EU Transport GHG: Routes to 2050 II

Identification of the major risks/uncertainties associated with the achievability of considered policies and measures

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TNO innovation for life

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Executive Summary

Objectives:

The purpose of this Task is to:

- Explore and identify key risks and uncertainties associated with the achievability of relevant policies and instruments, including lead times for policy implementation and time lags to the resulting impact on emissions
- Assess the extent to which key factors outside the transport sector will affect decarbonisation of transport
- Develop approaches to address those risks and uncertainties and optimize achievability

Objective of discussion at Focus Group Meeting

⇒ Challenge the analysis

⇒ Identify possible gaps, especially regarding the key risks & uncertainties that have been identified as potentially eroding the intended impact of the policy instruments

⇒ Discuss the implications of those risks, as well as the identified mitigation strategies which are considered to be relevant for the development of policy instruments

Task 5 looked at the risks and uncertainties associated with three types of policy instruments for reduction of GHG from transport (biofuels, electricity and hydrogen, economic instruments). The main objective was to assess how these risks may adversely impact the desired result from the considered policy instruments, as well as develop recommendations to avoid, manage and mitigate the consequences of the risks.

In general it was concluded that at least some of these risks and uncertainties can significantly reduce or otherwise hinder the desired impact of the considered policy instruments. It is therefore recommended that the recommendations which were developed in this paper are taken into account for policy development, monitoring and evaluation, and posterior assessment.

Main Findings regarding Biofuels:

⇒ There are still risks and uncertainties related to the four conditions that need to be met if the full potential of GHG reduction with biofuels is to be realised – the availability of biofuels, their sustainability and actual GHG reduction, their technical compatibility and public support.

⇒ In the coming years, the strategies should focus on effective implementation and improvement of the biofuels sustainability criteria. In addition, research into new (so-called 2nd generation) biofuels production processes should be promoted, to ensure a diverse biomass use in the future that does not compete with the food sector nor lead to significant negative impacts from land use change.

⇒ In the longer term, risks can be managed by setting the right biofuels targets, policies and (sustainability) boundary conditions. This should lead to a biofuels supply that is sustainable and diverse, leads to reasonable cost, and is compatible with the vehicles and engines use in the various transport modes.

⇒ In parallel, efforts should also be put into global initiatives that can reduce land use change and biodiversity loss due to biomass cultivation for biofuels, for example within the IPCC and CBD framework.

Main Findings regarding Electricity and Hydrogen in transport:

⇒ The implementation of electricity and hydrogen as GHG reduction options for the transport sector is a transition that involves drastic and structural changes in both the transport and the energy sector and that will take several decades to start up, roll out and complete.

⇒ Governments and stakeholders in the market need endurance and a long term vision to manage this transition in an effective way. Mitigating risks and taking away uncertainties is an important and unavoidable part of that.

⇒ Proactive steps are required in the short term in laying the ground work for longer term policy instruments, in early market formation and in setting up and managing a process that timely delivers the insights that are necessary to develop a suitable dominant design for the energy distribution infrastructure

Main Findings regarding Economic instruments, particularly usage pricing:

⇒ If road usage charging is to be introduced, it should take place in addition to, rather than instead of, fuel taxation.

⇒ Many of the associated risks are linked, and some often mentioned issues (*e.g.* public acceptability and wider political risks) can be seen in the context of a family of economic, social and environmental risks that were identified.

⇒ Many of the latter are real, and could be addressed either in the design of the charging scheme, or by the introduction of complementary policy instruments (which could even be introduced in advance of the charging scheme itself).

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Glossary[1]

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 **EV**.
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_2**.
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_2.
CNG	Compressed Natural Gas. **Natural gas** can be compressed for use as a transport fuel (typically at 200bar pressure).
CO_2	Carbon dioxide, the principal **GHG** emitted by transport.
CO_2e	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_2**. When the total of a range of GHGs is presented, this is done in terms of CO_2 equivalent or CO_2e.
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 **CO_2**.
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.

[1] Terms highlighted in bold have a separate entry.

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. **Natural gas** can be liquefied for use as a transport fuel.
LPG	Liquefied Petroleum Gas. A gaseous fuel, which is used in liquefied form as a transport fuel.
$MtCO_2e$	Million tonnes of **CO_2e**.
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_x	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 **GHG emissions** 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 **HEV**, but smaller than that in an **EV**.
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 **options** for reducing transport's **GHG emissions.**
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 **lifecycle emissions**.

1 Introduction

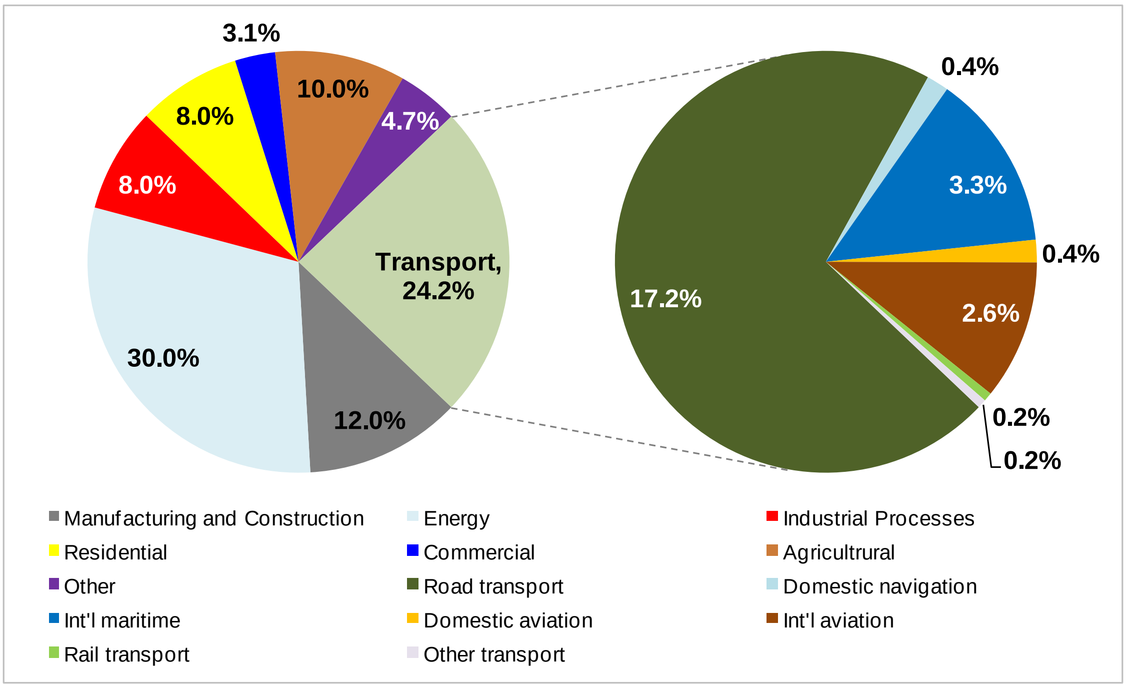
1.1 Topic of this paper

This paper is one of a series of reports drafted under the *EU Transport GHG: Routes to 2050 II* project. This paper focuses on ***risks and uncertainties associated with the achievability of considered policies and measures***.

1.2 The contribution of transport to GHG emissions

Transport is responsible for around a quarter of EU greenhouse gas emissions making it the second biggest greenhouse gas emitting sector after energy (see figure below). Road transport accounts for more than two-thirds of EU transport-related greenhouse gas emissions and over one-fifth of the EU's total emissions of carbon dioxide (CO_2), the main greenhouse gas. However, there are also significant emissions from the aviation and maritime sectors and these sectors are experiencing the fastest growth in emissions, meaning that policies to reduce greenhouse gas emissions are required for a range of transport modes[2].

Figure 1.1: EU27 greenhouse gas emissions by sector and mode of transport, 2007



Source: EC DG Energy (2010)[3]

Notes: International aviation and maritime shipping only include emissions from bunker fuels

While greenhouse gas emissions from other sectors are generally falling, decreasing 15% between 1990 and 2007, those from transport have increased by 36% in the same period. This increase has happened despite improved vehicle efficiency because the amount of personal and freight transport has increased.

[2] EC DG Climate Action (2010): http://ec.europa.eu/clima/policies/transport/index_en.htm
[3] Based on historic data from DG Energy (2010) *EU energy and transport in figures Statistical Pocketbook 2010* Luxembourg, Publications Office of the European Union, 2010. Publication and data available for download at: http://ec.europa.eu/energy/publications/statistics/statistics_en.htm

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."*[4]

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*[5] 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[6], 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.

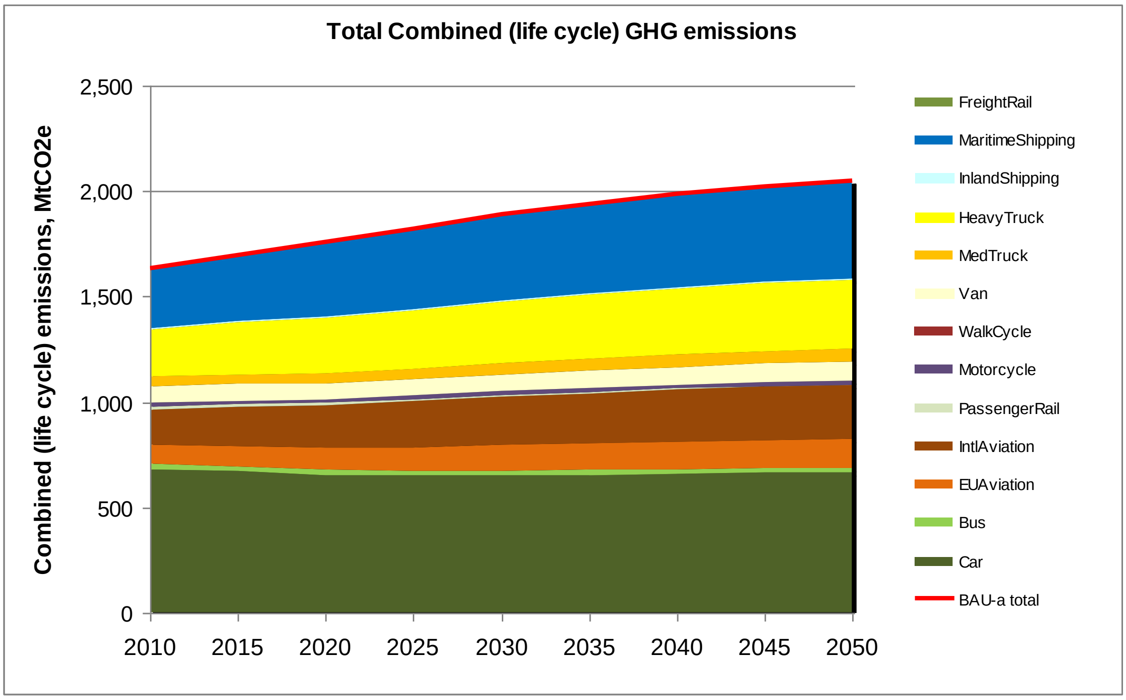
These high level political statements set the framework within which the original *EU Transport GHG: Routes to 2050* project was undertaken. One of the main aims of this project was to provide information and analysis to assist the Commission with its early thinking on a co-ordinated approach to reducing the GHG emissions of all modes of transport.

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. As mentioned earlier, since 1990, GHG emissions from transport, of which 98% are carbon dioxide (CO_2), had the highest increase in percentage terms of all energy related sectors[7]. Furthermore, transport's GHG emissions are predicted to continue to increase, without additional measures, to over 2,000 $MtCO_2e$ by 2050. This increase is shown in the next figure, with a split by mode of transport. The figure is an output from an Excel-based illustrative scenarios tool (IST) called SULTAN (**SU**stainab**L**e **T**r**AN**sport), which was developed under the previous project in order to identify the GHG reductions that transport could potentially deliver by 2050.

An increase of the order projected in the next figure would leave transport's GHG emissions 74% higher in 2050 than they were in 1990 (when the sector's emissions were nearly 1,200 $MtCO_2e$) and around 25% above 2010 levels. Significant emissions 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 declined slightly from 2010 levels, as anticipated improvements in the energy efficiency of vehicles negate projected increases in demand.

4 *Presidency Conclusions*, Brussels European Council, 29/30 October 2009; see http://register.consilium.europa.eu/pdf/en/09/st15/st15265.en09.pdf
5 Barroso, J (2009) *Political Guidelines for the next Commission,* September 2009, Brussels
6 European Commission (2010) *Europe 2020: A strategy for smart, sustainable and inclusive growth* COM(2010)2020, Brussels 3.3.2020.
7 DG TREN (2000) *Energy and transport in figures 2008-2009*

Figure 1.2: Business as usual projected growth in transport's GHG emissions by mode



Source: SULTAN Illustrative Scenarios Tool, developed for the EU Transport GHG: Routes to 2050 project

Notes: International aviation and maritime shipping include estimates for the full emissions resulting from journeys to EU countries, rather than current international reporting which only include emissions from bunker fuels supplied at a country level (which are lower).

The figure above 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[8]. 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.

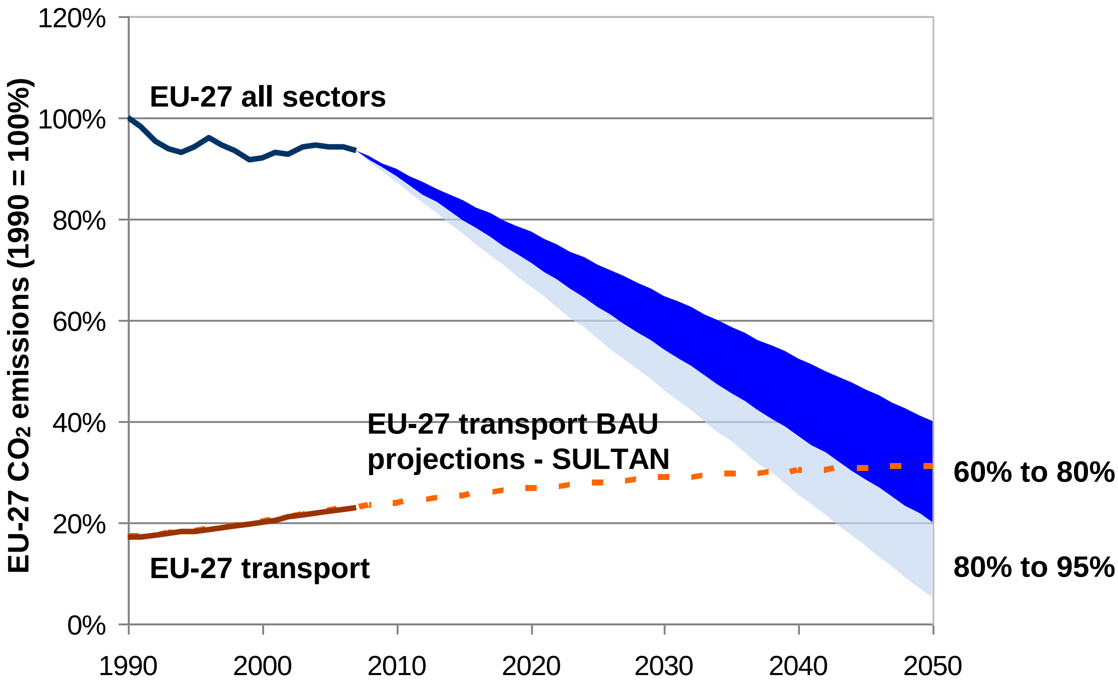
Figure 1.3 demonstrates that on current trends, transport emissions could be around 30% of economy-wide 1990 GHG emissions by 2050[9]. Whilst simplistic, in that it assumes linear reductions, the figure demonstrates that there is clearly a need for additional policy instruments to stimulate the take up of technical and 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[10].

[8] 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

[9] 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.

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

Figure 1.3: EU overall emissions trajectories against transport emissions (indexed)



Source: EC DG Energy (2010) and SULTAN Illustrative Scenarios Tool[11]

1.3 Background to the project and its objectives

EU Transport GHG: Routes to 2050 II is a 15-month project funded by the European Commission's DG Climate Action and started in January 2011. The context of the project is still the Commission's long-term objective for tackling climate change. The scope of the first project was very ambitious, and the outputs from the study were very detailed and have already proved to be of great value to the European Commission and to industry, governmental and NGO stakeholders. However, there were a number of topic areas where it was not possible within the time and resources available for the study team to carry out completely comprehensive research and analysis. In particular, as the project evolved, both the study team and the Commission Services became aware that there were a number of themes and topic areas that would benefit from further, more detailed research. This new project is a direct follow-on piece of research to the previous *EU Transport GHG: Routes to 2050?* study, building on the research and analysis carried out for that study and complementing other work carried out for the latest Transport White Paper. In particular, the outputs from this new study will help the Commission in prioritising and developing the key future policy measures that will be critical in ensuring that GHG emissions from the transport sector can be reduced significantly in future years.

Therefore, the key objectives of the *EU Transport GHG: Routes to 2050 II* are defined as to build on the work carried out in the previous project to:

- Develop an enhanced understanding of the wider potential impacts of transport GHG reduction policies, as well as their possible significance in a critical path to GHG reductions to 2050.

[11] Projections based on data from the SULTAN Illustrative Scenarios Tool (BAU-a scenario) and historic data from DG Energy (2010) *EU energy and transport in figures Statistical Pocketbook 2010* Luxembourg, Publications Office of the European Union, 2010.

- Further develop the SULTAN illustrative scenarios tool to enhance its usefulness as a policy scoping tool and carry out further scenario analysis in support of the new project;
- Use the new information in the evaluation of a series of alternative pathways to transport GHG reduction for 2050, in the context of the 50-70% reduction target for transport from the European Commission's Roadmap for moving to a competitive low carbon economy in 2050[12];

As before, given the timescales being considered, the project will take a quantitative approach to the analysis where possible, and a qualitative approach where this is not feasible. The project has been structured against a number of tasks, which are as follows:

- **Task 1:** Development of a better understanding of the scale of co-benefits associated with transport sector GHG reduction policies;
- **Task 2:** The role of GHG emissions from infrastructure construction, vehicle manufacturing, and ELVs in overall transport sector emissions;
- **Task 3:** Exploration of the knock-on consequences of relevant potential policies;
- **Task 4:** Exploration of the potential for less transport-intensive paths to societal goals;
- **Task 5:** Identification of the major risks/uncertainties associated with the achievability of the policies and measures considered in the illustrative scenarios;
- **Task 6:** Further development of the SULTAN tool and illustrative scenarios;
- **Task 7:** Exploration of the interaction between the policies that can be put in place prior to 2020 and those achievable later in the time period;
- **Task 8:** Development of a better understanding of the cost effectiveness of different policies and policy packages;
- **Task 9:** Stakeholder engagement: organisation of technical level meetings for experts and stakeholders;
- **Task 10:** Hosting the existing project website and its content;
- **Task 11:** Ad-hoc work requests to cover work beyond that covered in the rest of the work plan.

As in the previous project, stakeholder engagement is an important element of the project. The following meetings are being scheduled:

- A large stakeholder meeting currently planned for June 2011 at which the new project will be introduced to stakeholders and interim results presented.
- A series of four Technical Focus Group meetings TBC. These are currently scheduled to be held at the start of May 2011 and in November 2011.
- A second large stakeholder meeting at which the draft final findings of the project will be presented and discussed, anticipated to be held in February 2012.

As part of the project a number of papers will be produced, all of which will be made available on the project's website in draft and then final form, as will all of the presentations from the project's meetings.

[12] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, A Roadmap for moving to a competitive low carbon economy in 2050, COM(2011) 112 final. Available from DG Climate Actions website at:
http://ec.europa.eu/clima/policies/roadmap/index_en.htm

1.4 Background and purpose of the paper

The goals of this paper are to:

- explore and identify key risks and uncertainties associated with the achievability of relevant policies and measures, including lead times for policy implementation and time lags to the resulting impact on emissions;
- assess the extent to which key factors outside the transport sector will affect decarbonisation of transport;
- developing approaches to address those risks and uncertainties and to optimize feasibility of policy instruments and the targets they intend to achieve.

