, whereas others need action from private actors. Due to the importance of costs, economic instruments, such as pricing schemes (particularly variable costs, e.g. kilometre charges or fuel taxes; also see Section 6.2.7) are important instruments for improving vehicle utilisation. Additionally, it is also important to address any regulatory obstacles that exist, such as existing cabotage rules.

A main barrier for improvements in vehicle utilisation is the fact that often cooperation is required between many actors, which makes it more difficult in practice than it seems in theory. However, at least in the case of freight there is no obvious reason why this should not happen.

#### **6.2.6 Larger vehicles**

As noted in Section 2.4, as yet there is no consensus regarding the net GHG benefit of using larger vehicles for freight transport, including longer trucks, longer trains, larger ships and aircraft, as there are concerns that using larger vehicles would lead to increased transport

demand, as the capacity of the network would potentially increase. One of the major barriers to the wider use of larger vehicles, for any mode, would be the constraints imposed by infrastructure, for example, larger ships could require larger ports, larger inland waterway vessels could require larger locks, larger trains and trucks could require changes to bridges. Vehicle size could be limited by these constraints, but also actively limited (or allowed) by legislation, if it were decided that this was an appropriate route to take.

It is unlikely that larger vehicles would be able to use all infrastructure relevant for a particular mode. Such issues, including wider safety concerns, would need to be taken into account when taking policy action that affects the size of vehicles. Potential policy instruments that might stimulate the use of larger vehicles include transport pricing (e.g. kilometre charges; also see Section 6.2.7) and spatial planning that concentrates industries and other functions in such a way that the bundling of transport flows is stimulated.

### 6.2.7 Economic instruments

Section 3.2 discussed the rationale for the introduction of economic instruments, the fact that either emissions trading or fuel taxes could be considered the first best and most efficient approach for internalising external costs of climate change and the advantages and disadvantages of these two approaches. It was also noted that fuel taxes could be based on the available estimates for the damage or avoidance costs of a tonne of CO<sub>2</sub>. However, it was also highlighted that both emissions trading and fuel taxes have particular issues and that both appear to be insufficient for meeting long term reduction goals. For both instruments, the costs involved (fuel prices on the one hand and the price of carbon set by the market on the other) would need to become high for the instrument to be effective. In addition, neither instrument solves the problem of so-called split incentives (see Section 3.6). Additionally, internalising other external costs of transport, e.g. the cost of air pollution and noise, as well as infrastructure costs, could be achieved through the introduction of differentiated kilometre charging.

Fuel taxes are relatively easy to implement. To be effective and avoid distortions in border regions, EU harmonisation of road fuel taxes is strongly preferred. For aviation, a fuel tax could be environmentally effective when implemented on a European scale. However, in order to achieve this, many Bilateral Air Service Agreements would have to be adjusted. While this would take time, it is clearly feasible within the time frame under consideration. For maritime shipping, a fuel tax would only be likely to be effective if implemented on a global scale. Global implementation is certainly not easy to achieve and is thus only conceivable in the long run.

Overall, therefore, while either a carbon-based fuel tax or some type of emissions trading would be desirable in a long term GHG reduction strategy, particularly for the transport sector, such a generic instrument would not be a panacea. Other instruments, such as regulation (see Section 6.1) and the wide range of instruments discussed above, would also be needed.

However, the advantage of economic instruments is that they have the potential to simultaneously stimulate the uptake of a range of technical and non-technical GHG reduction options, including increasing the energy efficiency of vehicles and the use of low-GHG energy carriers. Hence, in addition to either a carbon-based fuel tax or an emissions trading system, a number of other economic instruments are also relevant in the context of reducing transport's GHG emissions, for example:

- CO<sub>2</sub>-differentiation of vehicle registration (or purchase) taxes, annual circulation taxes or road pricing;
- Targeted options, such as the differentiation of parking fees;

- The reform of taxes that current provide adverse incentives, such as company car taxation and the fiscal treatment of commuting and business travel; and
- Subsidies, which should be time-limited and well targeted, in order to ensure that they do not become an environmentally- and/or economically-damaging subsidy and that they target the appropriate technologies.

It should be noted that all of these can have indirect effects on the energy efficiency of vehicles via purchase choices.

It is important to make a distinction between temporary measures and structural instruments, as well as between specific and generic instruments. Subsidies are generally temporary and specific and, in principle, are a second best option if they result in prices being taken out of line with costs. For the long term, a structural fiscal framework or other more generic economic instrument is necessary to create a stable market for sustainable alternatives. A fuel tax or CO<sub>2</sub> charge levied through the fuel price incentivises all technical and non-technical reduction options. EU harmonisation is strongly preferred, but it is acknowledged that tax harmonisation at the EU level is difficult to achieve.

