COMPASS

**OPTIMISED CO-MODAL PASSENGER TRANSPORT FOR REDUCING CARBON EMISSIONS**

## DELIVERABLE D3.2

# KEY TRENDS AND EMERGING TRAVELLER NEEDS

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## EXECUTIVE SUMMARY

The research to be undertaken in the COMPASS project will recommend solutions that will allow improvements to the planning and operation of the passenger transport network to enhance co-modality in transport, thus contributing to the reduction of carbon emissions.

COMPASS aims to provide an overall picture of what travellers require from the transport system at present and in the future based on an investigation of the key socio-economic trends. The project will analyse how ICT (information and computer technology) and ITS (intelligent transport systems) applications can meet the future demand identified, favouring the integration of multi-modal transport solutions, and will assess how these solutions can contribute to the de-carbonisation of transport activities.

One of the key objectives of the COMPASS project is to identify key trends (demographic, societal, economical, policy etc.) that will affect mobility now and in the future and thus to identify the mobility needs of current and future travellers.

Deliverable 3.2 specifically addresses these objectives and provides the knowledge background for further COMPASS research. It is structured along two parts:

- Chapter 1 presenting the results achieved in Task 3.1 "Key Trends" aimed at identifying the key drivers that influence mobility patterns across Europe and at analysing their influence on mobility trends now and in the future;
- Chapter 2 reporting the research done in Task 3.2 "Emerging Traveller Needs" on the review of traveller needs, in the context of short-distance journeys, assessed in terms of physical, psychological and instrumental factors for all modes and combinations of modes.

So far, a huge amount of research projects and scientific publications have investigated the relationships between relevant socio-economic drivers and mobility patterns. Generally, the demand for the transport sector is examined by placing the sector itself at the centre of the analysis, and investigating variables that influence the changes to mobility and transport patterns. Nevertheless it cannot be neglected that transport demand is generated by factors that are exogenous to the transport sector and that mobility rises to satisfy specific individual needs as clearly expressed by the purpose for which passenger trips are made.

The effort made by COMPASS and presented in the next section is trying to overcome the boundary of consolidated transport sector research and expanding the investigation of factors potentially affecting mobility also to the different domains of reality; the objective of this widening lies not only in the need to enrich the analysis of *"well-known"* key drivers, but mainly in the interest of complementing the investigation with additional side aspects potentially influencing mobility that could gain increasing importance in decades to come.

The framework adopted for the analysis is based on the scanning of the social, technical, environmental and economic domains in order to provide an in-depth snapshot of the key drivers potentially affecting current and future mobility patterns. For each domain the main factors have been selected and, for each factor, the key drivers potentially affecting current and future mobility have been identified and reviewed in terms of:

- **Driver description** intended at providing an overview of driver's nature, together with a summary of the existing and expected trends, when available;
- **Interactions within the domain** the driver belongs to, that explores the main intra-domain relationships with other drivers;
- **Interactions with the remaining domains**, which completes the coverage of possible relationships with the drivers of other domains;
- **Impacts on mobility and transport** highlighting the potential effects that the driver and its interactions has or could have on passenger demand and the related transport modes.

The results presented in the next pages build upon a wide literature review of over 500 documents selected amongst transport research projects, scientific publications, statistic forecasts and studies not directly addressing the future of mobility, but discussing potential socio-economic transformations.

It was a specific aim of the project team to present the results of this interesting review without proposing any “pre-established” interpretation key, and allowing the reader the possibility to draw conclusions by him/herself.

To pursue this goal, the project team proposes a new approach in presenting the outcome of the literature review by putting the documents at the centre of the scene through the selection of significant quotations and their structuring within the predefined analysis framework.

Authors’ comments are generally provided to highlight minor aspects not covered by literature or for which no suitable quotation was detected, as well as to introduce or complement quotations with additional reflections.

The review process gave birth to a robust deliverable acting as a compass helping the reader to surf the wide literature collection by either reading the full report, or consulting individual sections.

Conclusions on current and future trends potentially impacting mobility patterns as emerged during the literature review are proposed in the final section of part 1.

The COMPASS project team is aware that diverse interpretations may arise from the reading of the document as in several cases reviewed literature provided different, if not contradictory, interpretations of the same phenomenon. Additionally, several other hypothetical scenarios may arise when considering the combination of different factors, thus making it even more difficult to reach an indisputable point of view. Therefore the synthesis provided in the final section reflects the authors’ understanding on key drivers and their potential impacts and should not be intended as substitutive of a full reading of the deliverable which will allow the reader to draw his/her conclusions.