To this end the paper explores risks and uncertainties associated with policies promoting three options for realising sustainability in the time frame up to 2050:

1) Biofuels
2) Electricity and hydrogen in transport
3) Economic instruments, particularly usage pricing, with the potential to directly affect demand for transport

With this paper we aim to understand what are the factors that could cause the instruments discussed not actually leading to the GHG reductions that many are assuming they will. Through understanding such mechanisms one can attempt to reduce those risks, consider how likely they are and see whether different strategies are needed to mitigate the identified risks.
The main potential causes for instruments not leading to the foreseen GHG emission reductions could be:

- It turns out that expected technical progress is not actually achievable;
- Expected technical progress takes longer than anticipated;
- The cost of the innovation or the policy turns out to be excessive;
- There is an unwillingness by users to adopt the innovation;
- It is not politically possible to implement the necessary policies;
- There are unanticipated consequences that reduce the expected GHG benefits;
- Unanticipated events make the measure/policy impossible to implement.

All three selected options can be considered transitions, i.e. structural changes to the transport system. In the case of the first two options, the transition focuses on the technologies used for propelling vehicles and providing energy to these vehicles. In the case of economic instruments structural changes pertain to the fiscal system that is applied to transport. All three transitions, however, involve drastic technical, behavioural and organisational changes.
Transitions are generally characterised by complexity, uncertainty and fragmentation. For that reason transitions, especially those that are intended to serve societal goals, require policies to promote the required changes, to manage the complexity, and to reduce uncertainty and fragmentation.
Concerning the main types of risks and uncertainties some key issues to be assessed in this paper are:

- maximum availability of sustainably produced biofuels and feasible pace for development of production capacity over time;

- overall (well-to-wheel) sustainability of next generation biofuels;
- availability of materials for alternative powertrain and vehicle components;
- development over time of sustainable production capacity for electricity and hydrogen for use in transport;
- uncertainties with respect to technological breakthroughs which are required to improve performance and reduce costs of new technologies;
- cost developments for technology, alternative energy carriers and fossil fuels;
- realistic time paths for scaling up market penetration of vehicles with alternative power trains, taking into account finite rates for fleet renewal and increases in production capacity, as well as factors in the realm of innovation system dynamics and transition theory;
- lead times for development and implementation of policy instruments that affect the demand for transport;
- possibilities to develop a consistent policy package that promotes the appropriate co-evolution of transport system and energy system and that delivers the desired GHG reduction levels;
- user acceptance of new technologies;
- political acceptance for new measures.

2 Elements of a holistic approach to identifying lead times, risks and uncertainties associated with implementing policy instruments and achieving their objectives

Objectives:

- The purpose of this section is to provide elements of a holistic approach to identifying lead times, risks and uncertainties associated with implementing policy instruments and achieving their objectives

Summary of Main Findings

⇒ A

⇒ B

⇒ …

2.1 Different types of risks and uncertainties

In general, risks and uncertainties with respect to the implementation and impact of GHG reduction policies and measures will pertain to the following issues:

- time
- costs / budget
- quality
- acceptance
- impact

Concerning **risks and uncertainties with respect to policies and measures** we discern the following processes:

- Risks and uncertainties related to the process of developing and implementing policy instruments. Risks relate to time and budget needed for development and implementation and the quality (and resulting effectiveness) of the outcome of the process as well as to the political and societal acceptance of new policies;
- Risks and uncertainties related to the societal response to implemented policies. This societal response has several components which each have their own specific risks and uncertainties:
  - **technical responses**, i.e. innovation and implementation of new technologies, which can be divided into **incremental technologies** and **transitional technologies**
  - **behavioural responses**, which can be divided into short term and long term, more structural, behavioural responses

2.1.1 Risks and uncertainties with respect to policy development and implementation

Aspects of risks and uncertainties with respect to policy development and implementation include:

- acceptance of policies by stakeholders, incl. industry, transport sector, NGOs and member states
- time required for developing and implementing policies, including:
  - lead times for policy development and adoption
    - Especially harmonised fiscal policies, requiring unanimous agreement in the Council, may take a long time to realise
  - possibilities for delay tactics by various stakeholders
- time required for developing associated test or assessment procedures or for changing codes and standards
- political compromise leading to flaws, loopholes or other inconsistencies in the developed policy instrument
- imperfect implementation of policies resulting in undesired impacts
- lack of enforcement
- changes in political landscape (e.g. elections leading to new parliaments and new governments / European Commission)
- lack of long term political consistency (e.g. with respect to subsequent tightening of emission standards or lowering emission ceilings under a cap & trade system)

2.1.2 Risks and uncertainties with respect to technical responses

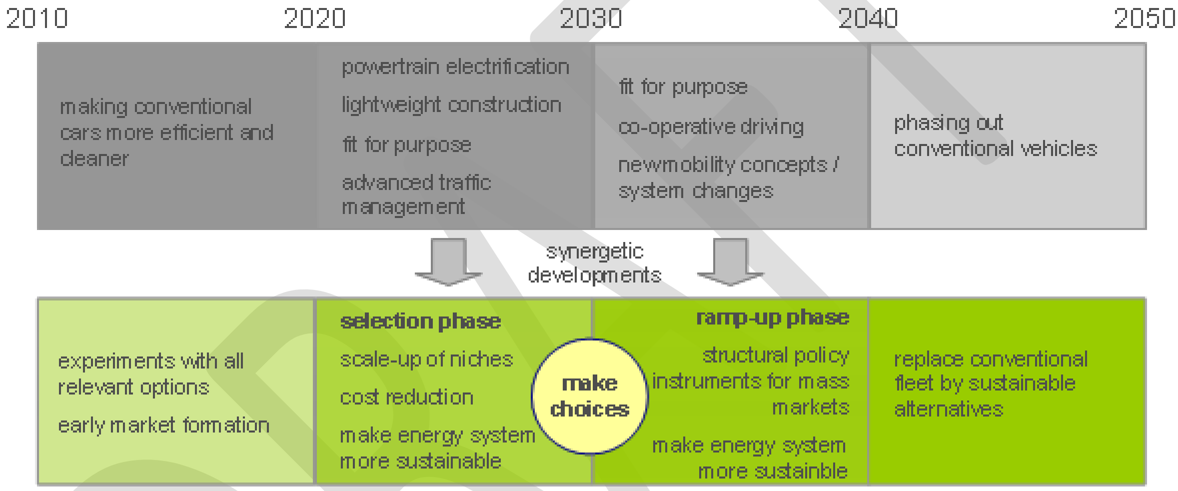
Aspects of risks & uncertainties with respect to societal responses through technology include the following:

- time required for developing technical innovations
- uncertain outcome of R&D activities and product development, incl. compromises with respect to environmental performance
- time required for implementing innovations, including model development cycles, fleet renewal rates (different in different sectors), S-curves for increasing market shares, etc.
- time required for implementing new infrastructures
- acceptance of new technologies by users and other stakeholders
- resistance by vested interests of existing market leaders
- institutional and legal barriers
- the so-called “valley of death” for innovations: how to bridge the gap from early adopters and innovators to early majority?
- dependency on developments in other sectors, specifically the energy sector for providing appropriate and sustainably produced energy carriers as well as the associated infrastructure
- lack of investment capital
- uncertainties in cost development of new technologies, incl. the chicken & egg issue that costs only go down seriously when production volumes increase so that market formation is necessary to reduce costs

- development of suitable business models and profitable business cases, and time required for setting up new types of business and services
- uncertainties wrt availability of resources (energy, materials, finance)
- incidents, leading to bad publicity for new technologies
- economic development
- development of energy prices
- magnitude of foreseen and especially unforeseen 2nd order impacts (knock-on consequences, rebound effects)[13]
- further improvements of conventional technologies, reducing the benefits of alternatives
- possible synergetic developments in conventional technology that may also benefit the development of alternatives

The latter is illustrated in the graph below:

Figure 2.1: Synergetic developments in the evolution of conventional and alternative powertrains



In the coming decade various options for sustainable mobility will be put to the test in different niche applications, and will undergo further improvement in performance and costs. Choices should not be made too early. We will need more than one technology to make all transport applications sustainable, and success is not guaranteed for all options.
The risks and uncertainties wrt technical responses apply most prominently to **transitional innovations**, i.e. new technologies causing or requiring structural changes in the transport system and other associated systems (e.g. energy system or ICT). As opposed to **incremental innovations**, which generally represent improvements of existing systems and therefore require little adaptation and will be easily accepted, transitional innovations are generally characterised by higher uncertainties wrt costs and added value and will receive more opposition from both users and stakeholders with vested interests in the existing systems.

2.1.3 Risks & uncertainties with respect to behavioural responses

Aspects of risks & uncertainties with respect to behavioural responses include e.g.:

- actual possibilities for changing behaviour available to actors

[13] See also the Task 3 paper on “Exploration of the likely knock-on consequences of relevant potential policies”

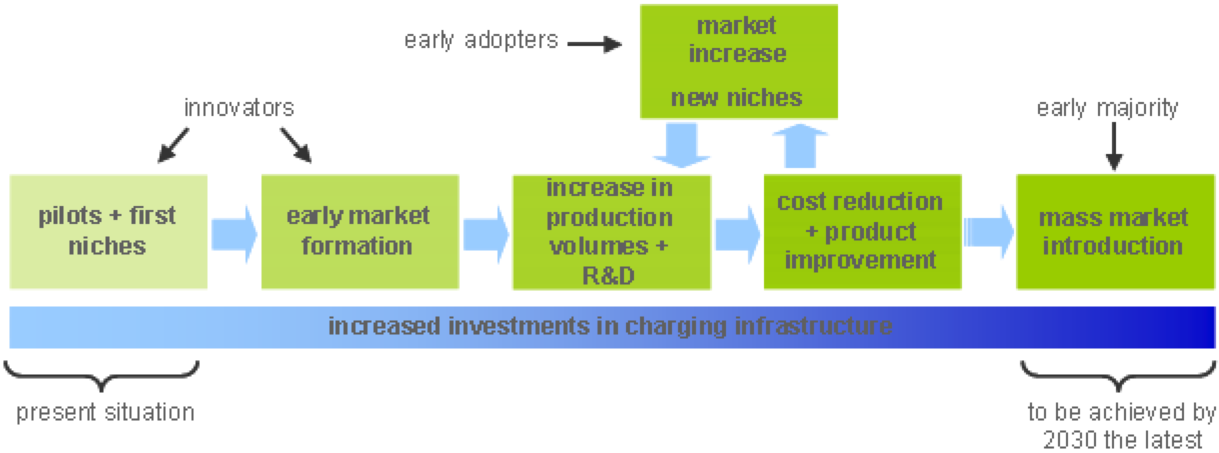
- e.g. the possibility to work from home or opportunities to move closer to the work location in order to reduce commuting distance

- time required for actors to change behaviour
- time required for development of new logistical concepts and new mobility concepts
- time required for structural changes in organisation of society
- cultural aspects
- quality / valuation of attributes of alternatives to original behaviour
- acceptance of welfare impacts
- market trends
- economic situation allowing actors to deal with costs associated with behavioural changes
- interaction with myriad of other factors that determine organisation of society
- lack of enforcement

2.1.4 Added value is the critical driver

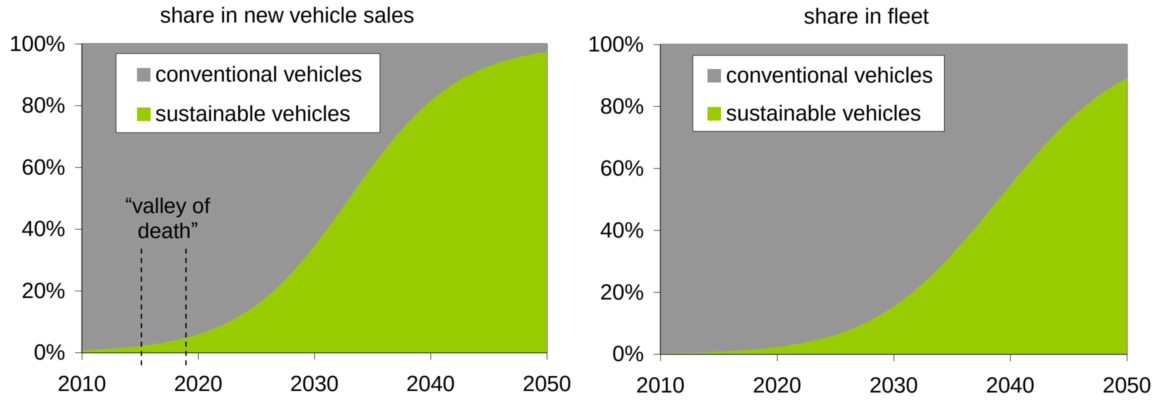
Especially for **transitional technologies**, which involve structural changes in the transport and energy system, many of the above issues are prominent. The lack of (easily recognisable) added value to the user, which characterises many of these innovations (as they serve a societal goal), makes it difficult to create acceptance and to generate investment capital.
Early market formation is necessary to induce the product improvements and cost reductions that are required for successful implementation in mass markets. The pace of product and cost improvements is difficult to predict and will be different for different innovations.

Figure 2.2: Solving the chicken and egg problem of costs and demand



A "valley of death" in the market introduction occurs when after serving the "innovators" and "early adopters" segments in the market the price and characteristics have not yet developed to a level that is considered acceptable by the "early majority" segment of the market.
Regardless of the incremental or transitional nature of the sustainable mobility innovations, it is clear that we are mainly looking at sustainable products and services that replace existing products and services. The pace of introduction in a replacement market is generally limited by fleet renewal rates, which in turn depend on vehicle lifetime and overall fleet growth. The development of the market share of new products is generally governed by S-curves.

Figure 2.3: Market share of new technologies develops along S-curve: initial scale-up phase may suffer from the "valley of death" when after serving the "innovators" and "early adopters" segments in the market the price and characteristics have not yet developed to a level that is considered acceptable by the " early majority" segment of the market.



In order to reach long term climate change goals by 2050 the lion's share of the fleet must be energy efficient vehicles driving on sustainable (i.e. renewable or low CO_2) energy carriers. The main options for such sustainable vehicles are biofuels in ICEVs, electricity in EVs or plug-in HEVs and hydrogen in FCEV. In order to reach the desired fleet penetration the share of sustainable vehicles needs to be ramped up from 2030 onwards. Between now and 2030 the main steps to be taken are:

- Experimenting with different options
- Bringing options to technical and economical maturity
  - meeting user needs
  - cost reduction
- Create a context in which scale-up can take place:
  - structural policy instruments
  - infrastructure

Market introduction of sustainable vehicles needs to start now to achieve 80 to 100% share in the fleet by 2050. Early market formation will trigger investments in R&D and in production capacity, and will this lead to product improvement and cost reduction. When costs have gone down sufficiently and the product has been further developed to meet user needs, mass market introduction will take off.

To overcome the "valley of death" the following are necessary:

- robust stimulation policies
- determined investors and early users (innovators and early adopters) with stamina / endurance to create, maintain and scale up early markets
- profitable niche applications

2.1.5 Transition management required to manage risks and uncertainties

A major purpose of transition management relates to the **avoidance, reduction, mitigation, and management of risks**. This involves the following aspects:

- risk avoidance though proper design of the policy framework, e.g.:
  - designing policy instruments to have intrinsic certainty of meeting the target

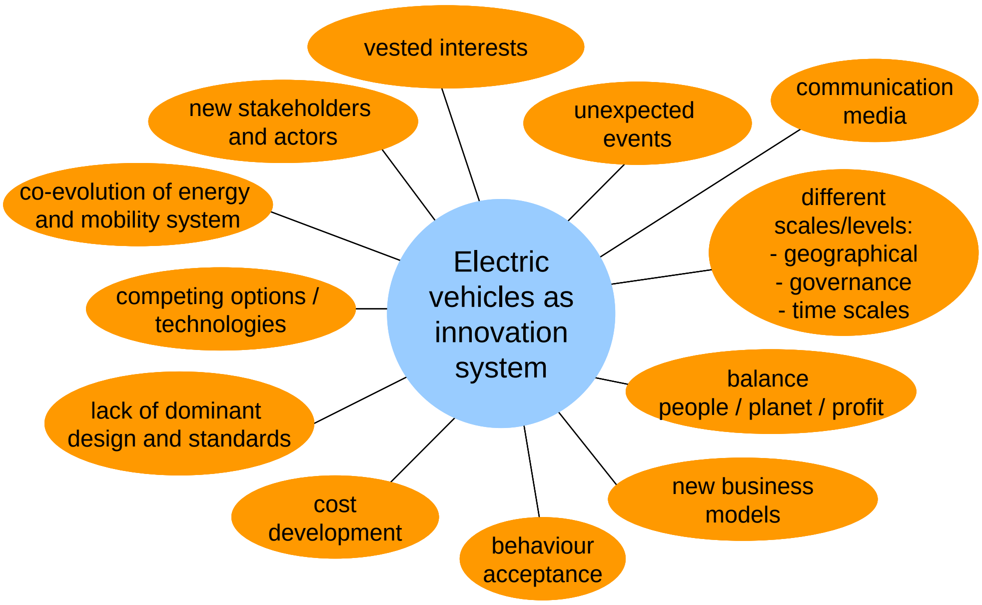
  - o appropriate combination of specific and generic policy instruments
  - o include flanking policies to remove barriers (e.g. market failures) hindering response to main policy instruments
  - o redundancy in (number and potential of) technical and behavioural responses promoted by policy instruments
    - i.e. "bet on more than one horse" to be available for meeting the target
- management of the policy making process, specifically with respect to stakeholder involvement
- monitoring of responses to implemented policies to assess effectiveness and possible barriers hindering the desired societal response
- creating room to adjust policies on the basis of observed responses
- management of the transition process on the basis of insight in innovation systems and system innovations

2.2 Innovation system theory provides tools for the management of risks and uncertainties

2.2.1 The nature of transitions

As an example of the above the graph below indicates some of the different forces and aspects that influence the implementation of in this case electric vehicles. Innovation system theory deals with the dynamics of these interactions and can be used to identify levers by which governments and other stakeholders can stimulate the development and especially implementation of innovative technologies and services.

Figure 2.4: Forces and other aspects that influence the implementation of system innovations, in this case electric vehicles



Transition processes are generally characterised by:

- Complexity:
  - o different time scales for technological development

  - unpredictable behaviour of users
  - competing alternative technologies incl. improvements in the existing conventional technology that may be spurred by the advent of alternatives
  - interdependence with other domains, e.g. within the mobility system or with the energy system
  - resistance from stakeholders with vested interests
  - unpredictable impacts on government income
  - open markets => impact of policies and developments in other countries / regions
- Uncertainty and change:
  - lack of knowledge or insufficient application of available knowledge
  - development of new insights over time
  - unexpected events
  - development of prices of energy and materials
  - policy development and longevity of existing policies, political changes
  - social acceptance of new technology
- Fragmentation:
  - insufficient governance and coordination
  - (potential) players remaining outside of the process (e.g. as they are not recognised or accepted by existing stakeholders, or themselves are not aware of there potential contribution to the transition)
  - parallel technological development paths that could strengthen each other but are not organised to do so

2.2.2 Functions of the innovation system

Innovation System Analysis (ISA) theory[14] discerns 7 functions of the innovation system that need to be fulfilled for a transition to be successful:

1. Entrepreneurial activities, e.g. actors setting up innovative projects to exploit (commercial) opportunities
2. Knowledge development: research and development create variations and are thus an important prerequisite for innovation.
3. Knowledge dispersion / dissemination: the typical structure of an innovation system is that of a network. This network facilitates exchange of knowledge.
4. Guidance / direction in the search process: This system function provides the selective pressure that is necessary to make innovations develop in a desired direction.
5. Market formation: At the start of an innovation market demand for the new technology is generally limited or non-existent. Creating "artificial" market conditions is usually necessary to generate the first demand.
6. Mobilising means and capacities: to enable all developments and changes Financial, material and human 'resources' need to be mobilised.
7. Lobby: support from interest groups. Introduction of new technologies usually leads to resistance from vested interest. New actors need to organise themselves in order to combat this resistance.