An advantage of the CO<sub>2</sub> differentiation of vehicle registration (or purchase) taxes is that these have a direct impact on purchasing behaviour. The differentiation of circulation taxes and road pricing, on the other hand, have a more indirect impact through differentiating the costs of use and the total cost of vehicle ownership. Road pricing should be highlighted here as a potentially effective instrument if it is desired to address both congestion and GHG emissions, as it can reduce traffic congestion without generating additional traffic.

For other transport modes various types of GHG-based infrastructure charging are conceivable, which may have indirect effects on the energy efficiency of vehicles. Examples are port charging (on a regional or EU scale for inland shipping and on a global or regional scale for maritime) and airport taxes for aviation. This can be done on the basis of TTW or WTW emissions and requires appropriate procedures for establishing GHG emissions and, in the latter case, needs lower GHG energy carriers to be available and viable.

The removal of hidden subsidies and perverse incentives are important actions that can be taken early on. Two examples are the revision of company car taxation and fiscal treatment of commuting and business travel. This not only provides an opportunity for basing these taxes on GHG performance of vehicles, but also to remove hidden subsidies that promote long commuting distances and the use of cars over other modes.

### **6.2.8 Managing the demand for travel**

In addition to being used to promote economic efficiency and overcome market barriers, economic instruments could also be used directly to manage the demand for travel. In areas where space is constrained, and therefore the potential for infrastructure development is limited, road pricing can be used to manage demand by increasing the price of use, either generally or at particular times, e.g. peak hours. Similarly, tolls on inter-urban roads could be used to manage demand and attempt to maintain consistent traffic flows. Such an approach might be relevant in areas of natural beauty, including national parks, where it is not desirable to increase the capacity of the transport infrastructure. More generally, at the national level, fuel duties could be increased in an attempt to reduce the rate of growth of transport, or ultimately absolute levels of transport.

The promotion of slower modes could also contribute to the management of demand, due to the link between speeds and travel resulting from the apparently constant time budgets of individuals (discussed in Section 5.2.6). In this respect, policy instruments that stimulate co-

modality are also relevant to managing demand. Other policy instruments that are relevant in the context of reducing speeds are clearly, speed limit enforcement and lower speeds, pricing policy for the faster modes and the abolition of perverse incentives and subsidies for faster modes. Additionally, if it turns out that demand for certain types of travel are approaching saturation point, as also discussed in Section 5.2.6, then there might be a natural ceiling on the demand for certain types of travel.

Managing the demand for freight, other than by simply increasing the price of transport, is more challenging, as demand is linked to various macro-economic trends, particularly the growth of production and consumption, globalisation, specialisation of industries and cost optimisation (labour, economy of scale). Managing demand for freight, therefore, is linked less to speed as is the case for passenger transport, but more to prices.

As noted in Section 3.2, for most types of goods transport costs are only a minor share in their overall production costs. However, freight transport has shown itself to be sensitive to prices, particularly as average distances decrease with higher kilometre or fuel prices. Consequently, higher taxes and charges may reduce freight transport growth, but if prices are too high, then there is the potential for adverse economic effects. Consequently, while pricing could be a key element in managing the demand for freight transport, it is definitely not a panacea. Spatial and infrastructure policy are also important. Moreover managing the demand for freight transport also requires policy actions outside of the transport domain, which touch on overall economic structures and growth paths, in particular:

- Redesign policies in other sectors to make the economy less dependent on transport growth, e.g. by decreasing differences in labour cost.
- Development of changing attitudes to natural resource use such as in a Green GDP which takes into account the use of raw materials and environmental impacts.

These types of policy have not been studied in much detail within the current project, but need further consideration in order to manage the demand for freight transport growth, while contributing to an overall growth in prosperity.

### **6.3 Policy instruments: Prioritisation and responsibility**

It is clear from the above discussion that a wide range of policy instruments are needed in order to stimulate the uptake of a wider range of technical and non-technical options for reducing transport's GHG emissions. A range of measures is needed, in particular, to:

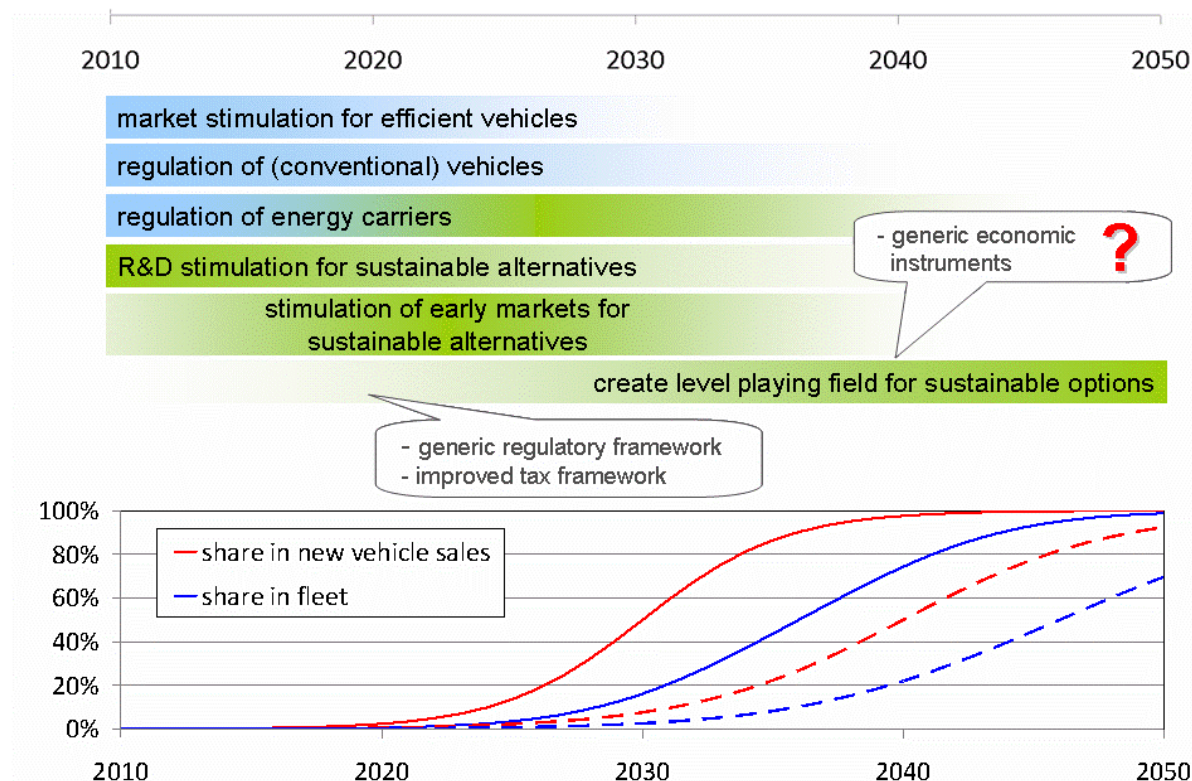
- Overcome the problem of split incentives, i.e. that manufacturers are required to invest in technology to improve the energy efficiency of their vehicles, while it is the users who benefit from the improvements in energy efficiency of the vehicles.
- Overcome various potential rebound effects, e.g.
  - The use of more energy efficient vehicles could stimulate more travel, as the use of these vehicles would be cheaper.
  - The shift of journeys from more GHG intensive to less GHG intensive modes has the potential to stimulate demand for travel, as infrastructure capacity is freed up.
- Stimulate the uptake of the full range of technical and non-technical options that are needed to reduce GHG emissions from transport to the levels potentially required.

In this section, the main policy instruments are prioritised and the administrative levels responsible for implementing the respective policy instruments are discussed.

### 6.3.1 The prioritisation of policy instruments for reducing transport's GHG emissions

In the short to medium term for road transport a continuation and further extension of the regulatory approach used by the European Commission seems to be most appropriate for ensuring that the GHG intensity of transport energy and the technical efficiency of vehicles are improved. These can be supported by demand measures such as subsidies, labelling and tax differentiation which in part should be arranged at a European level, but can mostly be implemented at the national level. Where existing instruments are in place, e.g. for cars and road transport fuels, the requirements need to be progressively tightened to ensure that technical developments continue at the necessary pace, taking account of wider issues of cost-effectiveness. These should eventually stimulate the development and application of alternative powertrain technology that enables the widespread use of alternative energy carriers in transport. Comparative standards for vehicles and energy carriers need to be developed and implemented for those modes and fuels for which such standards do not currently exist, largely non-road modes, but also for road transport freight vehicles.

**Figure 32: Possible timeline for evolution from the present regulation-oriented approach towards a more integral approach in which generic economic instruments provide a long-term level playing field and stable market for sustainable transport options. Blue bars denote stimulation of incremental options, while the green bars indicate measures aimed at promoting transitional options**



In the long-term, it also is likely to be important to introduce a CO<sub>2</sub> price faced by transport where none currently exists. This could involve a CO<sub>2</sub> tax or a cap & trade system, and may be general (for all sectors) or sector-specific. A CO<sub>2</sub> price as part of a tax would need to increase over time, for example as proposed by the IMPACT project. If increased understanding of damage and/or mitigation costs of GHG emissions requires increases in future estimates of CO<sub>2</sub> prices, then these would need to be raised accordingly. The combination of economic instruments with regulation will ensure the availability of efficient



technologies and thus enable users and other stakeholders to respond effectively to the financial incentives provided by the economic instrument(s). In this combination the economic instrument should provide a level playing field for alternative low carbon options to compete on the basis of costs and environmental performance. Figure 32 illustrates a possible timeline for the above-sketched evolution from a regulation-oriented approach towards a more integral approach involving generic economic instruments.