The scanning of the social, economic, environmental and technological domains has revealed that all of them could play an important role in reshaping future mobility: every domain has relevant driving forces that, by their own or in combination with others, could substantially impact on transport demand. The review has also disclosed that in most cases it is hard, if not impossible, to predict the intensity of such impacts as well as their rapidity in the course of the years. In fact, the speed by which environmental and technological mutations could take place is really hard to predict, and thus their implications on the planning and development of the future transport system remain uncertain.

As witnessed by the current European situation, it is also very hard to predict the development and the implications of economic, political and financial decisions on the global market, affecting in second order overall mobility of people and goods. Less challenging could be the prediction of the impacts deriving from demographic factors whose dynamics, unless there will be disruptive events, can be more easily understood and forecasted.

Future planning and policy interventions are crucial in addressing the new challenges deriving from the key drivers and transport policy measures are expected to increasingly address the characteristics and the needs of the future population. The identification and satisfaction of user needs have been an integral part of European transport policy. The 2001 Transport White Paper (CEC, 2001) stressed that users are at the *‘Heart of transport policy’* and a review of Common Transport Policy (CEC, 2009) stressed the *‘Need to focus future European transport policy on the pursuit of an integrated, technology-based and user-friendly transport system...whilst ensuring that users, with their needs and rights are always kept at the centre of policy making’.*

Set against this policy background, the main objectives of COMPASS Task 3.2, whose results are presented in the second part of this deliverable, are focused on performing a systematic and comprehensive review of available literature on ‘the needs’ of current (and potential) travellers, taking into account the key trends potentially influencing mobility trends across Europe.

The review includes the needs of the full range of travellers, including more vulnerable groups, (such as older and mobility-impaired, people with young children), although the focus is on those groups identified as significant in terms of key trends, e.g. older people, gender differences and migrants. The review of user needs is structured to cover all transport modes both singularly and also in combination when making multi-modal trips. Unlike in the ORIGAMI project, user needs for air and long-distance coach journeys are not considered here and the analysis is restricted to those modes that are typically used in short-distances, namely rail, local bus, metro and ferries.

In line with current EU objectives to encourage sustainable transport choices (i.e. non car use), this section of the report will not consider user requirements for car use per se, although it will examine the reasons as to why people are so ‘attached’ to their cars, and the barriers that prevent people from switching from car use to alternative modes.

Based on the evidence reviewed, it can be concluded that they are 16 main user needs for short-distance intermodal journeys. These are identical to those identified for long-distance intermodal journeys which suggests these needs are generic for all intermodal journeys, irrespective of distances involved. However, the relative importance of these users needs to each other is still not fully established, due to lack of research studies which have attempted to address this question. The relative importance attached to each user need, as well as specific attributes of these broad user requirements, are also shown to be dependent on both personal (age, mobility-impairment, gender and migrant status) and situational factors (trip purpose).

# 0 INTRODUCTION

## 0.1 OBJECTIVES

The research to be undertaken in the COMPASS project will recommend solutions that will allow improvements to the planning and operation of the passenger transport network to enhance co-modality in transport thus contributing to the reduction of carbon emissions.

COMPASS aims at providing an overall picture of what travellers require from the transport system at present and in the future based on an investigation of the key socio-economic trends. The project will analyse how ICT (information and computer technology) and ITS (intelligent transport systems) applications can meet the future demands identified, favouring the integration of multi-modal transport solutions, and will assess how these solutions can contribute to the de-carbonisation of transport activities.

The key objectives of the COMPASS project are to:

1) Identify key trends (demographic, societal, economical, policy etc) that will affect mobility now and in the future and thus to identify the mobility needs of current and future travellers;
2) Identify the potential role of ICT in promoting co-modality and data collection;
3) Identify the information that would be needed from data in order properly understand mobility, to optimise a future co-modal transport system and to assess the impact of new solutions;
4) Analyse existing surveys with regard to data available concerning long-distance, rural and urban travel;
5) Identify solutions to improving behavioural data (from ICT or elsewhere) and needs and opportunities for harmonisation of the data collected, in particular in the various national surveys (this also includes new definitions of accessibility indicators);
6) Identify and investigate ICT solutions to influence mobility patterns for long-distance, rural and urban travel towards increased co-modality;
7) Develop business models that enable and promote these solutions in practice;
8) Assess the potential impact of the solutions identified both on local and on European level, in particular with regard to carbon emissions;
9) Derive conclusions and recommendations for national and EU transport policy and actions;
10) Disseminate the findings widely amongst policy makers and other stakeholders as well as researchers and the transport industry.