[14] Suurs, R.A.A. Motors of Sustainable Innnovation, 2009

Creating synergy between these innovation functions can strongly enhance the dynamics of the innovation process. Analysis of these innovation functions for specific transitions can help in the design of effective policy instruments for promoting the desired transitions, in particular options for managing risks and uncertainties.

2.2.3 Managing different phases in the transition

In transitions three phases can be discerned:

- Pre-development → Experimentation phase
- Take-off → Pre-implementation phase
- Acceleration → Implementation phase

2.2.4 Government roles in the transition

Based on the 7 functions of the innovation system, specific government roles will be identified for managing the transition.

3 Exploration and selection of the main risks and uncertainties to be analysed for the three selected policies and instruments

Objectives:

- The purpose of this section is to explore and identify key risks and uncertainties associated with the achievability of relevant policies and instruments
  - Biofuels
  - Electricity and hydrogen in transport
  - Economic instruments, particularly usage pricing

3.1 Selection of policies and instruments

In close consultation with the European Commission the following policies and instruments have been selected for an in-depth assessment of risks and uncertainties:

1) Biofuels
2) Electricity and hydrogen in transport"
3) Economic instruments, particularly usage pricing, with the potential to directly affect demand for transport

The reasons for selecting these policies and instruments are the following:

- All three of these instruments were shown in the previous work to be quite important in terms of the scale of their contribution to overall decarbonisation. They have all also been picked up in the transport White Paper as important measures.
- For biofuels and for electricity and hydrogen in transport one can already see big technical and cost challenges to be overcome. For biofuels the main issue is how to get their GHG performance to the levels required for making significant GHG reductions in the time frame assumed. ILUC is a large question mark for now. For electric vehicles the question is how fast battery costs will decline and their performance will improve.
- The introduction of E10 in Germany has shown that even if costs are not excessive and there is not a technical barrier, consumers may be reluctant to adopt a new measure.
- For economic instruments particularly, the question is whether there will be sufficient political support and popular acceptance to enable these measures to be put in place. If there are undesired consequences of the other two policies will they also continue to enjoy political support? The various recent attempts and discussions on road user charging schemes are an important example.
- The other big policy measure of improving vehicle efficiency (CO_2 legislation) is actually comprised of lots of small innovations and improvements. Even if one bit doesn't work out, there are a lot of others that will. In the case of the policies selected here that is less so. Although for biofuels it can be argued that there are a wide range of different processes under development, land/biomass availability is the main constraint for many.
- For biofuels in particular, expectations are high since in principle they can be deployed in all transport modes and are hoped to deliver a large part of the required savings in aviation, shipping and HDV where there seem less viable alternative options.

3.2 Biofuels

A number of key risks and uncertainties related to the future biofuels availability and application can be identified. They will be listed here, while a more detailed discussion and recommendations regarding how to address those risks can be found in section 4.

- Economic risks and uncertainties
  - A range of uncertainties are related to the cost of biofuels uptake and growth. Biofuels cost may reduce due to future technological developments or economics of scale, but at the same time a number of issues can be identified that may increase biofuels policy cost, such as the following.
  - Increasing cost of biofuels that meet the sustainability criteria, due to
    - limited availability/supply and increasing demand for feedstock that meets the sustainability criteria
    - limited production (biomass conversion) capacity
    - high cost of future biofuels production (in particular related to 2nd generation biofuels production)

    Increase of fuel cost may increase the cost of the transport modes that use biofuels (with potentially wider impacts on economy, modal split and environment).
  - Increase of costs of food and feed commodities, either due to direct competition on the commodity market, due to competition for fertile agricultural land, trade policies etc. Note that these cost increases may also have social impacts (see below).
  - Increasing cost of biomass feedstock for electricity production, chemistry and materials
  - Decreasing cost of fossil fuels will make biofuels more costly
  - Lack of investment in production capacity of biofuels from waste and non-food biomass, and biofuels for aviation.
  - Additional uncertainties:
    - Cost fluctuations due to annual and seasonal changes in agricultural yield
    - Economic and political stability in biomass producing countries
  - Another type of risk are the economic risks that investors face in R&D, biofuel production capacity, biomass production etc.

- Social
  - Risk of negative social impact due to large scale land conversion and biomass plantations, and associated water use
  - Socio-economic impacts of increasing food and agro commodity prices, and higher land prices (these may be both positive, for farmers and producers, and negative, especially for low income groups)
  - Public concerns regarding potential (technical) risks of biofuels use in their vehicles
  - Public concerns about the sustainability of biofuels

- Environmental
  - Less GHG reduction than expected, or even increase of global GHG emissions, in particular due to direct or indirect land use change
  - Negative impacts on biodiversity (on both a global and regional scale), again in particular due to direct or indirect land use change
  - Environmental impacts from use of scarce water resources for irrigation (in some regions)

- Technical
  - Problems with compatibility of biofuels in existing engines (e.g. lack of flex fuel cars in car fleet, or incompatibility of current biofuels with aviation engines and conditions, problems with degradation due to longer storage periods in marine applications, etc)
  - Risk that the biofuels production technologies that can convert non-food biomass feedstock such as waste, woody biomass and algae to biofuels that can be readily used in the current car and airplane fleets are not successfully scaled up and made competitive. This may result in continued dependence on agricultural commodities for a large part of biofuel production and associated environmental, social and economical risks.

- Political
  - Lead times for implementation of (effective) biofuels incentives and sustainability criteria, both on a national and EU level
  - Risk of ineffectiveness of policies (both regarding biofuel volume goals and sustainability)
  - Risks for investors, associated with the dependence of the biofuels market on government policies. If policies are modified, investors will be affected – see the last bullet point under economic risks above
  - Lead times for development and implementation of effective policies that prevent or limit GHG emissions from indirect land use.

3.3 Electricity and hydrogen in transport

Vehicles running on electricity and/or hydrogen are important options for achieving a sustainable transport system in the longer term. Electric vehicles in this context include battery-electric or full-electric vehicles as well as plug-in hybrid and range extender electric vehicles.

In order for electric and hydrogen-fuelled vehicles to contribute significantly and effectively to meeting longer term GHG emission reduction goals the following conditions must be met:

1. Policies must be developed and implemented which promote the installation of the required energy infrastructure and the use of electric and hydrogen-fuelled vehicles;
2. Electric and hydrogen-fuelled vehicles need to reach significant market shares;
3. The environmental impact of the applied electric and hydrogen-fuelled vehicles must be such that it leads to a significant net reduction in GHG emissions.

All three conditions are not automatically met. Risks and uncertainties are associated with the effective realisation of these conditions. These risks and uncertainties may be subdivided into main determining aspects as follows:

1. Policy development and implementation
   - lead time for policy development
   - availability of appropriate test procedures
   - quality of the policy instruments
2. Market development
   - vehicle technology and cost development
   - infrastructure development

   - energy cost development
   - impact of supply and demand oriented policy measures on the business case
   - availability of resources
   - "sustainability" of stakeholder attitudes and interests
3. Net environmental impact
   - timely availability of sufficient renewable energy
   - interaction with the energy system
   - LCA-aspects of vehicle manufacturing and decommissioning

Various aspects include factors outside the transport sector that will affect possibilities for decarbonisation of transport.

In Chapter 5 these various aspects are further decomposed into concrete examples of risks and uncertainties that may be relevant for the implementation of vehicles on electricity and hydrogen.

3.4 Economic instruments, particularly usage pricing

This section will focus on the risks and uncertainties associated with the use of economic instruments that could be put in place to charge users to use roads. (While it is possible to apply user charges of some format to other modes of transport, e.g. see van Essen *et al*, 2010, this paper focuses on roads.) The issue discussed in this section is different to the other two issues assessed in this report, which focus on the risks and uncertainties with respect to technical options for reducing transport's GHG emissions, as it focuses on the risks and uncertainties associated with the implementation of a type of policy instrument. In the final report of the previous project, the risks and uncertainties relating to the use of economic instruments targeting transport demand were identified as an issue (Skinner *et al*, 2011). In this paper, the aim is to explore in more detail what these risks and uncertainties are and, ultimately, how these might be overcome. The current section contains a brief overview of the identified risks and uncertainties, while a deeper exploration, as well as recommendations for their management, can be found in section 6.

A summary of the potential risks and uncertainties associated with the introduction of road user charging as a CO_2 reduction instrument for transport, based on the literature review as well as expert judgement, is given in Table 1.

Table 1: Potential risks and uncertainties associated with road user pricing

Type of risk/uncertainty:	Description of risk/uncertainty
Economic (macro)	• Potential effect on wider economy of applying road user charging • Potential impacts on competitiveness position of (national/EU) economy
Economic (micro) and business acceptability	• Local concerns that passing trade would be affected where user prices increase, e.g. in a particular charging zone • Opposition from local business resulting from concerns over potential economic impact • Delivering overall benefits by balancing benefits with costs associated with implementation and monitoring
Social and public acceptability	• Impacts on personal mobility (and therefore accessibility to economic opportunities and social interactions) in areas where user pricing increases price of use • Potential social impacts from increased traffic levels where charges are not applied due to some traffic avoiding the charging zone or infrastructure • Distributional impacts, e.g. particularly short-term impacts on those on low incomes who have no alternative to using their cars in areas where user prices increases • Opposition from public due to concerns over potential adverse impacts
Environmental	• Some environmental impacts, e.g. air pollution, noise, could increase, e.g. where charges not applied due to traffic avoiding charged area/route
Political	• Difficulties caused by economic and social concerns, where user prices increase • Risks of being seen to use additional revenues in an appropriate manner • Risks of linking user charging to external cost pricing • Difficulties of agreeing taxation/charging policies at the European level (e.g. subsidiarity)
Privacy	• Charging according to time and location of travel requires knowledge of movements, which potentially lead to privacy issues
Technical and administrative	• Need to develop, potentially complex, technical and administrative systems to administer road user charging

4 Biofuels

Objectives:

- Explore and identify key risks and uncertainties associated with the achievability of Biofuels-related policies, including lead times for policy implementation and time lags to the resulting impact on emissions
- Assess the extent to which key factors outside the transport sector will affect decarbonisation of transport
- Develop approaches to address those risks and uncertainties and optimize achievability

Summary of Main Findings

⇒ There are still risks and uncertainties related to the four conditions that need to be met if the full potential of GHG reduction with biofuels is to be realised – the availability of biofuels, their sustainability and actual GHG reduction, their technical compatibility and public support.

⇒ In the coming years, the strategies should focus on effective implementation and improvement of the biofuels sustainability criteria. In addition, research into new (so-called 2nd generation) biofuels production processes should be promoted, to ensure a diverse biomass use in the future that does not compete with the food sector nor lead to significant negative impacts from land use change.

⇒ In the longer term, risks can be managed by setting the right biofuels targets, policies and (sustainability) boundary conditions. This should lead to a biofuels supply that is sustainable and diverse, leads to reasonable cost, and is compatible with the vehicles and engines use in the various transport modes.

⇒ In parallel, efforts should also be put into global initiatives that can reduce land use change and biodiversity loss due to biomass cultivation for biofuels, for example within the IPCC and CBD framework.

4.1 Using biofuels to reduce transport's GHG emissions

Most, if not all, scenario studies that look at long term GHG emission reduction in the transport sector conclude that a) biofuels have a significant potential for GHG savings in the transport sector, and b) significant volumes of biofuels are necessary to meet long term GHG emission targets. In addition, recent biofuels research and discussions have led to the conclusion that biofuels do not always lead to GHG emission reductions, and that effective policies (for example sustainability criteria, and policies that reduce of prevent negative impacts from indirect land use change) are a prerequisite to ensure that the well-to-wheel effects of these fuels are positive.

In part of the transport sector, in particular light duty road transport and rail transport, significant GHG savings could also be achieved with a switch from the current fossil fuels to electricity from low-carbon or renewable energy sources. However, other transport modes, namely aviation and maritime transport, and probably also a large part of heavy goods road transport, have few alternative, low-carbon energy sources. A successful further development and deployment of sustainable biofuels thus seems to be especially important for these modes – and perhaps also for part of light duty transport, if electric driving does not prove to be a viable and attractive alternative.

As shown in section 3.2, there are quite a number of risks and uncertainties associated with biofuels achieving the full potential of GHG emission reduction. The following further explores these risks and uncertainties.

4.2 Summary of information from the literature

The risks and uncertainties listed in section 3.2 will be discussed further below. In that section they were divided into the following categories: economic, social, environmental, technical, political and other. This categorisation will be followed here as well.

Economical risks and uncertainties
Costs of biofuels may reduce over time due to upscaling of production, technological development etc., but there are also a number of potential drivers that may increase the cost and thus potentially reduce availability (at an acceptable price) and political and public support. The following are the key drivers for (potential) cost increases of biofuels: .

- limited supply of sustainable biomass compared to demand (either structural or temporarily due to annual or seasonal changes in agricultural yield or political developments in biomass-exporting countries),
- increasing cost of sustainable biomass production,
- high cost of conversion technology,
- trade policies such as import and export duties or
- low oil price, which increases the cost of biofuel policy.

The cost of biofuels depends on the cost of the feedstock, on the production cost and on the global market for both the feedstock and the biofuel, i.e. on the balance of supply and demand, trade barriers etc,.
The cost structure of the biofuels depends on the biofuel type. In case of FAME (biodiesel), for example, the main cost element is the feedstock, whereas with bioethanol, conversion cost is dominant. The cost of the first type of biofuel is thus especially sensitive to feedstock cost fluctuation, whereas the latter typically has relatively high investment and operational costs. Also, biofuels cost will depend on cost of other energy sources, as this determines cost of both biofuel production and, in case of biofuel from agricultural commodities, biomass cultivation. Global food demand is expected to increase further in the coming decades and the supply can most likely not be increased sufficiently by increasing yields of current agriculture (CE Delft, 2008) only. Any additional demand for agricultural crops for biofuels will thus further increase the demand for land and thus increase cost.

Biofuel costs not only depend on the feedstock and production cost, but also on the market conditions: the balance between demand and supply of both the feedstock and the final product (the biofuel), and possibly trade policies. Cost increases due to an imbalance of supply and demand can be limited or prevented if biofuels demand is increased gradually, and if any demand increases are known well in advance. The industry can then anticipate on future developments, and production capacities and feedstock cultivation can be increased in line with the demand increases. Biofuels supply and demand is, however, a global market, which means that biofuel cost are not only affected by EU demand but also on demand from other countries.

And finally, biofuels cost (and availability) may also be affected by sustainability criteria. Tightening these criteria further can be expected to reduce the volume of biofuels that meet these criteria, and increase their cost. An important issue in this respect could be the development of biofuels production from waste and residues: if this R&D is successful, it may result in a significant increase of the potential supply of biofuels that meet the criteria.

High biofuel cost (and reduced availability of low-cost biofuels) may then have various economical impacts.

- It will increase transport fuel cost. This will have an adverse economic impact on the transport sector, and on sectors that are make use of transport (both businesses and households).
- If biofuel demand is such that it increases the cost of the biomass feedstock, other sectors such as food and feed, or electricity, chemical and materials from biomass may be affected.
  - If the biomass feedstock is a food or feed commodity, as is currently the case for a large share of the EU biofuels, increasing feedstock cost may result in increasing food or feed cost. This may have various social or economical impacts, especially in developing countries, were a relatively large share of income is spent on food. However, the impact of biofuels demand on food cost seems to be limited so far to some specific commodities, and price impacts seem to have been quite modest. The potential impact of biofuel policies on increasing food prices was studied by various researchers, especially in the light of global food price increases in 2008 (Faaij, 2008; LEI, 2008). The agricultural commodity market is complex and number of drivers are found to cause price increases[15], but some conclusions can be drawn from the literature (IEA RETD, 2010). First, effects will be highest for those commodities where biofuel demand accounts for a significant share of total demand (e.g. maize, oilseeds, sugar care). Second, potential price impacts are most likely to occur when biofuel demand increases rapidly, and biomass production is not increased accordingly at the same time.
  - If biofuels feedstock changes from agricultural commodities to non-food feedstock such as woody biomass, residues or waste in the future, biofuels may increasingly compete for this biomass with the other sectors that want to deploy biomass to reduce emissions: the electricity sector, materials and chemical production. This may lead to cost increases and thus economical impacts in those sectors.

Another type of risk worth noting is the potential economical impact on the aviation sector. As this sector has relatively limited technical alternatives for CO_2 reduction (insufficient to compensate the predicted growth rate, see AEA/CE/TNO, 2010), insufficient supply (or perhaps even lack of) bio-kerosine at reasonable cost levels could lead to high CO_2-cost and a barrier to further growth in the future, depending on climate policy developments (SWAFEA, 2010)[16].

And finally, the biofuels industry and investors are faced with economic risks associated with potentially fluctuating markets. Added to the risks related to, for example, global demand and supply and energy cost uncertainties, the biofuels market is specifically prone to effects of policy changes. In the past years, this was illustrated by, for example, the overcapacity of biofuel production capacity after the German quota were cut back in 2009 (Eurobserver, 2010), and the effects of US bioethanol support policies on the EU bioethanol production volume (IEA RETD, 2010).

Social

A number of risks of negative socio-economic impacts of biofuel production, and in particular of biomass cultivation, are identified in the literature (IEA RETD, 2010). These impacts are mainly seen in developing countries, and are often related to rapid expansion of biomass production and large-scale production of agro-commodities in these countries (Kessler eta al., 2007). Typical issues that are observed are land use conflicts, water use conflicts, labour issues and increased inequality in terms of income, access to land and gender issues. It should be noted, however, that these are issues that are not specifically related to biomass

[15] For example, local or regional weather increases, rising food or feed demand, speculation on international food markets, etc
[16] Other transport modes also face that risk, but they do not seem to be so dependent on this specific GHG reduction measure.

production but have other origins, and are therefore not a necessary effect of biomass cultivation. In fact, biofuels policy may also have positive socio-economic impacts, on individual farmers and local communities. Even though a number of criteria have been developed with which any negative impacts can be limited or prevented (see for example IEA RETD, 2008), in practice it appears to be difficult to address these issues effectively in policies.

As mentioned earlier, if biofuels demand leads to increases in food and feed prices and increased demand for agricultural and (potentially) fertile land, this will also have social impacts, especially in developing countries. Evidence has also been found that the price of especially vegetable oil is now linked (to some extent) to that of fossil oil, since these two products now partly compete on the same market (see, for example, MVO, 2009): if the crude oil price increases, biofuel producers can afford to pay more for their feedstock (such as vegetable oil) whilst maintaining the same profit margin. Furthermore, (global) biofuel demand is typically found to increase with increasing fossil fuel prices (and, vice versa, decrease when oil prices go down), putting additional pressure on the prices for these commodities and agricultural land[17].

These risks do not directly affect the availability and GHG potential of EU biofuels policy. They may, however, have indirect effects: they may reduce public support for biofuels, and the may lead to the extension of the current environmental criteria for biofuels with socio-economic criteria. These may reduce biofuels availability and increase biofuels cost.

Another type of social risk is related to potential public concerns of car owners in the EU. Firstly, there must be public support for and trust regarding the use of biofuels in cars. An example of how these concerns (whether real or perceived) can impact biofuels growth is the recent E10 debate in Germany, where concerns emerged about possible damage that E10 could do to vehicle engines. In addition, there could be a risk that public support for biofuels policy decreases if governments and fuel sellers can not prove that the biofuels are sustainable.