In addition to regulation and a general economic instrument, such as a GHG-based fuel tax or emissions trading, most of the other instruments need to be developed and applied in the short-term, and reviewed and amended in the long-term in order that the least carbon-intensive pathway to a future GHG reduction target be realised. In this respect, this study concurs with many previous studies<sup>54</sup>, in that early action across the board is needed to reduce GHG emissions from the transport sector.

Action should not be limited in the short to medium term to measures that are currently cost effective. Such an approach risks leading to a situation where the long term targets cannot be reached because the measures with higher abatement costs that are required to be put in place can no longer deliver the savings needed in the timescale available due to the long lead times that might be needed to implement these measures. Additionally, the long vehicle lifetimes, and thus long times required for fleet turnovers in these modes, also underlines the need for the early introduction of new technology for these modes.

### **6.3.2 Responsibility for introducing policy instruments for reducing transport's GHG emissions**

From the above discussion, it is clear that there is a need to introduce policy instruments to reduce transport's GHG emissions at all administrative levels from the global and EU levels to the national and regional/local levels. The EU is clearly the most appropriate level for much product-focused legislation, such as that targeting fuels and vehicles, while standards for some vehicles, particularly those most used internationally, might be best developed at the global level, e.g. via the IMO or ICAO. However, such measures need to be complemented by action at the Member State and regional/local level, e.g. the differentiation of national tax regimes and local traffic management measures. While the development of global standards might be important for some vehicles, they might be difficult to achieve. Additionally, given the different stages of development of different countries, the more developed countries might need to take additional action compared to the less developed countries to reduce their GHG emissions. Hence, it is important to balance the aspiration of a global agreement with the need to take action to reduce the EU's transport GHG emissions.

It is clear that some regulatory instruments could only be implemented at the EU level. The same is true for the main options for economic instruments. To establish the right mix of push and pull measures, required to solve the split incentive problem, EU measures need to be augmented by Member State actions. Global instruments are especially relevant for aviation and maritime transport, with the exception of (air)port charges. Such global instruments require the involvement of global organisations such as ICAO and IMO. But even for these (sub)sectors, global instruments or harmonisation may not be always appropriate. In some cases, efforts required for global harmonisation may slow down the regulatory process in EU.

Local policy is also important, e.g. for stimulating a shift to slower modes (cycling, walking, efficient public transport), managing demand, e.g. by developing more compact cities with

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<sup>54</sup> See Appendix 17 *Review of projections and scenarios for transport in 2050* for more details; also see <http://www.eustransportghg2050.eu/cms/additional-reports/>

shorter distances between key functions, urban congestion charging, parking and speed policy, etc. In this context it must be highlighted that the development of indicators could contribute to local targets and benchmarking.

Also at a national level, various actions can be taken. First of all, setting long-term objectives for reducing GHG emissions in national law can help to provide a guarantee of a consistent long term policy objective. In addition spatial and infrastructure policy could be focused on compact cities, allow bundling of flows and only a limited extension of road and airport infrastructure capacity. At the national level a broad range of pricing policies can be considered, such as kilometre charging, the abolition of subsidies for company cars and other subsidies (e.g. for travel expense declarations) and possibly a ticket tax for aviation to compensate for its current VAT exemption. Solving congestion by congestion charges before increasing road capacity could limit transport growth and therefore GHG emissions.

## 7 Towards the decarbonisation of the EU's transport system by 2050

### 7.1 Overview of the main findings with respect to achieving a virtually carbon-neutral system by 2050

The analysis undertaken within this project concludes that **it is possible for the EU's transport sector to reduce its GHG emissions by nearly 90% by 2050 compared to 1990 levels**. This requires the ambitious uptake of a wide range of technical and non-technical options and assumes the deliverability of some as yet unproven technologies, in addition to the introduction of a wide range of complementary policy instruments.

The reasons for the need for **both technical and non-technical options** are as follows:

- **It would be very challenging to deliver the levels of GHG reduction required by stimulating technical options alone:** In common with other studies, the scenarios developed within this project suggest that it would be very difficult (if not impossible) to achieve GHG reductions of 50% or more through the uptake of technical options alone. The scenarios suggest that it is possible to achieve a 36% reduction of transport's GHG emissions on 1990 levels through technical options (see Figure 16 in Section 5.3). Even reaching this figure assumed that alternative energy carriers used by transport, e.g. electricity and hydrogen, would be providing virtually decarbonised energy by 2050 and that the use of biofuels would reach levels that would otherwise be equivalent to approximately 30% of total BAU fuel consumption. Hence, GHG emissions reduction of nearly 90% can only be achieved through the additional uptake of non-technical options and the use of economic instruments to internalise external costs.
- **The maximum potential for application of some alternative energy technologies is likely to be limited:** While there are alternative energy carriers for transport that have the potential to deliver virtually carbon-neutral energy, these are often not widely applicable across of the transport modes. For example, electricity is only applicable on certain modes of road transport and rail transport, but not in aviation and shipping.
- **The modes with the largest projected growth have relatively fewer decarbonisation options and often have slower fleet turnovers:** For the transport modes with the highest demand growth rates (road freight transport, aviation and shipping), there is currently a comparative lack of alternative energy carriers, which have the potential to be decarbonised, that can be used to reduce their GHG emissions. Additionally, the lifetimes of these vehicles tend to be longer (up to 40 years), and hence the turnover of the respective fleets takes longer, which means that it is unlikely that the full penetration of less GHG intensive technologies could be achieved for these modes by 2050.
- **There are uncertainties and risks associated with the principal alternative fuels and energy carriers:** While the means of decarbonising transport's energy supply have the potential to be virtually carbon-neutral by 2050, it is not certain that these potentials will be realised. There are a number of risks and uncertainties associated with these alternative energy carriers, such as:
  - At present, low GHG intensity electricity and biomass are scarce goods and these are likely to remain so for the foreseeable future, so their supply will remain constrained in the short-term. In the longer-term, given the likely demands for such electricity and biomass from other sectors, which are also

trying to reduce their GHG emissions, it is likely that the transport sector will continue to face competition for these fuels/energy carriers.

- The development of increased demand for electricity in the transport sector, from different types of electric vehicle and fuel cell vehicles, will put an extra burden on the electricity sector.
- The use of biofuels has a number of challenges, including ensuring that biofuels deliver GHG emissions reductions when measured over the lifecycle of the fuel (its WTW GHG emissions), after the effect of direct and indirect land use changes have been taken into account. Land use and water constraints also have the potential to limit the development of biomass from conventional sources. A large demand for biomass from transport could be incompatible with feeding the growing population of the planet, particularly with the anticipated increase in meat consumption, which is more land-intensive.

The reasons why a wide range of complementary policy instruments are needed include:

- **A wide range of policy instruments are needed to stimulate the uptake of the necessary options:** In the scenario that delivers the most ambitious GHG reductions, a wide range of policy instruments were applied. Regulation was used to stimulate the development of low carbon fuels and energy carriers and to improve the energy efficiency of new vehicles and economic instruments were used *inter alia* to internalise selected external costs. In addition to these instruments, measures were introduced to stimulate cycling, walking and public transport in urban areas, to stimulate freight co-modality, to enforce and reduce speed limits, to improve spatial planning and to improve driving behaviour. Together, all of these instruments delivered nearly a 90% reduction in GHG emissions from transport. Many of the assumptions were reasonably ambitious, so if they did not deliver, then additional reductions would need to be delivered by other policy instruments.
- **No single policy instrument addresses the problem of split incentives:** A challenge for policies promoting low carbon transport is the issue of split incentives. This is especially the case with respect to transitional technologies that are characterised by long lead times and that require high investments in (energy) infrastructure. To solve this problem it will be necessary to apply both **push** (supply side) and **pull** (demand side) instruments. Even though economic instruments can in principle be more cost effective, the issue of split incentives makes the effect of economic instruments with respect to promoting transitional options indirect and possibly slow. As such, regulation and economic instruments may not need to be alternatives but can act as complementary elements of an integrated approach to achieving virtually carbon-neutral mobility. Consequently the theoretical discussion about regulation versus economic instruments should not slow down the process of innovation and transition.
- **The need to foster the co-evolution of the transport and energy systems:** A future policy framework for low GHG mobility will need to foster the co-evolution of the transport and energy systems. The production of appropriate low GHG energy is needed to match the growth in energy efficient vehicles that require it. Possible synergies should be harvested, for example in the longer term related to the role of electric vehicles in facilitating large scale uptake of intermittent renewable energy sources (e.g. wind and solar).
- **Action is needed at a range of administrative levels:** As is evident from the policy instruments considered in the most ambitious scenario, a range of administrative levels will need to be involved in developing and implementing the necessary policy instruments.

- Complementary policy instruments are needed in order to ensure that **rebound effects do not undermine the GHG reduction potential** of some instruments. For example:
  - The development and use of more energy efficient vehicles will make their use cheaper (by reducing the marginal cost of travel) and thus potentially increase demand and so negate at least some of the potential GHG savings.
  - Maximising co-modality in its own right does not necessarily deliver GHG emissions reduction, as there is a risk that additional travel could be stimulated if the capacity of the network is simply increased or enables faster transport.

In both these example, complementary measures, e.g. road pricing, could be applied to reduce, or preferably eliminate, any rebound effects.