By addressing the issues identified at point 1, Deliverable 3.2 provides the knowledge background for COMPASS research; the objective of this report is to document the activities undertaken within Task 3.1 ñKey Trendsò and Task 3.2 ñEmerging Traveller Needsò.

## 0.2 STRUCTURE

COMPASS Deliverable 3.2 is structured along two parts:

- Chapter 1 presents the results achieved in Task 3.1 ñKey Trendsò aimed at identifying the key drivers that influence mobility patterns across Europe and in analysing their influence on mobility trends now and in the future;
- Chapter 2 reports the research done in Task 3.2 ñEmerging Traveller Needsò on the review of traveller needs, in the context of short-distance journeys, assessed in terms of physical, psychological and instrumental factors for all modes and combinations of modes.

# 1 KEY TRENDS

## 1.1 INTRODUCTION

### 1.1.1 Objectives and Methodology

- *"The vast majority of actions to reduce the carbon footprint of the transport sector has been taken within the transport sector itself and ignore the key drivers which create the demand for transport. A better understanding of the reasons behind the growth in transport demand is therefore crucial to formulating effective measures to manage and reduce the emissions." (Ref: **CO_5031**)*

So far, a huge amount of research projects and scientific publications have investigated the relationships between relevant socio-economic drivers and mobility patterns. For example, the TRANSvisions study (2009) developed a set of long-term scenarios (2030-2050) for transport and mobility in Europe; the Communication from the Commission - A sustainable future for transport: Towards an integrated, technology-led and user friendly system (COM/2009/0279 final), has identified some of the global drivers, the ones whose influence on mobility trends is more important.

The key driving forces influencing transport demand (e.g. population ageing, migration flows, urbanisation and urban sprawl etc) are therefore clearly identified and addressed in transport sector literature.

The effort made by COMPASS Task 3.1 is trying to overcome the boundary of consolidated transport sector research and expanding the investigation of factors potentially affecting mobility also to the different domains of reality.

The objective of this widening lies not only in the need to enrich the analysis of *"well-known"* key drivers, but mainly in the interest of complementing the investigation with additional side aspects potentially influencing mobility that could gain increasing importance in decades to come.

Generally, the demand for transport sector is examined by placing the sector itself at the centre of the analysis, and investigating variables that influence the changes to mobility and transport patterns. Nevertheless it cannot be neglected that transport demand is generated by factors that are exogenous to the transport sector and that mobility rises to satisfy specific individual needs as clearly expressed by the purpose for which passenger trips are made (e.g. shopping, working, studying, holiday etc).

In order to identify the drivers of transport demand and its dynamics a detailed analysis of sectors of activities outside the transport domain is therefore needed.  This concept underlies the methodology adopted for COMPASS Task 3.1 and presented in the next sections.

#### *1.1.1.1 The Analysis Framework*

The framework adopted for the analysis takes stock from the classical STEEP analysis approach which, through the scanning of the Social, Technical, Environmental, Economic and Political (STEEP) dimensions, provides an in-depth snapshot of the key drivers for changes that will happen in the future.

In particular:

- The Social domain encompasses the changes in composition or attitudes of people, including trends in demographics, urbanisation, gender issues, consumer values etc;
- The Technology domain analyses the changes due to innovations and applications of science and technology;
- The Environment domain takes into account changes in natural systems/ecology;
- The Economy domain considers the changes in the system of material exchange;
- The Political domain analyses changes in government, related institutions, issues and their constituents.

For the purpose of COMPASS Task 3.1 the analysis framework is structured along the four following domains:

- Social domain;
- Economy domain;
- Environmental domain;
- Technology domain.