Environmental

The most notable environmental risk related to biofuels policies are the large variations in GHG emissions, in some cases even leading to GHG emission increases, and biodiversity loss. In recent years, quite a number of publications have looked at these issues. From these studies, it can be concluded that a key driver for these negative environmental impacts are both direct and indirect land use changes caused by the increasing demand for biomass. These changes can lead to very significant changes in carbon stock, both above and below ground, potentially resulting in significant GHG emissions. In addition to any land use change, biomass cultivation itself may cause significant GHG emissions (as any agricultural activity may do), it may impact the local and regional water table and cause eutrophication and water pollution. These effects depend on the type of crop that is cultivated, on local conditions and agricultural practices.

In order to prevent these environmental impacts, the EU has included a number of sustainability criteria in the Renewable Energy Directive (EC, 2009). It also contains a provision to count biofuels from waste and residues double towards the renewable energy transport target, as these are deemed to cause less or no land use change and other environmental effects. These criteria are not yet complete and fully developed, and thus can not yet effectively ensure all aspects of biofuels sustainability, but they are a step towards ensuring the sustainability of the EU biofuels.

[17] As (OECD/FAO, 2008) concludes, food expenditures average over 50% of income in many low-income countries, higher food prices will then push more people into undernourishment. However, these effects also depend on the type of commodity that is affected. For example, in countries such as India, rice is the main staple food, and there are virtually no effects predicted of biofuels demand increases on rice prices (IEA RETD, 2010).

An important omission in the current criteria is the prevention of indirect land use change (ILUC) (EC, 2010). According to a broad scope of recent scientific literature, ILUC can lead to GHG emissions that are in the order of the GHG emissions saved by reducing the use of fossil fuels. This effect depends on a number of variables and conditions, but most importantly on the type of land that is being converted, and on the crop that is being cultivated. Notably, ILUC may also have a positive impact in some cases, for example if marginal land with low carbon stock is converted to agricultural land with higher carbon stock. ILUC may also lead to impacts on other environmental parameters such as biodiversity, eutrophication and water pollution – these effects may not differ from the direct land use change impacts and are thus important risks to prevent or limit.
These indirect effects are, however, more difficult to quantify, as they are not directly linked to the biofuel production chain.

The EC is currently working on the development of policies that prevent negative ILUC effects (EC, 2010). On the one hand, these policies can be expected to result in a limitation of the biofuels availability in the EU, and possibly an increase of biofuels cost. On the other hand, however, they can ensure that the biofuels policies indeed lead to the desired GHG emission reduction, also from a global point of view.

Technical

Firstly, a number of technological barriers may have a negative impact on biofuel deployment. The main risks in this area are probably

1. the current car fleet can not drive on high blends biodiesel or bioethanol.
2. most current biofuels are not suitable for use as aviation fuel, see for example (SWAFEA, 2010).

The first issue directly limits the biofuels volume that can be sold in the EU. It may be solved by two means: by ensuring that the vehicle fleet, or at least a significant part of the fleet, can process high blends of these biofuels, or by switching to biofuels that are more compatible with the current engine and aftertreatment technology and materials. The first can be expected to take quite some time because it takes many years to replace the vehicle fleet (the lifetime of an average passenger car is about 15 years), and in most countries, there is no policy in place yet to achieve such a shift. Examples of the latter are HVO diesel, a biofuel that is expected to come onto the EU market in significant volumes in the coming years (www.nesteoil.com), or Fisher-Tropsch biodiesel, also known as BTL (Biomass-to-Liquid). The BTL biofuel is still under development, and proven in relatively small scale pilot projects only. This route will therefore also take quite some time and effort to achieve (IEA Bioenergy, 2008).

Secondly, there are a number of technological risks related to the future large scale conversion of biomass, in particular of non-food biomass such as waste, residues, woody biomass and algae. Biofuels from food commodities may have a number of adverse effects (see above), these technologies might therefore be crucial to the future sustainable growth of biofuels demand. However, potential future biofuels such as Fischer-Tropsch diesel, bioethanol from woody biomass and large scale biodiesel production from algae are not yet developed fully, and large scale production is not yet viable (IEA Bioenergy, 2008)(SWAFEA, 2010). If these R&D developments are unsuccessful in the medium term, this can be expected to negatively affect the future sustainable biofuel potential.

Political

The Renewable Energy Directive (RED) aims to reduce a number of the risks related to biofuels that were identified for the period until 2020, by obliging member states to achieve

10% renewable energy in transport in 2020, and by specifying the sustainability criteria that these biofuels need to meet. EU member states now have to implement this directive in national polices. In view of the obligatory nature of the RED, it can be expected that this implementation will be carried out in the coming years.

Regarding longer term targets and further development of sustainability criteria, developments are still very uncertain.
The scientific and political debate on how to effectively prevent ILUC is still ongoing (EC, 2010). It is difficult to predict the outcome of this debate, but it may be reasonable to expect some form of EU policy on ILUC in the coming 1-2 years. It might be possible, though, that it may then take some more years to further refine this policy.

4.3 Risks and uncertainties associated with applying biofuels to reduce transport's CO_2 emissions

Based on the literature review in the previous paragraph, four key *conditions* can be identified under which biofuels policy can deliver maximum GHG emissions reductions:

a) Biofuels availability
b) Biofuels sustainability and GHG reduction
c) Technical compatibility
d) Public support:

The key *risks and uncertainties* arising from the introduction of the EU policies for GHG reduction are all related to these conditions, and thus have the potential to impact on the GHG emission reduction of biofuels in the future transport system.

a)_ Biofuels availability
Large volumes of biofuels, and therefore biomass, have to be available, at reasonable cost. Whether this will be achieved depends on

- the future biofuel, renewable energy and/or energy CO2-emissions targets for the transport sector
- effectiveness of the biofuel policies implemented by the Member States
- the cost of biofuels that meet the EU sustainability criteria
- the global supply and demand of biofuels that meet the EU sustainability criteria

b) Biofuels sustainability and GHG reduction
The biofuels policies should result in biofuels that

- lead to GHG emission reductions, from well-to-wheel and including both direct and indirect land use change.
- do not cause other sustainability impacts, including impacts on biodiversity, air and water pollution, etc.
- do not impact on food and feed prices and availability

c) Technical compatibility
The biofuels need to be compatible with the vehicles, planes and ships that are operational, and provide trouble-free operations.
This is especially an issue for aviation, where fuels need to meet very stringent technical criteria (which current biofuels do not yet meet), but it also plays a role in road transport, where the large majority of the current fleet is not suited for high blends of FAME (biodiesel) or ethanol.

d) Public support:
The public needs to feel confident that the biofuels policies are

- technologically sound, i.e. they do not create problems in their vehicles

- sustainably produced.
- cost-effective, i.e. their cost are acceptable.

4.4 Identification of timelines and key relevant decisions for developing and implementing policies

From the above, a number of key policy decisions can be identified that can reduce the risks and uncertainties, and help ensure that the GHG reduction potential of biofuels is utilised.

The main EU biofuels policy in place at the moment is the EU Renewable Energy Directive (RED, 2009/28/EC). In addition, the Fuel Quality Directive (FQD, 2009/30/EC) sets well-to-wheel CO_2-reduction targets for transport fuels. It is currently expected that he first will be the main driver for biofuels growth in the coming decade, but the second may also play a role in ensuring CO2-emission savings from these biofuels – on top of the minimum CO2-savings required by the RED.

In the **short term**, i.e. in the next 1-2 years, it is therefore important to ensure effective transposition of the biofuels articles of the RED in all EU member states, and effective implementation of the FQD.
At the same time, the biofuels sustainability criteria in the RED and FQD need to be developed further. The main focus in the short term should be to implement ILUC into the sustainability criteria for biofuels, if possible, since land use change may have significant negative impacts on both GHG emissions and biodiversity.
Provide adequate and widespread communication regarding potential technical issues with biofuels, in order to prevent problems but also to build confidence in these fuels.

In the **short to medium term**, i.e. the next 10 years, the following issues should be addressed:

- Monitor whether the 10% renewable energy goal for transport in 2020 will indeed be met, and monitor and review the effectiveness of the sustainability criteria.
- Aim for a diverse and flexible mix of biofuels and biomass type, to increase availability and security of supply of biofuels, and reduce the economic risk related to cost increase of specific feedstock.
- Aim for a gradual increase of the share of biofuels from non-food feedstock in the overall biofuel supply. Monitor if the current double-counting provides an effective incentive for their practical deployment and market uptake.
- Improve collection and use of bio-waste and residues, promote reuse of biomaterials (for other products or for bioenergy)
- Monitor if biofuel demand growth is found to compete with food and feed production (for product or land), and has negative impact on food and feed prices and availability. Assess and implement policy options to prevent this[18].
- Investigate whether socio-economic criteria can be included in the sustainability criteria.
- On a global scale, aim to develop more general policy means to prevent land use change that causes GHG emissions.
- Promote R&D into biofuel production from waste, residues and lingo-cellulosic biomass, and into biofuels that are compatible with the current (and future) vehicle fleet (for road transport) and aviation standards (for air transport).
- Promote R&D into sustainable biomass cultivation and implementation of the findings. Examples are biomass cultivation on marginal or degraded land, and optimisation of agricultural practice to minimise GHG emissions and maximize biodiversity, multi-cropping.

[18] For example. further promote the demand for biofuels from non-food feedstocks

- Promote or mandate the sales of flex fuel vehicles, to accommodate higher blends of bioethanol (>10vol%) throughout the EU[19].
- Continue communication efforts, to maintain public support for the policies.

In addition, the EU needs to develop and decide on ambitious but achievable long term goals and policies during the next 5-10 years. These should be a result of the actions and decision listed above, as there are still quite a number of uncertainties related to biofuels that should first be clarified and assessed further before post-2020 policy can be decided on. On the one hand, there are the EU ambitions regarding GHG emission reduction in transport, and the potential significant positive contribution that biofuels can and should make to meet these goals. On the other hand, however, there is the potential global impact of the EU biofuels policies on issues such as food and feed prices, land use and related impact on GHG emissions, biodiversity and water use, and socio-economic developments. The continuing increase of the global population and the expected economical growth of many developing countries clearly lead to predictions of continued increase in demand for food and feed, and in agricultural land for the cultivation of these commodities. The biofuels ambitions and policies need to be seen in that context.

Regarding the type of EU-level biofuels policies for post-2020, a number of options could be explored further, such as:

- Continuation of the current approach, in particular gradually increasing the renewable energy target for the transport sector, in combination with sustainability criteria that include minimum GHG emission savings.
- Increasing the importance of the CO_2-standards of fuels as a driver for biofuels, by further tightening the standards to levels that require more biofuels or higher GHG emission reductions than defined in the RED.
- Setting separate renewable energy targets and/or fuel GHG reduction targets for the various transport modes. This could be introduced in order to specifically promote the development, production and uptake of biofuels or other low-carbon fuels in the transport modes that have few alternative means to significantly reduce GHG emissions in the longer term, such as aviation and shipping.

The various options should be assessed and compared, regarding for example cost, effectiveness, robustness to future developments and market impacts. This can then result in a clear decision regarding the way forward.

In the **longer term**, the future biofuels market need to be developed further.

- Long term targets, policies and market conditions will need to be developed, relevant R&D has to be continued, investments in sustainable biomass cultivation and biofuel production capacities need to be further developed.
- A stable policy environment needs to be created, both on EU and member state level, providing stable incentives and boundary conditions (regarding sustainability), to reduce the risks for investors.
- Global initiatives that can reduce land use change and protect biodiversity may contribute in the longer term to the reduction of indirect land use change impacts. This can be achieved for example within the IPCC and CBD frameworks.
- It can be expected that most of the issues that are listed above for the short to medium term require continued attention also in the longer term.
- Specifically, remaining sustainability issues and the competition with food and feed, and other sectors need to be resolved.
- Also, investments and R&D probably need to be continued, in particular regarding:
  - R&D into biofuels that can be produced from waste, residues and woody biomass, and into biofuels that are compatible with the current (and future) vehicle fleet[20]. Expansion of production capacity of these biofuels.

[19] A further assessment of the options is required before a more definite recommendation can be given.
[20] Note that for example Fischer-Tropsch biofuels meets both demands, whereas 2nd generation bioethanol only meets the first.

  - R&D into biofuels for aviation (drop-in fuels that can be used in the current airplane fleet)
- If necessary, additional policies need to be developed and implemented to ensure that biofuels are not only developed for and used in road transport, but also in other transport modes[21].

4.5 Exploration and identification of lead times, risks and uncertainties

The list of recommended policy actions in the previous section is quite extensive, and covers a long time frame. It is thus important to ensure that the policies put into place are effective, and that risks, negative impacts and remaining uncertainties are indeed reduced over time. This requires careful and continuous monitoring of a number of issues - some of these were already mentioned in the previous section, but are repeated here to provide a complete overview:

Short to medium term

- Monitor effective transposition of the RED transport target and sustainability criteria into national laws and regulations
- Continue to monitor the development of biofuels volumes in the EU member states, assess whether the 10% target is likely to be met.
- Assess the impacts of the biofuels volume growth on the commodity markets, especially on the prices of food and feed.
- Monitor prices of biofuels, and total cost of the biofuels policies.
- Monitor the biomass mix that is used for biofuel production. Is it diverse enough to prevent security of supply issues, is there a shift from food to non-food biomass?
- Monitor and assess the effectiveness of sustainability criteria, and continue to assess the risks of indirect impacts.
- Continue dialogue with fuel and car manufacturers regarding potential technical problems of increasing biofuels shares. If necessary, take action to prevent these.
- Define a strategy and timeline for post-2020 biofuels policy development, and adhere to that strategy.

Medium to longer term

- Assess whether the R&D into biofuels production from waste and lignocellulosic biomass is successful, and is expected to lead to significant volumes of these biofuels in the future.
- Assess whether the R&D into biofuels production for aviation is successful, and is expected to lead to significant volumes of these biofuels in the future.
- When defining post-2020 biofuels policies and targets, take the results of the previous two bullets into account.
- Re-evaluate what the expected potential is for sustainable biofuels in the longer term. What does this mean for the longer term GHG reduction scenarios?

4.6 Possible strategies for managing and reducing risks

In order to properly manage and reduce the identified risks, quite a number of issues need to be monitored in the coming years and decades. Negative (i.e. undesired) results of these

[21] It is not clear whether biofuels use in other models requires separate policies, or whether the more generic GHG policies in this transport sectors, such as the EU ETS, provide enough incentives.

monitoring exercises should then lead to policy improvements, in some cases probably preceded by further research into the causes of the problems and the options available.

In the coming years, the strategies should focus on effective implementation and improvement of the biofuels sustainability criteria. In addition, research into new (so-called 2nd generation) biofuels production processes should be promoted, to ensure a diverse biomass use in the future that does not compete with the food sector nor lead to significant negative impacts from land use change.
In the longer term, risks can be managed by setting the right biofuels targets, policies and (sustainability) boundary conditions. If necessary, address issues with vehicle compatibility, for example by addressing these issues in vehicle regulations.
This should lead to a biofuels supply that is sustainable and diverse, leads to reasonable cost, and is compatible with the vehicles and engines use in the various transport modes.

In parallel, efforts should also be put into global initiatives that can reduce land use change and biodiversity loss due to biomass cultivation for biofuels, for example within the IPCC and CBD framework.

4.7 Conclusions

Biofuels are expected to contribute significantly to the future GHG emission reduction in the transport sector, as there is a large global potential and they do not require a completely new infrastructure or engine technology. However, there are still quite a number of risks and uncertainties related to the four conditions that need to be met if the full potential of GHG reduction with biofuels is to be utilized. These conditions are:

a) Biofuels availability
b) Biofuels sustainability and GHG reduction
c) Technical compatibility
d) Public support:

The risks and uncertainties can be divided into various categories:

- **Economical**: A number of developments were identified that could increase biofuels cost and have adverse wider economic impacts. This may lead to effects such as reduced public and political support for higher biofuels shares, or increased cost of transport, food commodities, etc..
- **Social**: Biofuels policies may have a negative socio-economic impact in biomass-producing countries, and impact global food and feed prices, unless the right conditions are set. Also, there is risk that public support (within the EU) could reduce, for example if costs would increase or negative impacts (e.g. on food prices) would be observed.
- **Environmental**: Despite the current efforts, it is still uncertain whether the sustainability criteria can be developed further and implemented so that negative environmental impacts are effectively prevented, and positive impacts are maximised. And, if it is, there is a risk that the environmental boundary conditions significantly reduce the available biofuels supply, and increase biofuels cost.
- **Technical**: A number of technical issues may hamper future biofuels growth, especially problems with compatibility with existing engines, and specific aviation requirements.
- **Political**: there are also risks that the biofuels policies are less effective than envisaged, or that lead times for longer term policies are longer than expected. This may lead to lower biofuels shares and/or less GHG reduction than anticipated.

All these risks and uncertainties could affect the conditions listed above, and thus may reduce the longer term contribution of biofuels to GHG reduction in the sector. Both the EU and member states (and indeed also stakeholders) should thus aim to reduce these risks and uncertainties. A strategy to achieve this is provided in section 4.4.

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5 Electricity and hydrogen in transport

Objectives:

- Explore and identify key risks and uncertainties associated with the achievability of electricity- and hydrogen-related policies, including lead times for policy implementation and time lags to the resulting impact on emissions
- Assess the extent to which key factors outside the transport sector will affect decarbonisation of transport
- Develop approaches to address those risks and uncertainties and optimize achievability

Summary of Main Findings

⇒ The implementation of electricity and hydrogen as GHG reduction options for the transport sector is a transition that involves drastic and structural changes in both the transport and the energy sector and that will take several decades to start up, roll out and complete.

⇒ Governments and stakeholders in the market need endurance and a long term vision to manage this transition in an effective way. Mitigating risks and taking away uncertainties is an important and unavoidable part of that.

⇒ Proactive steps are required in the short term in laying the ground work for longer term policy instruments, in early market formation and in setting up and managing a process that timely delivers the insights that are necessary to develop a suitable dominant design for the energy distribution infrastructure.

5.1 Using electricity and hydrogen to reduce transport's GHG emissions

Vehicles running on electricity and/or hydrogen are important technical options for achieving a sustainable transport system in the longer term. Electric vehicles in this context include battery-electric or full-electric vehicles as well as plug-in hybrid and range extender electric vehicles.

In order for electric and hydrogen-fuelled vehicles to contribute significantly and effectively to meeting longer term GHG emission reduction goals the following conditions must be met:

1. Policies must be developed and implemented which promote the installation of the required energy infrastructure and the use of electric and hydrogen-fuelled vehicles;
2. Electric and hydrogen-fuelled vehicles need to reach significant market shares;
3. The environmental impact of the applied electric and hydrogen-fuelled vehicles must be such that it leads to a significant net reduction in GHG emissions.

All three conditions are not automatically met. Risks and uncertainties are associated with the effective realisation of these conditions. These risks and uncertainties may be subdivided into determining aspects as follows:

1. Policy development and implementation

- uncertainty about long term targets
- lead time for policy development
- availability of appropriate test and valuation procedures
- quality of the policy instruments

2. Market development
   - vehicle technology and cost development
   - infrastructure development
   - energy cost development
   - impact of supply and demand oriented policy measures on the business case
   - availability of resources
   - "sustainability" of stakeholder attitudes and interests
3. Net environmental impact
   - timely availability of sufficient renewable energy
   - interaction with the energy system
   - LCA-aspects of vehicle manufacturing and decommissioning

Obviously there is significant interaction between the different aspects. Policies and technology development influence the costs of these options, and costs are an important determinant for market demand. Various aspects also include factors outside the transport sector that will affect possibilities for decarbonisation of transport.