In summary, the packages of complementary policy instruments need to:

- Over time effectively stimulate the transition towards virtually carbon-neutral vehicles and energy carriers;
- Combine demand and supply oriented instruments to take care of split incentives problems and address potential rebound effects;
- Stimulate innovation and early market formation in the short to medium term; and
- Create a level playing field and stable market for potentially carbon-neutral options in the longer term.

In developing and implementing particular policy instruments, attention needs to be given to:

- **The importance of a strategic approach:** The ultimate, economy-wide GHG reduction target is important in determining the options that need to be taken up and, therefore, the policy instruments that need to be applied. The larger the reduction that is required, the wider range of options that need to be taken up, thus requiring a broader range of policy instruments. In this project, we have assumed that GHG reductions of the order called for by the European Council of December 2009 will be required. If different levels of GHG reduction are required, the options to achieve this and the policy instruments required could be different.
- **The importance of appropriate metrics:** Most regulatory and economic instruments require the development of appropriate metrics for defining the GHG emissions of vehicles or activities. In this respect, it is important to take account of the relationship between TTW and WTW emissions of vehicles, the WTW emissions of energy carriers and the relationship between the metric and real world impacts. This is important, both from the perspective of transparency, i.e. that it is clear what savings vehicle users can expect to receive from using more efficient vehicles, and to enable the GHG savings from the introduction of associated policy instruments to be assessed (and anticipated) more accurately.
- **The importance of co-benefits:** While the focus of this report, and the project on which it is based, was on reducing transport's GHG emissions, it is important to remember that many transport policies are implemented for reasons other than reducing transport's GHG emissions, e.g. easing congestion, reducing air pollution or providing accessibility. All of these are important in the consideration of the most appropriate policy to reduce transport's GHG emissions. Where there are co-benefits from such policies, i.e. policies reduce transport's GHG emissions as well as delivering other benefits, the latter need to be taken into account, and quantified where possible, in the development and design of policies, including any complementary policies that are needed.
- **The problematic issue of costs:** In the implementation of any policy instrument, it is important to consider the costs associated with uptake of the options that the policy

instruments are expected to stimulate. It is often argued that the most cost effective measures should be implemented first. While, GHG abatement costs and Marginal Abatement Cost curves are a useful tool for comparing options, and for identifying these least cost solutions, these are too narrow a metric to dominate the discussion for a number of reasons, including<sup>55</sup>:

- For technologies, such as vehicles that use the potential alternative energy carriers (e.g. electricity and hydrogen), that require a transition rather incremental change, the stimulation of the least cost options might not be appropriate. Such technologies need to benefit from instruments that form an early market in order to stimulate investment and push the options down the learning curve, i.e. reducing their costs and stimulating innovation, so that they are available at mature costs when necessary.
- Particularly in the transport sector, the cost effectiveness of an abatement measure can be very different when assessed from the perspective of the end user or that of society as a whole.
- The choices made with respect to the cost assumptions can have a major impact on the estimates of direct expenditures, which are crucial to the estimation of cost-effectiveness.
- Most assessments of cost-effectiveness for environmental measures are calculated on the basis of direct expenditures. It is increasingly being argued that a comprehensive welfare-economic analysis would be more appropriate.
- The inclusion of co-benefits, such as the benefits to congestion, air pollution and energy security from various policies, is also important when comparing the costs associated with the implementation of policies, so a simple focus on the cost per tonne of GHG avoided can be misleading when comparing policy options.
- **The fact that transport is not an isolated sector:** Transport is a derived demand, so policies and other developments in other sectors have the potential to increase or decrease the amount of travel that is undertaken, and thus the level of GHG emissions that are emitted from the transport sector. This implies that action will also need to be taken in other sectors to minimise the demand for travel, which would contribute to lowering the overall cost of GHG reduction to society. In this respect, it will also be important to consider wider drivers of transport demand, such as globalisation, tourism and the growth of personal incomes, and identify how these can be decoupled from the growth in the demand from transport. In this respect, the consideration of the implications of alternative development paths and green GDP for transport might be relevant.

**Early action is needed** to introduce a set of complementary policy instruments as soon as possible. Important actions at the EU level include:

- **The need to regulate the energy efficiency of vehicles:** The advantage of regulation is that it targets parties that need to invest (manufacturers) and that it creates a level playing field for these parties. On the other hand, a CO<sub>2</sub> charge requires harmonisation at EU level, while a cap & trade system risks becoming complex for road transport and is likely to have a limited impact in the short to medium term. The need for regulation is unlikely to go away but with increases in GHG prices and the increasing complexity of reduction options, it may be useful to supplement it with more generic economic instruments. Standards for all vehicles for all modes should be developed, in cooperation with international bodies such as IMO and ICAO where appropriate and possible. Once in place, such standards should be progressively tightened and developed in parallel with the equivalent policy targeting

<sup>55</sup> See Appendix 14 *Methodological issues related to assessing cost effectiveness of climate change abatement options* for a further discussion of this issue; also see <http://www.eutransportghg2050.eu/cms/additional-reports/>

the GHG intensity of fuels and energy carriers. This could mirror the approach previously taken for conventional pollutants, in which emission limit values for road transport vehicles were developed in parallel with fuel quality standards in order to ensure that these were consistent and coherent and provided complementary policy messages.