The political domain has not been included among the domains investigated in Task 3.1 since it focuses on ñchanges in government, related institutions, issues and their constituentsò, which are supposed to not affect in a direct way mobility and transport.
Changes in the political environment are more likely to directly imply changes in social, economic and environmental policies of a country thus influencing the trend of the drivers belonging to these domains; the changes in these drivers can in turn have impacts on mobility and transport.
The effects of policy on mobility and transport are therefore wielded through some specific drivers already considered in the other domains: for instance political decisions could influence migration laws (e.g. through facilitation or restriction in obtaining a stay permit or a visa) and this could have impacts on migration and touristic flows and therefore on mobility. Always in the context of the social domain, political decisions can influence planning strategies at all level which could be driven towards more sustainable or unsustainable directions.
Policy is also highly impacting on the economic domain: decisions on market regulations, trade facilitation, investments, fiscal and labour policies and so on are some of the means used by policy makers to orient the development of the economy. The trends in these drivers have relevant impacts on mobility and transport, as it is clearly described in this report.
Last but not least policy can exert power also in addressing environmental issues, as clearly demonstrated by the implementation of more restrictive rules on GHG emissions and pollutants and by the adoption of emission trading schemes at worldwide level.
Additionally, policy actions can hardly be considered as ñindependentò driving forces since in the most of the cases they arise from the need to prevent or correct undesirable trends shown by some drivers belonging to other domains. As a consequence it can be argued that future policy decisions are strictly depending on future emerging trends and needs and they might result in a variety of options influenced by multiple alternatives arising from the combination of different factors.

Within each of the four domains identified for COMPASS Task3.1 objectives, the main factors have been selected and, for each factor, the key drivers potentially affecting current and future mobility have been identified (Table 1-1).

**Table 1-1 List of key factors and drivers**

| Domain | Factors | Drivers |
|---|---|---|
| **Social** | Demographics | Population ageing |
| | | Migration flows |
| | Structure | Households structure and distribution |
| | | Income structure and distribution |
| | | Car ownership |
| | | Gender roles |
| | Spatial distribution | Urbanisation |
| | | Planning |
| | Behaviour | Tourist flows |
| | | Change of lifestyle and values |
| | | Education |
| | Health | Health |
| **Economy** | Economic performance | GDP trends |
| | | Employment |
| | | Regional differences in economics |
| | Investments | Availability of public and private resources and investments in the transport sector |

| Domain | Factors | Drivers |
|---|---|---|
| | Market structure | Market regulations |
| | Global trade | Foreign trade, globalisation |
| | | Energy availability and prices |
| | | Intensified competition for scarce resources use |
| | Fiscal policy | Fiscal policy |
| Environment | Climate change | Climate change impacts |
| | | GHG mitigation |
| | | Emissions trading schemes |
| | Pollution | Noise levels and emissions standards |
| | | Pollution levels and emissions standards |
| | Resources | Energy availability, production and consumption |
| | | Scarce resources of fossil fuels |
| | | Scarce resources of raw materials |
| Technology | Technology development | Technology development in general and innovation diffusion |
| | Vehicle technology | New vehicles design |
| | | Advanced Driving Devices |
| | | Traction technologies |
| | | Material technology |
| | ICT and Telematics | Traffic management systems |
| | | Information systems |
| | | Booking and Payment systems |
| | | Monitoring |
| | Pollution | Pollution abatement and monitoring |
| | Energy | Renewable energy production |
| | | Energy efficiency |

On the basis of this selection, the aim of COMPASS Task 3.1 was therefore to provide an overview of the main drivers affecting possible future changes, of their main interactions and of their potential impacts on mobility and transport.

It should be noted that, as reported in the table, specific attention was paid to the energy sector and to its related drivers which occur in all domains except the social one.

This choice was made to respond to the complexity of the aspects related to energy which plays a fundamental role in the Economy domain (given the importance of energy availability and prices for production and trade of goods and for the economic competitiveness of a country), in the Environmental domain (given the environmental impacts deriving from the production and consumption of energy sources) as well as in the Technology domain (for the importance of pursuing energy efficiency and energy production from renewable sources). Obviously these aspects are highly interlinked and tend to overlap to some extent, but the introduction of more energy drivers allowed for a more complete coverage of the main domain-related aspects.

As explained in the next sections, the activities undertaken within Task 3.1 have been structured around two main steps: literature collection and literature review.

#### *1.1.1.2 The Literature Collection*

The results presented in the next pages builds upon a collection of over 500 documents selected amongst transport research projects, scientific publications, statistic forecasts by EUROSTAT and other international organisations, studies not directly addressing the future of mobility but discussing potential socio-economic transformations etc.