In the next paragraphs these various aspects are further decomposed into concrete examples of risks and uncertainties that may be relevant for the implementation of vehicles on electricity and hydrogen

5.1.1 Risks and uncertainties associated with policy development and implementation

Uncertainty about long term targets

The level of long term GHG emission targets for the transport system strongly determines the need for truly zero-emission vehicles. Especially when electric and hydrogen vehicles do not achieve a profitable business on their own, industry will depend on ambitious climate policy to invest in widespread implementation of these technologies. In that case, besides ambitious targets, regulation and/or economic instruments will be necessary to promote implementation or to create a profitable business case.

As the introduction of electric and hydrogen fuelled vehicles constitutes a transition in both the mobility and energy system that will take several decades to complete, one has to start now with the first pilots and early market developments in order to have the technologies technically and economically mature as soon as their large scale application is required to meet longer term targets. Timely setting of long term targets helps to convince the market that the first steps on the S-curve need to be made in the coming years.

In its recent White Paper the European Commission has defined a target for the transport of 60% GHG emission reduction in 2050 compared to 1990. Long term targets tend to be quite robust, but the more short to medium term targets derived from that are more susceptible to change as a result of fluctuations in the political climate. Stakeholders with vested interest in existing technology have large influence on politics. Especially in economically more dire periods vested interests motivate politicians to have a preference for achieving short term economic goals over long term sustainability goals.

For electric and hydrogen vehicles future developments in existing EU policies such as the EU-ETS and the renewable energy directive (RED) are relevant.

The acceptance of ambitious GHG reduction targets depends on (the perception) of their achievability. This in turn depends on the short and longer term sustainability of vehicles on electricity, hydrogen or other alternative energy carriers. Real or perceived uncertainty about the sustainability undermines the legitimacy of policy for sustainable mobility. The increasing evidence for (In)direct Land Use Change (ILUC) effects of biofuel production has put biofuel policies largely on hold in many countries. Doubts about the short term sustainability of electric vehicles, e.g. through possible adverse impacts on composition of the electricity generation system as described in [T&E, 2009], could do the same for electric vehicles. In the discussion about environmental impacts of electric vehicles also questions are raised concerning impacts associated with production and decommissioning of vehicle components. As long as these can not be answered convincingly these concerns cast a shadow over the public perception of electric vehicles as a solution for sustainable mobility. More on this subject can be found in section 5.1.3.

Lead times for policy development

Lead times for development and implementation of policy instruments at the EU and Member State level can be of the order of 5 to 10 years.

The case of the current CO_2 legislation for passenger cars is a good example of how long it can take to define and implement policy instruments. It started with the signature of the voluntary agreement between ACEA and the European Commission in 1998. When the voluntary approach turned out not sufficiently successful, preparations for a regulatory approach started in 2002. The final legislation was approved end of 2008 and will start to have legal impacts by 2012 with the phasing in of the target leading to a sales average CO_2 emission of 130 g/km in 2015.

In the longer term new fiscal systems may be needed that provide a level playing field for different technological options and that reward these options as much as possible on the basis of their real impact on GHG emissions. At the Member State level fiscal stimulation can be developed and implemented quite fast, but this tends to lead to very different fiscal systems in different Member States, resulting in a market fragmentation that is not beneficial for the widespread introduction of electric and hydrogen-fuelled vehicles. Developing harmonised fiscal policy at EU level, however, requires unanimity and is generally difficult. Moreover, the use in transport of energy carriers that are also used in other sectors makes it difficult to implement specific energy taxation for transport applications. Without such specific taxation, increased use of electricity and hydrogen in transport will lead to reduced fuel excise duty revenues. This may cause reluctance at MS level.

If regulation is used to promote the introduction of electric and hydrogen-fuelled vehicles, appropriate CO_2 or energy efficiency standards are needed that are able to deal with the mix of conventional and alternative technologies that is foreseen for the longer term future. Under the present CO_2 legislation for cars and vans, electric and hydrogen-fuelled vehicles count as zero-emission. This creates a leverage for these vehicles compared to conventional ones that certainly in the short term may not fully justified. Discussions are on-going on how future regulation may be defined to treat conventional and alternative vehicles in a more balanced way, but so far no convincing proposals have been made.

An alternative for fiscal instruments of regulation is the possible integration of transport in an emission trading system. Inclusion of transport in EU-ETS has severe drawbacks with respect to realising GHG emission and energy independence goals within the transport sector in the short to medium term. Setting up a separate trading system for transport is complex due to the large number of actors. All in all, if a cap and trade system would be preferred, the lead time for establishing this is probably also significant.

Availability of appropriate test and valuation procedures

The effective implementation of policy instruments often depends on the availability of appropriate test and valuation procedures that are required to assess the sustainability of products. The (un)timely development of appropriate procedures may thus contribute to lead times for policy development. An example is the development of the WLTP[22]. This new test procedure for light duty vehicles takes over 5 years to develop and implement a new test procedure. And after that it takes some more time to adapt existing legislation to the new procedures. The WLTP is crucial for making sure that the next steps in reducing vehicle emissions work out similarly in the real-world as they do on the type approval test.

Appropriate regulatory test and valuation procedures may also be necessary to enable development of long term fiscal systems that provide level playing field and technology-neutral incentives to sustainable vehicles.

Provided that the WLTP process delivers a test cycle that is sufficiently representative for real-world driving, the issue of availability of appropriate test procedures may not be pressing anymore for battery-electric and hydrogen fuelled vehicles. These vehicles do not produce tailpipe emissions and the test procedure as such for measuring energy consumption is fairly straightforward. For plug-in hybrid and range extender electric vehicles the situation is somewhat different. Here also the procedures for measuring electricity and fuel consumption as such are not problematic, using one test starting with a full battery and a second test starting with an empty battery. But the current provisions in the test procedure for determining the overall fuel consumption and CO_2 emissions based on these two separate tests may require improvement in order to be able to deliver more meaningful and representative results. The value of this combined test result is crucial for how plug-in hybrids and and range extender electric vehicles are treated by CO_2-based fiscal systems in comparison conventional vehicles on one side and pure electric vehicles on the other side.

Quality of the policy instruments

Policy instruments may be found to contain flaws and loopholes leading to undesired effects that counteract the required impact on GHG emissions. Such flaws and loopholes can result from errors design but more often are introduced through amendments to the legislation that have been adopted as part of the political negotiation process.

Such undesired effects can not always be foreseen, so that possible existence contributes to the risks and uncertainties associated with the policy making process.

An aspect to be taken into account in the design of policy is the possible interaction between policy instruments, having impact on net incentives for and net sustainability of electric and hydrogen fuelled vehicles. Examples are the interaction of electric vehicle policies with (future development of) the EU-ETS.

From the perspective of system innovation theory an important risk is the fragmentation of policy development at different government levels and in different geographical regions. The European Commission can to some extent avoid this by creating an overall framework and incentives, but Member States and cities in the end are the main players in promoting transition at the local level.

[22] Worldwide harmonized Light-duty Test Procedures (WLTP): activity under UNECE-GRPE aiming to establish a worldwide test procedure to measure light duty vehicle emissions and energy consumption

5.1.2 Risks and uncertainties associated with market development

New technologies generally have high costs in the early stage of production. When production increases costs go down. With increasing market size investments in product improvement will increase leading to further cost reductions. The combination of added value offered by the new technology and an acceptable cost level in the end define whether the business case for such new technologies is profitable. The same applies to sustainable products such as electric and hydrogen fuelled vehicles, or even to a larger extent as sustainable products are designed to have benefits at the societal level but do not necessarily provide direct added value for the users.

Development of profitable business cases for users and suppliers thus depends on development of technology costs, energy prices and fiscal regimes. In the short term establishing an acceptable residual value for vehicles with new technology is an important issue

In addition the market development for electric and hydrogen fuelled vehicles is governed by a chicken-and-egg problem with respect to infrastructure.

As far as lead times for large scale market uptake are concerned a back-casting exercise may be enlightening. If we are to achieve GHG emission reduction in transport of 60% or more by 2050, the lion's share of the fleet by then must consist of very efficient vehicles driving on renewable / low-CO_2 energy. Given finite fleet renewal rates and the finite speed at which production capacity can be increased that means that start of the roll-out of sustainable options need to happen by 2030 the latest. That gives us 20 years between now and 2030 to make conventional cars more efficient (in order to already achieve significant GHG emission reductions before more sustainable alternatives are ready to do so) and to:

- test the various alternatives in pilots and niche applications;
- bring suitable options to technical and economical maturity;
- in part by creating first markets through pilots, niches, and early adopters, and to
- create a context that supports roll-out by means of appropriate policy instruments, (growing) availability of infrastructure and increasing production of renewable energy.

Vehicle technology and cost development

Purchase costs for electric and hydrogen fuelled vehicles are currently still high. It is certain that costs will go down over time, but It is not a priori certain that in the end electric and hydrogen fuelled vehicles will be cheaper to produce or have lower total cost of ownership than conventional vehicles.

The costs of electric and hydrogen fuelled vehicles will change substantially as a function of the scale of application (economies of scale and learning effect) and time (innovation). This cost development, however, is difficult to predict for the following reasons:

- Future innovations and their impacts are by definition unpredictable;
- The theory of learning curves in principle provides a methodological framework for modelling costs as a function of cumulative production, but has many uncertainties;
- Investments in R&D and therefore the innovation rate will depend on government policies and expectations regarding future customer demand. If, for example, the CO_2 emissions of new cars are regulated, and the CO_2 standard is reduced in the future decade, car manufacturers will increase their efforts to develop cars with lower CO_2 emissions that are still attractive for customers. This will speed up the learning curve, and increase potential and lower costs of mitigation options, compared to the situation in which there is less pressure on the parties involved.

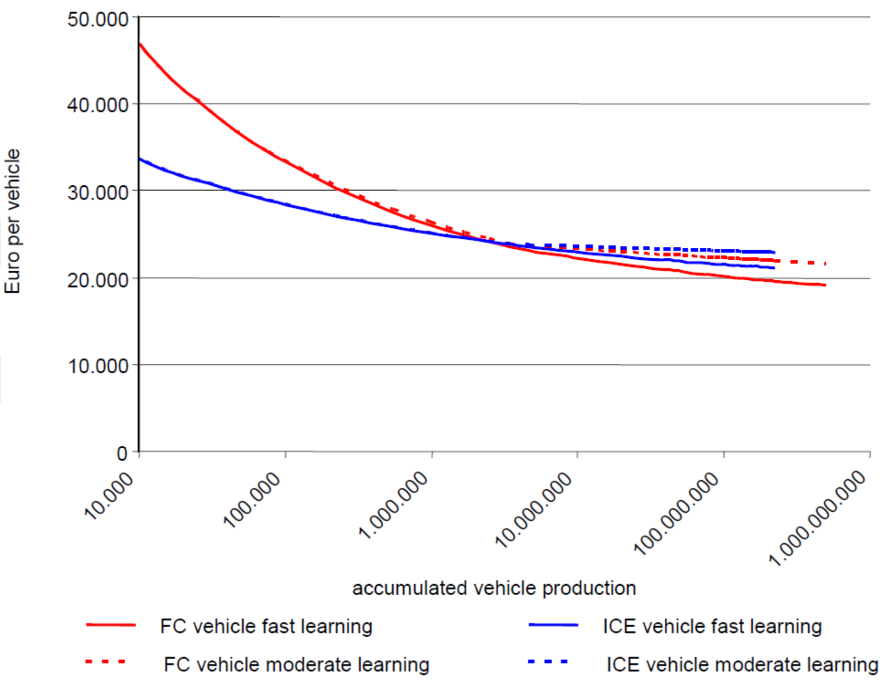
Learning curve theory is an empirical theory which describes the development of the costs of a given product as a function of the cumulative production[23]:

$$C_n = C_1 \times n^{\ln(S)/\ln(2)}$$

with n the cumulative production, C_n the cost of the n^{th} product, C_1 the cost of the 1^{st} product and S the learning rate. The learning rate S is equal to the factor by which the costs fall when cumulative production is doubled. Learning rates are usually between 1 and 0.8, with values in the range of 0.95 to 0.85 most commonly used. A low value for S corresponds to a strong decrease of costs as a function of cumulative production.

The size of learning effects depends strongly on characteristics of the technology. If product and production process improvements can be used to eliminate expensive materials or production steps, cost can go down strongly with the scale of production and the cumulative production. E.g. in catalytic converters a large share of the costs stems from the application of expensive precious metals. Reducing the amount of precious metals used in a catalyst has had a high leverage on the price so that innovation in this respect has led to a low learning rate S (i.e. well below 1 meaning that costs fall sharply with cumulative production). In the case of electric machines or lithium batteries, however, a large reduction of the use of an expensive material is probably not an option to reduce costs so that learning effects have to come more from improved production processes than from improved design. This may result in a higher value for the learning rate S.

Figure 5.1: Learning curve theory applied to the price of compact class passenger cars on hydrogen [HYWAYS 2007]



The cost development of electric and hydrogen fuelled vehicles is uncertain due to uncertainties with respect to technological breakthroughs which are required to improve performance and reduce costs of electric and fuel cell vehicles. The main components requiring cost reduction are batteries, electric motors, fuel cells, and H_2 storage systems.

[23] For more information on learning curve theory see e.g. [DAU 2006], [IEA 2000] and [NASA 2007]

Besides high costs, the business case for electric and hydrogen fuelled vehicles is also affected by component performance and lifetime issues. This is especially the case for batteries.

The chances for a successful large-scale market for electric vehicles would greatly benefit from the development of alternatives for lithium-based batteries with equal or better performance. Battery developments not only allow cost reductions, but can also be used to increase range, thus expanding the possible applications of EVs.

A crucial question for the market of electric and hydrogen fuelled vehicles is whether the applied technologies will allow production of better cars with added value to consumers. If electric and hydrogen fuelled vehicles provide added value to users, they can be sold for what they are worth rather than for what they cost. This added value could come from better performance and comfort, but also from possibilities for utilising the characteristics of new propulsion technology to create new vehicle designs or new functionality.

Electric and hydrogen fuelled vehicles have to become an attractive proposition in comparison to the existing conventional technology and relative to competing alternatives. The advent of a new technology, however, usually spurs further improvements in development of the competing conventional and alternative technologies. As such the conventional car is a "moving target", in terms of costs, quality and environmental impacts. As an example, in the 90’s the “threat” of EVs in California as a result of the ZEV-mandate greatly accelerated the application of exhaust aftertreatment in ICEVs.

Infrastructure development

The timely roll-out of an appropriate energy infrastructure is a prerequisite for the successful implementation of both electric and hydrogen fuelled vehicles. This dependence creates risks and uncertainties for the implementation of these technologies. At the same time there are a number of risks and uncertainties that influence the chances for a successful realisation of the required energy infrastructure.

Both for electricity and for hydrogen the current situation with respect to infrastructure is characterised by a lack of dominant design. Lots of choices are still to be made, e.g.:

- for electric vehicles:
  - slow vs. fast charging, conductive vs. inductive charging, public or private charging spots, battery swapping, inductive charging “from the road”
  - combinations of various charging options
- for hydrogen vehicles:
  - energy sources for production of hydrogen
  - distribution in gaseous or liquid form
  - storage in compressed or liquid phase, metal hydrides or other options for distribution and storage of hydrogen

Especially in the case of electric vehicles the dominant design is not just about technical choices but also about business models and payment systems. In the case of hydrogen the business model and payment system is expected to resemble that of conventional vehicles.

In the longer term the infrastructure for electric and hydrogen fuelled vehicles can not be seen separate from developments in other sectors. What is needed in fact, is a co-evolution of changes in mobility and energy systems.

Electric vehicles, as well as a range of other developments in electricity consuming devices as well as e.g. decentralised energy production, will have large impacts on required capacity of the distribution grid. Increased demand can be met by "more copper" or by "smart grids". The first option is expensive, but the business case for the second is as yet far from clear.

Provided that "smart grids" are the way to go as a solutions for managing increased local demand and matching local demand with local production of electricity, electric vehicles may even play a role as decentralised storage capacity for matching supply and demand in a future energy system with a large share of intermittent renewable energy production. But this vision also requires more substantiation. In any case it will require development of agreed standards for vehicle-to-grid interaction. One of the challenges for smart grids is the development of suitable and user-friendly spot market arbitrage systems.

For hydrogen it makes a difference whether it will also be used in other sectors also or not. If it has wider use in the energy system the development of production and distribution capacity for transport may profit from investments made for other applications of hydrogen.

Furthermore for hydrogen underutilisation of the infrastructure in the early stages of market development appear to be seen as a larger risk than for electric vehicles. In the initial stages the charging infrastructure for electric vehicles can possibly be better matched with the number of vehicles on the road. Due to the limited range these vehicles are expected to be used in a limited geographical area near the main charging point. Hydrogen vehicles are expected to be used in applications with longer driving distances, and already with small numbers of vehicles on the road may need a network of filling stations with sufficient coverage over a wide geographical area.

For electric vehicles the risk of underutilisation is more specifically associated with fast charging facilities that may be installed to reduce drivers' range anxiety and improve vehicle utilisation. In various experiments it has been shown that the presence of fast charging stations does encourage EV drivers to also use their vehicles for longer trips, but that the fast charging infrastructure is actually hardly used.

For both types of infrastructure the timely development of appropriate standards is a prerequisite and thus also an uncertainty.

Further risks and uncertainties for the successful roll-out of charging or hydrogen infrastructure are institutional and legal barriers. Pilots programmes are extremely useful in finding these barriers and in motivating stakeholders to find solutions for removing them.

Energy cost development

The business case for electric and hydrogen fuelled vehicles is relative to conventional, fossil-fuelled vehicles. As such it is not only determined by cost developments in the alternative technologies but also by the costs of the conventional technology. Developments in the latter are dominated by the price development of fossil energy, specifically oil.

To maximise the GHG benefits of electric and hydrogen fuelled vehicles they need to run on energy produced from renewable resources. The cost development for the production of sustainable energy carriers, however, is also highly uncertain. As with the vehicles it depends on innovation, technological breakthroughs and learning effects.

In the costs of renewable energy also the costs of additional provisions for dealing with the intermittent nature of e.g. wind and solar energy should be included.

Furthermore it should be noted that the price of sustainable energy carriers is partly determined by production costs but also by demand and by competition for sustainable energy by other energy-consuming sectors.

Development of energy efficient and cost-effective technologies for sustainable production of hydrogen is a challenge. The energy chain that converts renewable electricity to hydrogen by electrolysis and on-board conversion of hydrogen back to electricity in a fuel cell is a relatively inefficient way of getting renewable energy to the wheels (e.g. compared to direct use of renewable electricity in pure electric vehicles). More efficient ways of producing renewable hydrogen may improve not only chain efficiency but above all costs.

Impact of supply and demand oriented policy measures on the business case

The above considerations largely relate to autonomous developments of costs and business case. The business case at the user level, however, is determined not only by costs but also by the applicable tax regime. As such changes to the tax regime can be used to influence the business case from a user perspective, either temporarily to overcome high initial costs in the early stages of market introduction, or more structurally to make sure that options with structurally positive GHG abatement costs at the societal level become an attractive proposition at the user level due to lower costs from a user perspective compared to non-sustainable options. Economic instruments such as CO_2 taxation or a cap & trade system can serve the purpose of demand oriented measure tilting the business case at the user level in favour of sustainable alternatives.

An alternative for these economic instruments can be found in supply oriented measures such as CO_2 regulation which basically demands vehicles to meet certain sustainability standards. Electric and hydrogen fuelled vehicles can be "forced" into the market by standards that can only be met by such vehicles or by selling a large share of these vehicles.

In the context of policy based on economic instruments the use of regulatory instruments can still be useful and justified. Vehicle based standards can help to make sure that technologies are effectively brought to the market which may help consumers to respond to the price incentives provided by the fiscal / economic instruments.

Availability of resources

In the longer term the large-scale, world-wide application of electric and hydrogen fuelled vehicles may be limited or hindered by the finite resources of materials for alternative powertrain and vehicle components. These materials include lithium, rare earth metals, and other metals such as copper and platinum. In the short and medium term scarcity of these materials not or not only related to finite resources but also to the speed at which production capacity can be increased. A lagging production capacity for e.g. lithium batteries, electric machines or fuel cells that is unable to meet the growing demand may lead to strong price increases in the short and medium term. This may hamper the cost reductions which are required for generating a positive business case at the user level.