- **The need to regulate the greenhouse gas intensity of fuels and energy carriers:** The current legislation that aims to reduce the greenhouse gas intensity of transport fuels and energy carriers is important to ensure that developments in the energy supply and transport sectors develop in parallel. As with energy efficiency standards for vehicles, the standards for the GHG intensity of fuels and energy carriers should be progressively tightened and developed in parallel to the vehicle efficiency standards.
- **The need for standards and criteria to ensure that alternative fuels and energy carriers deliver GHG emissions and do not have other adverse sustainability impacts:** The Commission has developed sustainability criteria with respect to biofuels in an attempt to ensure that these deliver GHG emissions reductions when measured over the full lifecycle of the fuel and that the adverse environmental consequences of the production of biomass are limited. When the development of biofuels as a transport fuel was first proposed, the scale of these issues was not foreseen. Potentially similar situations with other alternative fuels and energy carriers, e.g. any implications of a significant increase in the use of the various rare metals used in electric vehicles, need to be avoided by the early assessment of the potential for similar concerns and early action on relevant criteria if any concerns are identified.
- **Internalise the external costs of transport for all modes:** The inclusion of a CO<sub>2</sub> charge in fuel taxation for all modes, along with the internalisation of other external costs through kilometre charging, should be included in the prices that users face, in order to ensure that these costs are reflected in transport prices.
- **Harmonisation of pricing policies for transport:** A harmonised EU pricing policy, that enables and coordinates kilometre charging and congestion charging, particularly for all road modes, is important. At a later stage an EU-wide carbon tax or emissions trading scheme for transport may be appropriate.
- **The elimination of existing hidden subsidies and perverse incentives:** The removal of hidden subsidies, such as the way in which some countries tax company cars and the fiscal treatment of commuting and business travel, is also important in reducing transport's GHG emissions.
- **Support for innovation and the development of new technology:** Existing EU funds should be used to support the development of low carbon technologies, both with respect to vehicles, but also potential low carbon fuels and energy carriers. Such support needs to be targeted and time-limited so that it does not become a subsidy for commercially-viable technologies.
- **Review of EU policy towards the development of transport networks:** A coherent approach is needed between relevant EU policies, particularly a coherent policy regarding the trans-European Transport Networks, Cohesion Policy and Structural Funds, in order to ensure that climate mitigation is mainstreamed in relevant policies, particularly those that develop the transport system.
- **Development of evaluation tools to reflect better GHG emissions:** In particular, improved weights should be given to GHG emissions in EIA, SEA and CBA procedures, some of which could be required by amendments to existing EU legislation.

There are some important policies that are usually considered to be the competence of Member States or regional and local authorities. The Commission should work with Member

States and regional authorities to achieve coordinated action and share good practice with respect to:

- **Harmonising and lowering speed limits.**
- **Optimal spatial planning policies for GHG reduction in transport.**
- **Setting the framework for the differentiation of vehicle taxes (purchase, registration and circulation) by CO<sub>2</sub> emissions.**
- **Develop new business models for transport.**

## 7.2 Recommendations for further work

As a result of the discussion above, it is clear that there is a need for additional work on reducing transport's GHG emissions up to 2050, including work to obtain a better understanding of:

- **Co-benefits.** Co-benefits have been included in the project's analysis at a relatively high level. However, as noted above these are important, particularly with respect to the further economic, social and environmental justification of policies to reduce transport's GHG emissions.
- **How best to assess the cost effectiveness of policies to reduce transport's GHG emissions.** As noted above, there are already concerns that existing approaches to assessing cost-effectiveness are not sufficient for the transport sector. Additionally, there are problems associated with attempting to identify relevant costs so far into the future, e.g. up to 2050, as the longer into the future one is looking, the larger the uncertainties that will be associated with any cost estimates.
- **The risks and uncertainties associated with long-term GHG reduction options, and the implications of these for GHG reduction in the transport sector.** As noted above, the most ambitious scenario identified in the project relied reasonably heavily on the ability of alternative fuels and alternative energy carriers to deliver virtually carbon-neutral energy for transport. However, with all of these potential alternatives, there are risks and uncertainties associated with both their respective GHG reduction potentials, as well as their wider sustainability impacts. A greater understanding of these risks and uncertainties would be important in developing future regulation for vehicles and energy carriers.
- **Link between vehicle regulation and fuel regulation.** As noted above, it will be important to develop regulation to improve the energy efficiency of vehicles and regulation to reduce the GHG intensity of transport fuels in parallel, so that these work together in a coherent and consistent manner. Consideration will need to be given regarding the most appropriate means of doing this.
- **The GHG reduction potential of non-technical options.** As noted in the text, there is better knowledge of the GHG reduction potential of technical options than of non-technical options. Efforts need to be made to better understand the potential of non-technical options, as well as what policy instruments are needed, and at what levels these need to be implemented, to ensure that the potential GHG reductions are realised.
- **The appropriate administrative structures and business models.** An issue that was raised in the course of the project, but never investigated in detail was whether the existing administrative structures and business models used in the transport are appropriate to delivering a virtually carbon-neutral transport system. In particular, it was suggested that maximising the potential for co-modality might require more coordinated administrative structures, while maximising the potential for vehicle utilisation, particularly for cars, might require different business models such as those that focus on mobility services.