In light of the above resources of various materials become strategic assets. As a consequence political developments in countries with large resources will influence price.

Availability of resources not only applies to materials for the production of vehicles, but also to the development over time of sufficient (sustainable) production capacity for electricity and hydrogen for use in transport. As mentioned above, this includes adaptations in generation and distribution infrastructure necessary for dealing with the intermittent nature of various renewable resources. Different economic sectors will be competing for possibly scarce renewable energy. This drives up prices and may reduce the speed with which ambitious GHG emission reductions can be realised in the transport sector.

Different routes for providing transport may already create competition, as e.g. biomass can be used as a source of renewable electricity or hydrogen or for direct usage in vehicles as biofuel.

"Sustainability" of stakeholder attitudes and interests

Currently electric vehicles are a bit of a hype. They have been that before in the early 90's of the last century as hydrogen was in the late 90's. This attention and favourable attitude towards new technologies tends to be temporary and may fade away for various reasons.

At the moment we are only at the very beginning of the S-curve for electric vehicles. Although some large-scale pilots exist, the market introduction of hydrogen vehicles still has to start. For both technologies the development of a mass market requires a well managed process of creating early markets, based on early adopters and innovators, scaling up to larger niches and finally development of the early majority market (see **Error! Reference source not found.**).

In every step production volumes increase, costs go down and investments in product quality and production efficiency increase. A "valley of death" in the market introduction may occur when after serving the "innovators" and "early adopters" segments in the market the price and characteristics of electric or hydrogen fuelled vehicles have not yet developed to a level that is considered acceptable by the "early majority" segment of the market (see **Error! Reference source not found.**). Consistent policy creating a stable investment climate and entrepreneurs with determination, endurance and stamina are required to bridge this "valley of death".

Even without the "valley of death" the time required to fully develop the market for electric and hydrogen fuelled vehicles will span several decades, which is much more than timescales required by industry for return of investment nowadays. The willingness of investors to support the roll-out of electric and hydrogen fuelled vehicles and the associated infrastructure all through this time-consuming process of creating, maintaining and scaling up early markets depends on a wide range of factors. The economic “climate” is one of them. The willingness and ability to invest on the basis of a long term vision is another.

Not only the "sustainability" of the motivation of investors is an issue. The development of public acceptance and consumer attitudes and preferences is an equally important risk or uncertainty. The acceptance of electric and hydrogen fuelled vehicles depends in part on the real or perceived added value of these technologies. Favourable attitudes towards these vehicles are easily destroyed by incidents leading to bad publicity. From a technical point of view safety is currently not always seen as a risk or uncertainty and does not need to be an issue. But incidents such as burning lithium batteries or hydrogen explosions are certain to happen now and then, and if incorrectly managed can lead to bad press. Incorrect claims of negative environmental impacts of electric and hydrogen fuelled vehicles may also undermines the legitimacy of policies promoting the application of these vehicles. A striking example has been the “Hummer vs. Prius - study”[24], proven scientifically incorrect25 but still popping up regularly in discussion on hybrids and EVs.

[24] http://cnwmr.com/nss-folder/automotiveenergy/DUST%20PDF%20VERSION.pdf
[25] see e.g. http://www.pacinst.org/topics/integrity_of_science/case_studies/hummer_vs_prius.pdf

5.1.3 Risks and uncertainties associated with net environmental impact

Timely availability of sufficient renewable energy

Electric and hydrogen fuelled vehicles can only realise their full environmental potential if the energy mixes used to produce electricity and hydrogen contain a sufficiently large share of renewables. The transition of the energy system from its present fossil-based state to a more or fully sustainable state has its own set of risks and uncertainties that through electric and hydrogen fuelled vehicles influence the chances that transport can meet long term sustainability goals.

Also for renewable energy productions aspects such as cost development, finite rate of production increase and scarcity of resources play a role. For solar, wind and biomass energy availability of land is one of these scarce resources. All in all the extent to which electric and hydrogen fuelled vehicles are able to realise a significant net contribution to reducing GHG emission will be influenced by the success of European policies and sector initiatives aimed at decarbonising the energy sector.

Interaction with the energy system

The introduction of electric and hydrogen fuelled vehicles in itself may have impacts on the structure and sustainability of the energy system.

In the case of electric vehicles, load management, leading to increased electricity demand at night and thereby flattening the overall demand pattern for electricity, would increase the demand for and profitability of cheap e.g. coal-fired baseload power. This could deteriorate the environmental performance of electricity production instead of speeding up its decarbonisation.

At the same time the implementation of electric vehicles could be managed in such a way that it creates synergies with the simultaneous implementation of increasing amounts of renewable energy.

LCA-aspects of vehicle manufacturing and decommissioning

With vehicles becoming more efficient and emitting less CO_2 in the use phase the share of energy use and GHG emissions in the production and decommissioning phases as part of the total life cycle emission will increase. The use of batteries, fuels cells, power electronics and other new components in electric and hydrogen fuelled vehicles will also lead to a net increase in the absolute energy use and GHG emissions in the production and decommissioning phases. At present insight in these LCA-implications is insufficiently developed. This should be improved in order to minimise the risk that increased emissions in the life cycle counteract the GHG emission reductions achieved by electric and hydrogen fuelled vehicles in the use phase.

The production of components for electric and hydrogen fuelled vehicles and of materials for these components will to significant extent take place in developing economies and low wage countries. Environmental and labour standards may not be at the level that is applied to the same types of industry in Europe. Chain management is required to make sure that the future production of components and materials for electric and hydrogen fuelled vehicles meets a level of environmental and labour standards that is consistent with the sustainability goals that we are trying to achieve by getting these vehicles on the road.

5.2 Summary of information from the literature: electric vehicles

The studies reviewed below identify risks and uncertainties related to the introduction of electric vehicles (incl. plug-in hybrids and range extender electric vehicles. The findings are largely in support of the overview presented in the previous section but also provide some useful additional insights.

IEA Technology Roadmap for Electric and plug-in hybrid electric vehicles

This roadmap presented in [IEA 2009] identifies six strategic goals for accelerating EV/PHEV development and commercialisation:

1. Set targets for electric-drive vehicle sales.
    - National governments should working with “early adopter” metropolitan areas, targeting fleet markets, and supporting education programmes and demonstration projects via government-industry partnerships.
2. Develop coordinated strategies to support the market introduction of electric-drive vehicles.
    - making vehicles cost competitive with today’s internal combustion engine (ICE) vehicles
    - ensuring adequate recharging infrastructure is in place
3. Improve industry understanding of consumer needs and behaviours.
    - Consumer willingness to change travel behaviour and accept different types of vehicles and, perhaps, driving patterns is an important area of uncertainty.
    - Industry needs to gain a better understanding of “early adopters” and mainstream consumers in order to determine sales potential for vehicles with different characteristics (such as driving range) and at different price levels.
    - Auto manufacturers regularly collect such information and a willingness to share this can assist policy makers.
4. Develop key performance metrics for characterising vehicles.
    - Additionally, governments should set appropriate metrics for energy use, emissions and safety standards, to address specific issues related to EVs, PHEVs and recharging infrastructure.
5. Foster energy storage RD&D initiatives to reduce costs and address resource-related issues.
    - In particular, lithium and rare earth metals supply and cost are areas of concern that should be monitored over the near-to mid-term to ensure that supply bottlenecks are avoided.
    - Over the medium term, strong RD&D programmes for advanced energy storage concepts should continue, to help bring the next generation of energy storage to market, beyond today’s various lithium-ion concepts.
6. Develop and implement recharging infrastructure.

Realisation of these strategic goals can be seen as a critical success factor. Inversely anything that may hinder the realisation of these goals then contributes a potential risk / uncertainty to the implementation of electric and hydrogen fuelled vehicles.

Recommendations from this document, pertaining to various risks and uncertainties, further include:

- Governments should help offset initial costs for battery manufacturing plant start-up efforts to help establish and grow this important part of the supply chain.
- When EVs and PHEVs gain a sufficient long-term market share, increased taxation on electricity may be needed to maintain state revenues currently lifted by taxation on fossil fuels. This may be partly counterbalanced by cost reductions resulting from technological advances and learning. Countries may also shift toward different taxation systems, possibly based on factors such as GHG emissions, infrastructure use, pollutant emissions, noise, and/or the occupation of public land.
- While it will be necessary to standardise the vehicle-to-grid interface, it is important to avoid overregulating in order to allow for innovation.
- Use a comprehensive mix of policies that provide a clear framework and balance stakeholder interests. Governments should establish a clear policy framework out to at least 2015 in order to give stakeholders a clear view.
- National roadmaps can be developed that set national targets and help stakeholders better set their own appropriate targets, guide market introduction, understand consumer behaviour, advance vehicle systems, develop energy, expand infrastructure, craft supportive policy and collaborate, where possible.

CE Delft / Ecologic / ICF 2011 study on the potential impacts of large scale market penetration of EVs in the EU, with a focus on passenger cars and light commercial vehicles

According to [CE 2011] electric vehicles are still far from proven technology. There exist many uncertainties with respect to crucial issues like:

- The battery technology (energy capacity in relation to vehicle range, charging speed, durability, availability and environmental impacts of materials).
- Well–to-wheel impacts on emissions.
- Interaction with the electricity generation.
- Cost and business case of large scale introduction.

Key variables that impact the development but are currently still uncertain are:

- Cost of the vehicles and/or batteries, in combination with the vehicle and battery lifetime.
- Customer response to cost and ranges of battery-electric vehicles as well as plug-in hybrids and range extender electric vehicles.
- Charging point availability and grid limitations to charging.
- Government policy.
- Battery and electric vehicle production capacity limitations.
- Oil and electricity price.

How to Avoid an Electric Shock Electric Cars: From the Hype to the Reality, T&E 2009

[T&E 2009] highlights the following issues:

- EU ETS sets a cap on emissions from the power sector and large industry of 21% below 2005 levels by 2020. CO_2 emissions from electric cars are indirectly covered by the EU ETS through the cap. This means that, in principle, any additional CO_2 emission resulting from the additional demand for electricity production for electric vehicles would have to be compensated by emission reductions in another sector. In practice, this may not be (entirely) the case, for two reasons:
    - The first is that over half of the emission reductions may be offset through the Clean Development Mechanism (CDM), which funds emissions savings in developing countries. Additional demand for electricity could thus lead to extra emissions withing the EU, if this extra demand is met by fossil energy sources. The global emissions will increase if the funded CDM projects do not fulfil strict requirements with respect to additionality, meaning that they would not also have been implemented in the absence of funding through CDM.
    - The second reason is that the ETS cap is only set until 2020, and after this period it will be renegotiated. Extra power sector emissions for electric vehicles might play a role in setting a future cap. The net long term effect of EVs thus depends on the post-2020 target.
- Electric vehicles may increase the demand for cheap, CO_2-intensive base load power:
    - Charging large numbers of EVs on the low voltage grid requires load management or eventually smart grids. Load management flattens the demand profile, leading to increased demand for base load. Coal-fired power plants are the cheapest but most CO_2-intensive form of base load. [T&E 2009] suggests that strict application of ET-ETS cap or additional policy is necessary to avoid increase in carbon intensity of electricity production.

Green Power for Electric Cars, CE Delft 2010

In addition to the above [CE 2010] states that the Renewable Energy Directive (RED) could be further improved so that actual data is reported on renewable electricity used for vehicle charging. In the FQD and regulation on CO_2 and cars, more realistic methodologies should be implemented to take into account the actual energy use and the CO_2 emissions of electricity used in these vehicles. This requires accurate metering, which is also an important aspect to ensure any future regulation of electricity and to provide an opportunity for demand side management.

In addition to the latter it can be noted that this is also important /essential to allow the possibility of differentiated tax rates for electricity once it becomes necessary to recoup lost revenue from decreased sales of conventional fuels – i.e. different tax rate for transport electricity use versus households / heating.

EUCAR 2009, The Electrification of the Vehicle and the Urban Transport System

In [EUCAR 2009] the following risks and uncertainties as well as mitigation measures are identified:

- Coordinated action required in a consistent direction from short term (based on today's technologies), to long term solutions where adapted and new technologies will enable the electric vehicle to be affordable and dominant in the urban regions.
- Standards and common interfaces (e.g. vehicle-to-infrastructure) need to be agreed upon quickly for Europe as a whole to avoid a fragmented pattern of local competing and incompatible solutions.

- To achieve a large scale replacement of the conventional fossil-based ICE vehicle by EV, there is a need to support an accelerated evolution (but not revolution) of today's EV technologies. For future electric vehicles it seems to be appropriate to progressively introduce more and more dedicated design solutions for the vehicle in order to be able to use optimised component technologies.
- R&D needs to address the following major areas:
    - An affordable and safe battery system with improved performance and lifetime
    - An efficient vehicle and energy management system
    - A dedicated vehicle-to-infrastructure interface

ERTRAC 2009, European Industry Roadmap Electrification of Road Transport

The roadmap presented in [ERTRAC 2009] mentions the following risks and uncertainties:

- Substantial reservations persists about the long-term performance of Li-ion batteries under the extreme heat, cold, humidity and vibration conditions that automobiles have to endure on a daily basis.
- Cost and supply constraints will keep the booming HEV, EV markets in a critical state of flux for several years. Specific uncertainty is related to the availability of reliable and diversified supplies of permanent magnets necessary to assure high efficiency and high power density (compact) electrical motors.
- From one side prospective users are asking for EV capabilities well beyond those that the OEMs can deliver, on the other side an overenthusiastic market threatens to pressurise the spread of unsafe vehicles, bad practices and inefficient infrastructures that must be avoided.

AEA 2009, Market outlook to 2022 for battery electric vehicles and plug-in hybrid electric vehicles

Risks and uncertainties identified in [AEA 2009] include:

- The greatest barrier for successful EV introduction is public perception. Consumers need to be convinced that electric vehicles are a robust technology and that they can fulfill their requirements, particularly in light of the lack of infrastructure and the need to plug-in the vehicle.
- The major technological risk associated with EVs and PHEVs is owning the battery:
    - Firstly, the batteries are expensive to replace (they are largely responsible for the price premium over conventional vehicles) so if they failed prematurely yet outside the vehicle warranty the owner could be left with a sizeable bill.
    - Secondly, there is an issue regarding the value of the battery upon re-sale of the vehicle. Given that it will represent a large proportion of the value of the vehicle would the battery may need to be inspected prior to re-sale. It is also not clear how the residual value of the battery would be priced, given that battery performance (with most battery chemistries) degrades with use.
    - Thirdly, lithium-ion battery technology, which is likely to be the battery technology of choice for many EVs and PHEVs, is still relatively new to market, particularly in an automotive application. Consequently, this will exacerbate the fears amongst some consumers of a potentially costly battery failure.

This issue can be resolved using appropriate business models for battery leasing, vehicles leasing, or subscriptions for car use or mobility.

5.3 Summary of information from the literature: hydrogen vehicles

Socio / Economic Analysis, deliverable D 3.22 (Final Report) of Phase II of the HYWAYS project, www.hyways.de

One of the risks mentioned in [HYWAYS 2007] relates to infrastructure investments and how they can be matched to the number of vehicles on the road. The tendency exists to dimension initial infrastructure for growth, i.e. to match a fleet size that is aimed to met somewhere in the future. This first of all leads to underutilization of the infrastructure in the early phase of roll-out, involving significant costs. But given the overall uncertainties regarding the market success of H_2 cars the roll-out of hydrogen infrastructure also poses a potential risk of losing several billion Euro's due to investments in premature H_2 infrastructure and H_2 car development that in the end are not utilized at all.

Matthias Altmann, Towards a European Hydrogen Roadmap

According to [Altmann 2004] confidence in hydrogen to become a safe "public fuel" is an important issue and depends on:

- Existing set of EU-wide regulations/ technical standards relevant for hydrogen applications have to be implemented on national level for practical use
- Commitment and participation of authorities, R&D institutions, and commercial companies in the development and implementation of technical solutions, regulations and standards related to hydrogen safety
- Global collaboration in the development of internationally harmonised rules is specifically important for global vehicle and fuel markets
- Validation of safe applications, codes & standards in demonstration projects
- Continuous and systematic governmental and industrial funding for competence building measures to improve level of expertise in authorities and organizations assisting in approval processes
- Communication that industry works on standards which ensure safe products

McKinsey, A portfolio of power-trains for Europe: a fact-based analysis

[McKinsey 2009] analyses the consequences of a roll-out scenario that assumes 100,000 FCEVs in 2015, 1 million in 2020 and a 25% share of the total EU passenger car market in 2050. This scnerio is found to result in a cumulative economic gap (defined as the delta between the TCO of a fuel cell vehicle and that of conventional vehicle, multiplied by the number of vehicles in the respective year) of €25 billion by 2020. Almost 90% of this relates to the relatively higher cost of the FCEV in the next decade. Around €3 billion investment is required for a hydrogen supply infrastructure (production, distribution, retail) for 1 million FCEVs by 2020. Of this investment, around €1 billion relates to retail infrastructure. In the first decade the infrastructure will suffer from low utilisation by a small number of FCEVs. This could lead to a potential write-off of around €0.5 billion per annum if roll-out is terminated or delayed.

If the cumulative economic gap for FCEVs of €25 billion up to 2020 is to be met by only a few car manufacturers, they will each need to finance €1 billion per year. An incentive to ramp up production therefore only exists if most car manufacturers commit and co-ordinate, and government provides temporary funding support.

5.4 Summary of lead times, risks and uncertainties associated with applying electricity and hydrogen to reduce transport's CO_2 emissions

Table 1: Overview of lead times, risks and uncertainties associated with applying electricity and hydrogen to reduce transport's CO_2 emissions

	lead times, risks and uncertainties	EVs	PHEVs / EREVs	FCEVs
policy development and implementation	uncertainty about long term targets	xxx	x	xxx
	lead time for policy development – development of policy instruments that provide a structurally positive business case	xxx	xx	xxx
	availability of appropriate test procedures	x	x	x
	quality of the policy instruments	x	x	x
Market development	vehicle technology and cost development – costs of crucial components – improved storage technology	 xxx xxx	 x xx	 xx xx
	availability of appropriate infrastructure for energy distribution (fuelling / charging)	xx	x	xxx
	availability and costs of renewable energy	xx	x	xxx
	impact of supply and demand oriented policy measures on the business case	xxx	x	xx
	availability of resources – crucial materials – production capacity	 xxx xxx	 xx xx	 xx xx
	"sustainability" of stakeholder attitudes and interests – consumer acceptance of vehicle attributes – feasibility of developing new business models	 xxx xxx	 x x	 x x
Net environmental impact	timely availability of sufficient renewable energy	xx	x	xxx
	interaction with the energy system	xx	x	x
	LCA-aspects of vehicle manufacturing and decommissioning	xxx	xx	x

5.5 Possible strategies for managing and reducing risks

5.5.1 Policy development and implementation

Uncertainty about long term targets

- Early definition of long term climate goals. And making these targets more binding to future government by anchoring them in "climate laws".
- Provide convincing evidence of the achievability of ambitious long term targets in order to increase acceptance of these targets.
- Make sure that targets for transport and for energy sector are consistent.

Lead time for policy development

- Start in time with developing and creating acceptance for policy instruments necessary for supporting the large scale roll-out of electric and hydrogen vehicles and other sustainable transport options.
- If harmonised European tax policies are required, the design of these policies should start in time.

Availability of appropriate test procedures

- Develop necessary procedure well before technologies are ready for (next step in) market uptake.
- Invest in sufficient testing and evaluation of developed test and valuation procedures to be able to identify and repair design flaws in time.
- Concretely improvements may be necessary in the procedures for assessing CO_2 emissions from plug-in hybrid and range extender electric vehicles.

Quality of the policy instruments

- Develop methodology that allows future CO_2 or energy efficiency legislation as well as fiscal instruments to deal with electric and hydrogen vehicles in an adequate and balanced way.
- Make sure that future developments of RED and EU-ETS are tailored to ensure that increasing amounts of renewable energy can be supplied to transport sector to enable GHG reduction through application of electric and hydrogen fuelled vehicles.
- A harmonised approach at the European level may be necessary to develop tax policy reforms that make sure that increased use of electricity and hydrogen in transport will not lead to structural reductions in fuel excise duty revenues.
- The European Commission can to some extent help to avoid fragmentation of policy development at different government levels and in different geographical regions creating an overall framework and incentives.

5.5.2 Market development

Vehicle technology and cost development

- Focus R&D on innovations that use features of sustainable propulsion systems to create vehicles with added value.
- Focus R&D on product and production process innovations that reduce costs of (critical components for) electric and hydrogen fuelled vehicles.
- Invest in R&D aimed at development of alternatives for lithium-based batteries with equal or better performance.
- Develop consistent policies with a longer time horizon to create a favourable climate for investments in R&D, product development and production capacity.
- Develop short term policies for early market formation. Demand from pilots, early adopters and innovators lead to increased production volumes and increased investments that both accelerate cost reductions and product improvements.
- Prepare and implement (generic) economic instruments that improve the business case of sustainable options and enable market introduction also when options do not become sufficiently competitive compared to conventional vehicles on their own.

Infrastructure development

- Set-up large scale field tests to experiment with different options for the design of future energy infrastructures for electric and hydrogen fuelled vehicles. In different pilot regions different options for the dominant design can be tested.
- Besides with the technical aspects of the dominant design, large scale field tests should also experiment with business models and payment systems.
- Promote developments of alternatives for conductive slow charging.
- Develop a suitable strategy for sharing the burden of underutilisation of specific energy distribution infrastructure in the early stages of market introduction of electric and hydrogen fuelled vehicles.

Energy cost development

- Avoid increases in the price of renewable energy resulting from competition over scarce supplies.
- Invest in R&D on more efficient ways of producing renewable.

Impact of supply and demand oriented policy measures on the business case

- A combination of supply and demand oriented policy instruments can be used to make sure that sustainable options are developed and marketed on the one hand and adopted by consumers on the other hand.

Availability of resources

- In view of the scarcity of renewable energy in the coming decades, technological R&D for electric and hydrogen fuelled vehicles should be aimed at developing cost effective means to reduce energy consumption at the vehicle level. At the same time the development of renewable energy generation capacity needs to be managed so that it matches the increased demands from the transport sector.
- In view of the scarcity of specific materials in the coming decades, technological R&D should be aimed at developing components based on alternative, more abundantly available materials.
- A joint European foreign policy may be necessary to assure the availability of scarce materials to the European industry.
- The growth of production capacities may need to be actively managed at an international level to avoid that scarcity leads to increased prices that slow down the market uptake of electric and hydrogen fuelled vehicles.

"Sustainability" of stakeholder attitudes and interests

- Consistent and stable short and medium term policies are required to provide an investment climate that allows stakeholders in the market to bridge the "valley of death".
- Transition management by governments has a strong role in avoiding unnecessary incidents or other causes for bad press for electric and hydrogen fuelled vehicles.

5.5.3 Net environmental impact

Timely availability of sufficient renewable energy

- Make sure that future developments of RED and EU-ETS are tailored to ensure that increasing amounts of renewable energy can be supplied to transport sector to enable GHG reduction through application of electric and hydrogen fuelled vehicles.
- Additional policies may be necessary to assure that the demand from electric and hydrogen fuelled vehicles for renewable energy is met by additional supply capacity rather than by shifting delivery of existing renewable energy supply from one sector to another.

Interaction with the energy system

- When load management for charging electric vehicles leads to flattening of the demand curve, strict application of ET-ETS cap or additional policy is necessary to avoid increase in carbon intensity of electricity production.

LCA-aspects of vehicle manufacturing and decommissioning

- Identify possible problems with the life-cycle environmental impacts of electric and hydrogen fuelled vehicles as soon as possible so that mitigation measures, specifically in the realm of chain management, can be developed and implemented before large investments in production and recycling infrastructure are made.

5.6 Conclusions

The success of using electricity and hydrogen as a means to drastically reduce GHG emissions of the transport sector by 2050 depends on a multitude of factors. In as far as these factors are exogenous to the transport sector, or endogenous but unpredictable or difficult to manage, they constitute risks or uncertainties or cause undesired long lead times.

Risks, uncertainties and lead times can be categorised as pertaining to three main conditions that must be fulfilled in order for electric and hydrogen fuelled vehicles to have the desired impact on GHG emissions:

1. Policies must be developed and implemented which promote the installation of the required energy infrastructure and the use of electric and hydrogen-fuelled vehicles;
2. Electric and hydrogen-fuelled vehicles need to reach significant market shares;
3. The environmental impact of the applied electric and hydrogen-fuelled vehicles must be such that it leads to a significant net reduction in GHG emissions.

Main identified uncertainties pertain to:

- Developments of costs for critical components of electric and hydrogen fuelled vehicles and the resulting possibilities for creating a favourable business case without subsidies or fiscal stimulation;
- Availability of critical materials, including the feasibility of scaling up mining and production activities fast enough to keep up the pace with developing demand;
- Development of the prices for fossil and renewable energy;
- Timely availability of sufficient quantities of renewable energy.

The following factors have been identified as significant risks:

- Unforeseen loopholes in policy instruments reducing the effectiveness of the policy or the net GHG impact;
- The possible occurrence of a "valley of death" in the market introduction when after serving the "innovators" and "early adopters" segments in the market the price and characteristics of electric or hydrogen fuelled vehicles have not yet developed to a level that is considered acceptable by the "early majority" segment of the market;
- High costs per vehicles in the early stage of market entry due to underutilisation of energy supply infrastructure;
- The (lack of) endurance of the current favourable attitude of governments, investors, consumers and other stakeholders towards electric vehicles.

Substantial lead times are caused by:

- the time to develop and implement required policy instruments at the European level;
- the finite rate of fleet renewal;
- the slow, iterative process of early market formation through subsequent niches.

All in all the implementation of electricity and hydrogen as GHG reduction options for the transport sector is a transition that involves drastic and structural changes in both the transport and the energy sector and that will take several decades to start up, roll out and complete. Governments and stakeholders in the market need endurance and a long term vision to manage this transition in an effective way. Mitigating risks and taking away uncertainties is an important part of that. Proactive steps are required in the short term in laying the ground work for longer term policy instruments, in early market formation and in setting up and managing a process that timely delivers the insights that are necessary to develop a suitable dominant design for the energy distribution infrastructure.

5.7 References

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6 Economic instruments, particularly usage pricing

Objectives:
The purpose of this sub-task was to:

- Explore and identify key risks and uncertainties associated with the achievability of economic instrument-related policies, including lead times for policy implementation and time lags to the resulting impact on emissions
- Assess the extent to which key factors outside the transport sector will affect decarbonisation of transport
- Develop approaches to address those risks and uncertainties and optimize achievability

Summary of Main Findings

⇒ If road usage charging is to be introduced, it should take place in addition to, rather than instead of, fuel taxation.

⇒ Many of the associated risks are linked, and some often mentioned issues (*e.g.* public acceptability and wider political risks) can be seen in the context of a family of economic, social and environmental risks that were identified.

⇒ Many of the latter are real, and could be addressed either in the design of the charging scheme, or by the introduction of complementary policy instruments (which could even be introduced in advance of the charging scheme itself).

As noted above, this section focuses on the risks and uncertainties associated with the use of economic instruments that could be put in place to charge users to use roads. The potential role of economic instruments in reducing transport's GHG emissions was identified as a risk and uncertainty in the final report of the previous *Routes to 2050?* project (see Skinner *et al*, 2011)[26]. This section focuses on user charging, as the instrument clearly has a potential role to play in relation to reducing transport's CO_2 emissions, but has not yet been implemented that widely and its implementation still proves to be controversial. Additionally, the relationship between user charging and fuel taxation is a potential issue, as the latter is arguably a crude form of road pricing by itself. On the other hand, other economic instruments such as the potential role of vehicle taxation, including the differentiation of purchase and circulation taxes, in reducing transport's CO_2 emissions is more widely accepted and is being increasingly implemented. For this reason, within the *Routes to 2050 II* project it was considered to be more appropriate to examine other issues associated with the implementation of vehicle taxes, such as their knock-on consequences (see Smokers *et al*, 2012), rather than any risks and uncertainties associated with their implementation.

It is also worth noting that road user charging is different to the other two issues covered in Sections **Error! Reference source not found.** and 5 of this report, as these previous two focused on the risks and uncertainties with respect to selected technical options for reducing transport's GHG emissions, whereas this section deals with the risks and uncertainties associated with the implementation of a policy instrument. However, this section is set out in a similar way to the previous sections. First, it identifies the conditions under which, and therefore some risks and uncertainties attached to, applying road user charging to reduce transport's CO_2 emissions. This is followed by a review of the literature and then a summary of risks and uncertainties associated with applying user charging as an instrument to reduce

[26] Whilst it is possible to apply user charges to other modes of transport, e.g. see van Essen *et al* (2010), this paper focuses on roads.

transport's CO_2 emissions. The potential timelines, both political and relating to implementation, are then discussed, before the section concludes with potential elements of a strategy to manage and reduce risks the risks identified.

6.1 Using user charging to reduce transport's GHG emissions

As noted above, all Member States already have a crude form of road user charging in place in the form of fuel taxation. Existing fuel taxes bring in significant revenues for national administrations and were originally seen as a means of raising revenue, rather than as transport policy instrument. Fuel taxation has a number of benefits as a revenue-raising instrument as the level of income is relatively predictable and reliable; it is also generally considered to be progressive, as those on higher incomes generally drive more, and it is simple and easy to administer. However, in recent years fuel taxation has been used as an instrument of transport policy, either being raised above inflation to reduce CO_2 emissions or being differentiated to encourage cleaner fuels (Ekins and Potter, 2010).

However, fuel taxation is considered to be a crude means of user charging as there are better ways of charging vehicles to reflect their wider impacts, e.g. air pollution and congestion, which would be fairer, make the transport system more efficient and influence behaviour. Introducing user charging by adopting a marginal cost pricing approach in which the external costs of the wider impacts of transport are internalised, i.e. included in the price of transport, is considered to be the first best and most economically efficient approach, as was noted in the first EU GHG Transport 2050 project (see Section 3.2 of Skinner *et el*, 2010). User charging is also a more flexible instrument than fuel taxation, as it can be used to target particular modes, e.g. heavy goods vehicles, particular areas, e.g. city centres, or particular infrastructure, e.g. motorways, when a general increase in fuel taxation is not an option. For these reasons, user charging can be seen as an alternative to fuel taxation.

From the perspective of applying user charging as an instrument to reduce transport's CO_2 emissions, however, CO_2 emissions reductions will only be achieved if there is a reduction in the overall demand for transport, i.e. if the introduction of user charging leads to increased costs of use.

Whilst it is possible to estimate and internalise some of the external costs of transport, e.g. air pollution, noise, congestion, accidents and climate change, as well as the costs associated with the maintenance, operation and even the construction of roads, other external costs, such as those imposed on ecosystem services and biodiversity and the scarcity of space on infrastructure, are more difficult to evaluate and are rarely included in the assessment of the external cost pricing of transport. For example, the IMPACT study reviewed estimates of external costs associated with biodiversity, but did not include biodiversity in its subsequent policy analysis (CE Delft *et al*, 2008a and b, respectively). On the other hand, TEEB (2009) highlighted the value of ecosystems and biodiversity and recommended that this value be recognised in sectoral policies, such as those of the transport sector. The impact of road user charging is also dependent on the time and location of its use, as noted above. Hence, replacing fuel taxation with user charging would lead to reduced demand at certain times and places, e.g. peak travel in urban areas, but to increased demand elsewhere, e.g. in rural locations. The net impact on demand, and therefore on CO_2 emissions, of replacing fuel taxation with road user charges would therefore depend on the total impact on demand in all of these areas.

As the purpose of this paper is to look at the risks and uncertainties in terms associated with selected options and policy instruments for reducing transport CO_2 emissions, in the remainder of this section, it will be assumed that road user charging is introduced **in addition**

to, rather than instead of, fuel taxation. Such an approach can be justified (often referred to a "second best" from the economic perspective), as:

- It is often not possible to internalise all external costs, as noted above;
- External cost pricing on its own is often not sufficient for meeting wider policy objectives;
- Pricing incentives that are higher than can be justified on the basis of external cost pricing are often needed to change behaviour to deliver wider policy objectives;
- Additional revenues are often needed to, for example, improve transport infrastructure more generally, including for modes not covered by charging.

In this respect, it is likely that the principal risks and uncertainties associated with the introduction of road user charging will be related to:

- Economic impacts, particularly local impacts.
- Social impacts, relating to increasing the costs of transport use.
- Environmental impacts, e.g. caused by the displacement of traffic for location-specific instruments.
- Political risks, associated with wider public acceptability and justification for user charging.

6.2 Summary of information from the literature

This section summarises information from the literature review, complemented by issues raised by stakeholders at the focus group meeting on 4 May 2011 and comments by internal reviewers.

In relation to the economic risks and uncertainties of applying user charging to transport, Akyelken (2010) noted the economic arguments in favour of user charging for freight, but was concerned that the impact on prices could be inflationary (quoting TransCare, 2006). The paper also expressed concerns about the potential wider economic effects on employment and regional development of internalising the external costs of transport. In the final report of the ProgTrans study, Rommerskirchen et al (2010) concluded that the internalisation of external costs in the European road haulage industry would lead to substantially increased costs for the road freight sector as well as the foreign trade economy. It argued that this would potentially affect European competitiveness and the internal aim of equal opportunities for economic development, employment and competitiveness. However, the study does not appear to take account of the potential benefits of reducing externalities. On the other hand, JRC (2010) concluded that the benefits in terms of reduced externalities of charging hauliers for their external costs outweighed the limited negative impacts on individual operators.

Given that this assessment assumes that user charging is implemented in addition to, rather than instead of fuel taxation (see Section 6.1), governments have the potential to increase its income from applying user charging in addition to fuel taxation. However, in order to increase the political and public acceptability of the introduction of a new charge, revenues could be recycled to support the development of transport infrastructure for other modes (reference to be added in July).

ICCT (2010) noted that one of the challenges that needs to be overcome when introducing congestion charging was the concerns of business with respect to the economic impacts of any congestion charging scheme. They noted that Transport for London concluded that, after five years of the London congestion charge, there was no measurable impact on business and economic activity in London resulting from the introduction of the charge. Additionally, they quoted Opiola (2010) who argued that businesses should benefit from the congestion charging, service times should improve, as should the reliability of delivery vehicles. In its review of policies to reduce land transport's GHG emissions, UK ERC (2009) concluded that the public needed to be convinced of the benefits of road pricing, as they were generally sceptical of road user charging. This was in part due to a perception that they were already paying too much for their car use and concerns about increases in costs that would result, particularly in relation to the effects on low income groups (see below).

Policy instruments that aim to reduce transport's CO_2 emissions by increasing the cost of use all have the potential for adverse social and distributional impacts. In particular, such policies would impact on the affordability of transport and thus the mobility of different social groups, particularly low income groups and those living in rural areas. While on average, congestion charging and other forms of user charging targeting drivers could be considered to be progressive, as the rich tend to drive more, those worst affected would be low income car drivers who have no alternative to using their car, at least in the short-term. It was also noted that there is a risk of some traffic avoiding charging zones, which could also adversely affect the social groups living in those areas (reference to be added in July). There is also some evidence from the introduction of user charging for heavy goods vehicles in Germany that heavy goods vehicles also take action to avoid charged routes, in this case motorways, and use secondary routes instead (CE Delft *et al*, 2008b).

In a review of policy instruments to reduce transport's CO_2 emissions, UK ERC (2009) noted that road charging is viewed with scepticism by the public, although research on public attitudes leads to inconsistent conclusions. They note that any intervention that is perceived to interfere with how people use their cars tends to lead to knee-jerk reactions and public opposition. The report noted that complementary instruments are important, such as the prior investment in public transport that was undertaken in London prior to introduction of its congestion charge. Akyelken (2010) notes the perception of an "inalienable right to mobility" that would be a barrier to any policy instrument perceived as restricting travel, as well as concerns about distributional impacts. ICCT (2010) notes that securing initial public acceptance can be difficult, but that public support can increase once a scheme has been introduced. They note the importance of effectively communicating the overall benefits of the charge and of upfront investment in public transport to absorb those shifting modes and to provide affordable mobility for those on low incomes. The revenue from the charge could be used to improve public transport and travel conditions for other modes, which can also improve effectiveness of congestion charging. Some of the revenues could also be recycled back to residents of affected areas.

Many studies support the conclusion reached in Section 6.1 that implementing user charging instead of fuel taxation risks increasing CO_2 emissions. OECD/ITF (2007) note that fully aligning charges with external cost estimates could reduce off-peak driving costs and therefore increase off-peak demand. They note that, while localised congestion charging schemes were more likely to reduce overall driving, the approach would not necessarily be optimal from an economic perspective. UK ERC (2009) notes that some authors urge caution as optimising road use could increase traffic levels and CO_2 emissions, particularly if charges offset by reductions in fuel duty (quoting EAC, 2006). In turn, they note that reducing road usage could lead to increases speeds and therefore CO_2 emissions and that improving travel time without affecting demand could increase emissions, if, for example, a scheme is revenue neutral (quoting Grayling, 2005 and Graham and Glaister, 2004). UK ERC conclude that revenue raising schemes would deliver CO_2 reductions, while revenue neutral schemes would deliver no, or only marginal, reductions as a result of the redistribution of traffic to lower charged routes, increased speeds and generally lower costs on less congested routes.

ECMT (2007) argues that targeted road pricing and interventions to manage congestion and to influence modal split will be "less than fully successful". However, they note that the impact of road pricing on CO_2 is in part determined by whether it is accompanied by any reductions in fuel taxation, as well as the size of the charges. Ekins and Potter (2010) note that studies have suggested that replacing fuel duties with road user charging in a revenue-neutral way could increase traffic and emissions, as motoring costs in less congested areas would fall; activity would also be redistributed towards low-charge areas. Hence, there is a need to increase the price of use, as well as using targeted measures such as congestion charges in some areas and reforming the treatment of transport in personal and corporate tax regimes.

In relation to some forms of user charging, e.g. those that note (at least some elements of) the movements of vehicles, there are concerns about privacy, which need to be addressed (ICCT, 2010). Additionally, the potentially complex technical and administrative systems that need to be put in place could increase costs, thus outweighing the benefits of introducing the schemes (e.g. see Akyelken, 2010).

As a result of the economic and social concerns noted above, the introduction of charging for road users is often politically controversial. Introducing a charging scheme in addition to fuel taxes will increase the cost of use, at least in some locations, which will raise concerns about local social and economic impacts. Where the costs of use increase as a result of user charging, then there would be more general social and economic concerns associated with such costs. In many cases, such concerns can be unfounded or addressed by complementary measures or policy instruments. While arguably it would be important, from the perspective of the internal market, to better harmonise the way in which transport use is taxed within different Member States, in practice it is difficult to reach an agreement on such harmonisation, as agreement on taxation needs unanimity at the European level.

6.3 Risks and uncertainties associated with applying user charging to reduce transport's CO_2 emissions

A summary of the potential risks and uncertainties associated with the introduction of road user charging as a CO_2 reduction instrument for transport, based on the literature review as well as expert judgement, is given in Table 2.