- **The extent to which transport demand is reaching saturation point.** As was noted, there is a hypothesis that the demand for daily passenger travel in the UK is reaching saturation point. It would be useful to explore this hypothesis in more detail, including whether similar patterns can be discerned for other Member States.
- **The link between transport demand and increasing prosperity.** While it is clear that there are links between current patterns of economic development and transport demand, it is not yet clear whether there are alternative development paths that could be less transport intensive, but still deliver increasing levels of prosperity. It is important to explore in more detail recent developments with respect to alternative, potentially more sustainable and less carbon-intensive, development paths, including those concerned with the development of alternative macro-economic indicators, such as green GDP, in order to identify what these might mean for future levels of transport demand.

## Appendix 1: List of other Appendices

A full list of the full references for all of the papers and reports produced in this project, along with the respective Appendix in which the document can be found, is given in Table 6. All of the papers and reports can be found on the project's website ([www.eutransportghg2050.eu](http://www.eutransportghg2050.eu)).

**Table 6: List of papers and reports produced within the project**

Full reference	Appendix Number
Jozwicka, M. and Pulles, T. (2009) <i>Identifying transport's potential contributions to future GHG reduction</i>	2
Sessa, C. and Enei, R. (2009) <i>EU transport demand: Trends and drivers</i>	3
Sharpe, R. (2009) <i>Technical options for fossil fuel based road transport</i>	4
Hill, N.; Hazeldine, T.; Pridmore, A.; von Einem, J. and Wynn, D. (2009) <i>Alternative Energy Carriers and Powertrains to Reduce GHG from Transport</i>	5
Hazeldine, T.; Pridmore, A.; Nelissen, D. and Hulsotte, J. (2009) <i>Technical Options to reduce GHG for non-Road Transport Modes</i>	6
Kampman, B.; Rijkee, X.; Pridmore, A. and Hulsotte, J. (2009) <i>Operational options for all modes</i>	7
van Essen, H.; Rijkee, X.; Verbraak, G.; Quak, H. and Wilmink, I. (2009) <i>Modal split and decoupling options</i>	8
Smokers, R.; van Essen, H.; Kampman, B.; den Boer, E. and Sharpe, R. <i>Regulation for vehicles and energy carriers</i>	9
van Essen, H.; Blom, M.; Nelissen, D. And Kampman, B. (2010) <i>Economic Instruments</i>	10
Kampman, B.; van Rooijen, T.; Tavasszy, L.; van Essen, H. and Wilmink, I. (2009) <i>Infrastructure and spatial policy, speed and traffic management</i>	11
Brannigan, C.; Hazeldine, T.; Schofield, D.; Halsey, S. and von Einem, J. (2009) <i>Information to raise awareness and instruments to stimulate innovation and development</i>	12
Kollamthodi, S. and Haydock, H. (2010) <i>Energy security and the transport sector</i>	13
Davidson, M. and van Essen, H. (2009) <i>Methodological issues related to assessing cost effectiveness of climate change abatement options</i>	14
Enei, R. and Verbraak, G. (2009) <i>Structural changes in other sectors and their impacts on transport</i>	15
Pridmore, P.; Wynn, D.; Hazeldine, T. and Milnes, R. (2010) <i>An overview of the factors that limit new technology and concepts in the transport sector</i>	16
Xander, A. and van Essen, H. <i>Review of projections and scenarios for transport in 2050</i>	17
Wynn, D. and Hill, N. <i>Review of potential radical future transport technologies and concepts</i>	18
Hill, N.; Morris, M. and Skinner, I. <i>SULTAN: Development of an Illustrative Scenarios Tool for Assessing Potential Impacts of Measures on EU Transport GHG</i>	19
Skinner, I. and Hill, N. <i>Project methodology</i>	20



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