Table 2: Potential risks and uncertainties associated with road user pricing

Type of risk/uncertainty:	Description of risk/uncertainty
Economic (macro)	• Potential effect on wider economy of applying road user charging • Potential impacts on competitiveness position of (national/EU) economy
Economic (micro) and business acceptability	• Local concerns that passing trade would be affected where user prices increase, e.g. in a particular charging zone • Opposition from local business resulting from concerns over potential economic impact • Delivering overall benefits by balancing benefits with costs associated with implementation and monitoring
Social and public acceptability	• Impacts on personal mobility (and therefore accessibility to economic opportunities and social interactions) in areas where user pricing increases price of use • Potential social impacts from increased traffic levels where charges are not applied due to some traffic avoiding the charging zone or infrastructure • Distributional impacts, e.g. particularly short-term impacts on those on low incomes who have no alternative to using their cars in areas where user prices increases • Opposition from public due to concerns over potential adverse impacts
Environmental	• Some environmental impacts, e.g. air pollution, noise, could increase, e.g. where charges not applied due to traffic

	avoiding charged area/route
Political	• Difficulties caused by economic and social concerns, where user prices increase • Risks of being seen to use additional revenues in an appropriate manner • Risks of linking user charging to external cost pricing • Difficulties of agreeing taxation/charging policies at the European level (e.g. subsidiarity)
Privacy	• Charging according to time and location of travel requires knowledge of movements, which potentially lead to privacy issues
Technical and administrative	• Need to develop, potentially complex, technical and administrative systems to administer road user charging

The macro economic impacts of introducing road user charging will depend on the net impact of the costs imposed on users, be they road hauliers or private car users, and the benefits to society of reducing the external costs of transport, in terms of reduced levels of air pollution, congestion and other externalities, including of course transport's contribution to climate change. As noted in the previous section, some studies suggest that the impact on hauliers and the wider economy from the introduction of road charging focusing on these users might be significant (e.g. the ProgTrans study), whereas others suggest that once the benefits have also been taken into account, then these outweigh the costs to hauliers (e.g. JRC, 2010). It is also worth underlining that additional revenue raised from the introduction of road user charging will be used elsewhere in the economy and so be more widely beneficial (as noted by JRC, 2010). More generally, there is a risk of wider economic impacts if transport is overpriced (CE Delft *et al*, 2008b)

From the micro-economic perspective, there are often concerns from local businesses with respect to the economic implications of the loss of passing trade. Such concerns can often lead to local business opposing the introduction of congestion charging, for example. However, as noted in the literature, ex post assessments, e.g. of London's congestion charge, have not revealed any adverse economic impacts. Indeed, there is an argument that local businesses should benefit from lower congestion, which would help to improve access and lead to more reliable delivery times (e.g. ICCT, 2010).

Road charging systems are, by their nature, more complex policy instruments than, say, fuel taxation. In this respect, they are likely to need more complex technical and administrative systems (e.g. Akyelken, 2010). However, from an economic perspective, it is important not to make the design of the system too complicated to the extent that the costs of operation and enforcement risk outweighing the benefits or costing too much of the additional revenue raised. The systems also need to be designed to take account of people's concerns about privacy, as any system that charges by time and/or location has to monitor the movements of vehicles.

From a social perspective, there are often concerns about the impacts on personal mobility of increasing charges for using transport. In this respect, it is often argued that road user charging is progressive, as richer people tend to drive more. However, many people, particularly those on lower incomes who rely on their car use for access to services and employment, will have genuine concerns about the impacts on their personal mobility resulting from the introduction of road user charging. Additionally, in many countries there is a widespread perception that drivers already pay enough for their car use. As a result of these various concerns, the public is often reluctant to accept the introduction of road user charging, either locally in the form of congestion charging or more widely. In this respect, complementary policy instruments, which could be directly funded from the charging revenues, are important, such as the prior improvements to buses that were introduced in London prior to the introduction of congestion charging (e.g. UK ERC, 2009).

From an environmental perspective, reductions in CO_2 emissions will be guaranteed by introducing user charging in addition to, rather than instead, of fuel taxation (see Section 6.1). In the charged area, or on the charged infrastructure, other environmental impacts linked to vehicle use, such as air pollution and noise, are also likely to decrease. However, there is the possibility, depending on the design of the scheme, for non-charged zones or infrastructure near to the charging area to experience increased traffic levels (as some traffic avoids the charged area), which could lead to increased levels of adverse environmental and social impacts in these areas. However, it is possible to minimise such effects through the design of the scheme, e.g. traffic calm or restrict access to such areas.

Arguably the most significant risks associated with the introduction of road user charging are political, resulting from the potential lack of public and business acceptance based on the economic, social and environmental risks noted above. Such concerns often lead to reluctance on the part of the public and business to consider, let alone support, the introduction of road user charging. Some of these risks can be anticipated and overcome in the design of the policy or, for example where it is not possible to mitigate adverse effects through design, some of those adversely affected could compensated, e.g. through welfare payments or lower business taxes.

There are wider political risks associated with the way in which the introduction of user charging is presented. As noted in Section 6.1, from an economic perspective it is best to base user charging on the concept of external cost pricing, perhaps even instead of fuel taxation. However, in order to ensure that road user charging would deliver CO_2 reductions, it was argued that user charging should be used in addition to, rather than instead of, fuel taxation. Applying road user charging in this way already shows risks of arguing for user charging to be based on external cost pricing, as some would argue that existing fuel taxes already covers the external costs of, at least some modes of, transport, including its impacts on climate change. Whereas some forms of user charging, e.g. congestion charging in urban areas, are easier to justify on the basis of external pricing, as it is more difficult to conclude that the costs of congestion are covered by fuel taxation, justifying other types of user charging is more difficult to justify once the link is made to external cost pricing and the charge will be additional to existing fuel taxation. In the longer-term, such a link might make the introduction of charging, say to meet other policy objectives, more difficult.

Finally, there is a risk that if Member States develop their own respective charging schemes without any coordination, then there will be a proliferation of charging schemes that could potentially inhibit the free movement of goods and people within the European Union. However, as has been shown with the agreements on the Eurovignette Directive, it is often difficult to reach an agreement at the European level with respect to the common elements of even voluntary charging schemes.

As noted in Section 6.2, and as we will see in Section 6.5, many risks could be overcome with careful policy design or the introduction of complementary policy instruments. This is not to say that the risks are not real in some cases, just that they can often be addressed to a large extent.

6.4 Identification of political and implementation timelines and key relevant decisions for developing and implementing user charging

At the European level, legislation already existing that sets the framework for tolls and user charges that might be faced by heavy goods vehicles (HGVs) in the so-called Eurovignette Directive (1999/62/EC). This allows some environmental characteristics to be taken into account in such charges, although it does not yet permit the internalisation of all external costs. There is an outstanding proposal to amend the Directive, on which a political agreement was reached in the Council in October 2010, which would enable Member States to calculate and vary tolls on the basis of the external costs of road freight transport in terms of air pollution, noise and congestion. As long as any tolls or user charges are consistent with the requirements of this Directive, then Member States are permitted to introduce tolls and charges on their road transport infrastructure. Hence, there are currently no European policy barriers that present Member States introducing user charging, as long as the scheme is consistent with the Eurovignette Directive, as amended.

In the 2011 transport White Paper, the Commission signalled its intentions to further develop EU policy on user charging for transport (European Commission, 2011). As part of one of the 40 initiatives included in the White Paper, the Commission stated its intention by 2016 to phase in mandatory user charging for heavy duty vehicles, instead of the voluntary Eurovignette, to cover the costs of infrastructure damage, noise and local air pollution. Additionally, the Commission plans to develop guidelines for the application of user charging to other road vehicles, including cars, in order to cover the associated costs of congestion, local pollution, noise, accidents and possibly CO_2 (depending on whether the proposal to introduce a CO_2 element in transport fuel taxes is included in the final version of the revised Directive on the taxation of energy products). A second phase, to be implemented by 2020, would move towards mandatory internalisation of external costs, including noise, air pollution and congestion, for all road modes.

Given the risks associated with implementing charging policies at the European level, as noted in Section 6.1, it is possible that the deadlines set out in the White Paper will not be met, and indeed that the contents of the revised legislation will not be as stringent as desired by the Commission. However, delays with the development of mandatory charging legislation at the European level need not prevent the implementation of user charging in Member States. Some Member States have already implemented road user charging schemes, e.g. urban road user charging schemes in London, Stockholm, Rome, Bologna and Milan (May *et al*, 2010) and HGV road user charging in Germany, Austria, the Czech Republic and Slovakia (Significance and CE Delft, 2010). Generally, these have been successful, although as noted by May *et al* (2010) a number of proposed schemes have been abandoned prior to implementation, e.g. schemes Edinburgh and Manchester, as well as national scheme for the Netherlands and an HGV charging scheme for the UK. The rejections of these schemes, the first two of which were by local referenda, highlight the problems concerned with public and political acceptability of user charging schemes.

The implementation of a successful user charging scheme takes time. For example, in London the scheme took nearly three years from conception to implementation. Transport for London, the organisation responsible for transport in the UK's capital, was asked by the Mayor of London to investigate the options for a Central London charging scheme in July 2000. The Mayor gave the go-ahead for the scheme in February 2002 with a planned start date of one year later. The public consultation process itself lasted 18 months (Dix, 2002).

Apart from the potential timescales between the conception and implementation of charging schemes, there is also the possibility that national legislation will need to be amended in order to allow local or regional authorities to implement road user charging schemes. This was the case in the UK where legislation national legislation was needed in order to first allow London and then to allow other cities to implement congestion charging schemes (Snape and de Souza, 2005). Where such national legislation is required, it is likely that a few additional years will be required before local or regional schemes can be implemented.

6.5 Possible strategies for managing and reducing risks

A number of reports have reviewed the implementation of the existing urban user charges and HGV charges that have been implemented in the EU to date.

In a report produced as part of the IMPACT project, CE Delft *et al* (2008) concluded that successful pricing instruments to internalise costs have a number of identifiable elements. First, instruments should give users means of opting out of the charge, which could be by adopting technological alternatives, e.g. alternative fuels, or alternative means of transport, e.g. public transport. Other important elements include a cap on the maximum charge that can be levied in order to prevent over-pricing and the recycling of revenues to investment in transport infrastructure, particularly other modes. Both of these elements can also help to increase the public acceptability of the scheme. The report also noted that beneficial and adverse effects of the system should be monitored in order to identify whether there is a need for adjustments to charging. They argue that the initial focus of user charging schemes should be on travel where the gap between charges/taxes and costs is largest, where travel alternatives exist or can be provided, where the potential to use other measures is limited and where, consequently, public acceptability will be highest. Examples include roads in urban and sensitive areas, congestion charging and HGV charging. Finally, they noted that pricing strategies should not replace successful non-market instruments, but be used to complement these instead. In this respect, the need for pricing to be part of a wider climate change strategy was noted, which could include a range of other polices, such as vehicle efficiency standards and vehicle taxation and incentives. The need to enable people to opt out of the charging, as noted above, further underlines the need for a range of complementary measures in support of the central charging instrument.

May *et al* (2010), based on the European-funded project CURACAO that evaluated the implementation of various urban road charging schemes in the EU, identified a number of recommendations for the introduction of successful schemes. Most of the recommendations focused on cities and regional authorities that want to implement successful urban road user charging schemes. They begin by suggesting that the respective authorities state clearly, briefly and simply the objectives of the scheme and to adhere to these consistently. Subsequently, authorities should adopt a flexible and dynamic approach in developing their scheme, whilst ensuring that the scheme will be as effective as possible. They argued that it was important to address issues relating to acceptability from the beginning of the process, which should include a demonstration of the serious nature of problem that user charging is attempting to address, explain why an instrument that some might consider to be as drastic as user charging is needed, as well as the fact that it is likely to work. In this respect, all positive and negative impacts must be clearly identified and effectively communicated. Careful attention should be paid to the implementation process with the aim of obtaining a consensus among key stakeholders, as far as is possible.

The paper also noted that authorities should be cautious about holding referenda, unless there is an obligation to do so, as the public acceptance of user charging tends to increase once the scheme is operational, e.g. in London and Stockholm approval increased by 15% after the first year. Finally, they note that the design of the scheme should not be technology-driven and that the technology and administrative systems should be selected with costs in mind. Resources should also be allocated for establishing the baseline conditions and for monitoring of performance against the stated objectives. In line with the conclusions of CE Delft *et al* (2008), May *et al* (2010) also note that the use of revenues is important and that road user charging schemes should not be designed or implemented in isolation, but introduced in the context of wider complementary instruments. Indeed, they conclude they conclude that the way in which revenues are used is critical in determining both the acceptability and the effectiveness of the scheme.

Recommendations for national administrations focused on the need to develop clear national strategies that outline the rationale behind road user charging, which should be part of a wider transport strategy. National authorities should also ensure that appropriate legislation exists to allow local and regional authorities to plan and implement charging schemes, as well as ensuring that these authorities can put in place the necessary governance structures to implement road user pricing and the necessary complementary measures. On the other hand, the European Commission should develop guidance for authorities and offer relevant financial support.

In a report looking specifically at the potential social and distributional impacts of potential policies to reduce transport's CO_2 emissions, XX (2011) identified a number of recommendations for policy makers, such as the need to:

- Understand the type, scope and geographical location of the disadvantaged groups that might be affected by user charging.
- Engage with such groups, or at least their representatives, to understand their concerns, particularly with respect to accessibility and affordability. Take such concerns into account when designing policies, and communicate to disadvantaged groups how their concerns have been met.
- Focus on the potential impacts on low income drivers, particularly those who have a lack of viable alternatives to the car at the times at which they need to drive, or to the locations to which they need to drive.
- Consider the use of exemptions or concessions when addressing the concerns of disadvantaged groups.
- Take account of the alternatives to travel, and potentially improve, these, as a means of addressing the concerns of potentially disadvantaged groups.
- Ensure that the resulting reductions in transport's CO_2 emissions are maintained, i.e. that complementary demand management measures are needed to ensure that the CO_2 benefits of user charging are "locked in".
- Take account of, and communicate, the wider benefits of such policies for transport users and non-users in the course of developing policies, e.g. improvements in air quality and reduced noise levels, severance and road traffic accidents, that result from less traffic.
- Monitor the impact of policies on different groups over time in order to ensure that the benefits are maintained and that additional measures are taken to address any erosion of the CO_2 or other benefits.

6.6 Conclusions

This section has argued that, if road user charging is to be implemented to reduce transport's CO_2 emissions, it should be introduced in addition to, rather than instead of, fuel taxation. In this respect, a number of economic, social, environmental and political risks and uncertainties exist. Many of these risks are linked. For example, two of the main risks that are often mentioned in relation to road user charging are public acceptability and wider political risks. However, these risks are often based on the other economic, social and environmental risks that were identified. Many of the latter are real, but could be addressed in the design of the charging scheme, or by the introduction of complementary policy instruments (which could even be introduced in advance of the charging scheme itself).

At the European level, there is currently little in the way of barriers to implementing road user charging, as long as the schemes are consistent with the Eurovignette Directive. While the Commission has indicated that it intends to phase in mandatory charging (to cover at least some external costs) by 2016 for heavy goods vehicles and by 2020 for all road modes, in the meantime Member are still able to implement road user charging schemes. In Member

States, there might be a need for additional national legislation in Member States before national, regional and local authorities are able to implement road user charging. This could mean that add there would be a lead time of perhaps a couple of years in some countries before the relevant legislation is in place. Once permitted, it could take the relevant authorities a number of years, perhaps three, to design the scheme, engage the public, business and other stakeholder and make the scheme operational. When (or if) a mandatory charging framework is put in place at the European level, all national, regional and local schemes would potentially have to be redesigned in order to be consistent with the respective EU framework. However, EU legislation usually gives Member States a number of years to make national policies consistent with EU legislation.

As noted above, many of the risks can be reduced or even eliminated by adopting the various elements identified in the studies reviewed in Section 6.5, where a number of common themes emerged. Consequently, elements of a possible strategy to manage and reduce the risks and uncertainties associated with the implementation of road user charging to reduce transport's CO_2 emissions might be:

- The need for alternatives to travel in the charged area in order to ensure that journeys can still be made.
- The importance of recycling revenues to fund non-charged modes in the charged area in order to improve the public and business acceptability of the schemes.
- The need to monitor beneficial and adverse impacts, particularly those that form the objectives of the scheme, which should be clearly and simply stated from the outset. Changes to the scheme, e.g. charging levels, should be introduced as appropriate, in light of the evaluation of the monitoring results.
- The need for engagement with the public, business and other relevant stakeholders, as well as with representatives of disadvantaged groups. Authorities should be prepared to be flexible and dynamic in light of concerns raised, or any other issues identified.
- Issues that might cause a barrier to the acceptability of schemes need to be addressed explicitly and communicated transparently from the beginning of the process. The rationale for, and potential implications (both positive and negative) of, the scheme should be communicated, while adverse potential impacts should be addressed where possible in the design of the scheme.
- Pricing schemes should be introduced alongside complementary policy instruments in order to deliver a wide range of policy objectives, and ideally as part of a broader climate change or transport strategy.
- As part of the development process, resources need to be allocated to understanding the baseline situation, both from the perspective of the transport situation, but also in relation to wider economic, social and environmental issues. In this respect, it is particularly important to understand which parts of the population and businesses might be particularly affected by the implementation of the proposed scheme.

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7 Overall conclusions from this task

Task 5 looked at the risks and uncertainties associated with three types of policy instruments for reduction of GHG from transport (biofuels, electricity and hydrogen, economic instruments). The main objective was to assess how these risks may adversely impact the desired result from the considered policy instruments, as well as develop recommendations to avoid, manage and mitigate the consequences of the risks.

Biofuels are expected to contribute significantly to the future GHG emission reduction in the transport sector, as there is a large global potential and they do not require a completely new infrastructure or engine technology. However, there are still quite a number of risks and uncertainties related to the four conditions that need to be met if the full potential of GHG reduction with biofuels is to be realised – the availability of biofuels, their sustainability and actual GHG reduction, their technical compatibility and public support. In the coming years, the strategies should focus on effective implementation and improvement of the biofuels sustainability criteria. In addition, research into new (so-called 2nd generation) biofuels production processes should be promoted, to ensure a diverse biomass use in the future that does not compete with the food sector nor lead to significant negative impacts from land use change. In the longer term, risks can be managed by setting the right biofuels targets, policies and (sustainability) boundary conditions. This should lead to a biofuels supply that is sustainable and diverse, leads to reasonable cost, and is compatible with the vehicles and engines use in the various transport modes. In parallel, efforts should also be put into global initiatives that can reduce land use change and biodiversity loss due to biomass cultivation for biofuels, for example within the IPCC and CBD framework.

The implementation of **electricity and hydrogen** as GHG reduction options for the transport sector is a transition that involves drastic and structural changes in both the transport and the energy sector and that will take several decades to start up, roll out and complete. Governments and stakeholders in the market need endurance and a long term vision to manage this transition in an effective way. Mitigating risks and taking away uncertainties is an important and unavoidable part of that. Proactive steps are required in the short term in laying the ground work for longer term policy instruments, in early market formation and in setting up and managing a process that timely delivers the insights that are necessary to develop a suitable dominant design for the energy distribution infrastructure.

If **road user charging** (an economic instrument) is to be implemented to reduce transport's CO_2 emissions, it should be introduced in addition to, rather than instead of, fuel taxation. In this respect, a number of economic, social, environmental and political risks and uncertainties exist. Many of these risks are linked, and some often mentioned issues (*e.g.* public acceptability and wider political risks) can be seen in the context of a family of economic, social and environmental risks that were identified. Many of the latter are real, and could be addressed either in the design of the charging scheme, or by the introduction of complementary policy instruments (which could even be introduced in advance of the charging scheme itself).

In general it was concluded that at least some of these risks and uncertainties can significantly hinder the desired impact of the considered policy instruments. It is therefore recommended that the recommendations which were developed in this paper are taken into account for policy development, monitoring and evaluation, and posterior assessment.

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