Documents were collected by all COMPASS partners, mostly in pdf format, catalogued with identification codes and stored into an on-line library[1].

[1] Currently stored on the OPTIMISM project website: www.optimismtransport.eu

An Excel catalogue helps readers in surfing the library: besides general bibliographic information, every document is classified according to its domain and to the relevant contents identified in terms of its focus on drivers, trends, interactions and impacts on mobility. A brief abstract summarises the main findings.

| COMPASS_ID | TITLE | AUTHOR | YEAR | LANGUAGE | SCALE | BIBLIOGRAPHIC DETA |
|---|---|---|---|---|---|---|
| CO_0001 | The future mobility of the world population | Schafer A., Victor D. G. | 2000 | English | WORLD | Transportation Research 34 (2000) 171 - 205 |
| CO_0002 | Die urbane Wende: Forschung für die nachhaltige Entwicklung der Megastädte von morgen | Bundesministerium fur Bildung und Forschung | 2003 | German | | |
| CO_0003 | Scenarios of long-term socio-economic and environmental development under climate stabilization | Riahi K., Grübler A., Nakicenovic N. | 2007 | English | | Technological Forecastir Social Change 74 (2007) 887-935 |
| CO_0004 | Public transport city of the future | Rosenberg M., Weiste H. | 2007 | English | Finland | |
| CO_0005 | The Future of Mobility | Glockner H. , Rodenhäuser B. | 2008 | English | | |
| CO_0006 | Trends and challenges in passenger mobility | IFP Innovation Energy Environment | 2008 | English | | |
| CO_0007 | Low-mobility: The future of transport | Moriarty P. ,Honnery D. | 2008 | English | | Futures 40 (2008) 865-8 |
| CO_0008 | Future of Mobility 2020 The Automotive Industry in Upheaval? | D Little A. | 2009 | English | | |
| CO_0009 | User Aspects | Debbah F. | 2009 | English | | Transport Research Kno Centre. Thematic Resear Summary |
| CO_0010 | Wedded to the car: women, employment and the importance of private transport | Dobbs L. | 2009 | English | | |
| CO_0011 | Safe, accessible pedestrian environments: The key to mobility in ageing populations | Frye A. | 2010 | English | | International Transport F |
| CO_0012 | World Population Ageing 2009 | United Nations (UN) | 2009 | English | WORLD | |
| CO_0013 | Mobility: Rights Obligations and Equity in and Ageing Society | Frye A. | 2011 | English | | International Transport F |

**Figure 1-1 Catalogue of COMPASS Task 3.1 library**

COMPASS Task 3.1 library is a repository of significant knowledge covering several aspects of the different socio-economic, environmental and technology domains: it can be considered a "one-stop shop" of literature normally scattered in the web which is constantly accessible to project partners and constitutes a high value for COMPASS project activities.

#### 1.1.1.3 The Literature Review

The literature review made in Task 3.1 was intended to provide a structured overview of what is currently available in the research field.

The COMPASS project team recognises the importance, often neglected in similar activities, of preserving the integrity of the literature material and the point of view of the authors.

It was a specific aim of the project team to present the results of this interesting review without proposing any "pre-established" interpretation key, allowing the reader the possibility to draw conclusions by him/herself.

To pursue this goal, the project team proposes a new approach in presenting the outcome of this task by putting the documents at the centre of the scene through the selection of significant quotations and their structuring within the predefined analysis framework.

The approach followed in the review shaped the structure of this report: in the next sections drivers are analysed through the following elements:

- The **Driver description** intended at providing an overview of driver's nature, together with a summary of the existing and expected trends, when available;
- The **Interactions within the domain** the driver belongs to, that explores the main intra-domain relationships;

- The **Interactions with the remaining domains**, which completes the coverage of possible inter-domain relationships;
- **Impacts on mobility and transport** highlighting the potential effects that the driver and its interactions has or could have on passengers demand and the related transport modes.

Quotations selected during the review process have been framed in this grid and composed in order to provide the reader with a panorama on main research findings. To differentiate them from authorsô comments, quotations are presented in the form of bullet points in italic text.

The report is mainly based on quotations which are used wherever possible. Authorsôcomments are generally provided to highlight aspects not covered by literature or for which no suitable quotation was detected, as well as to introduce or complement quotations with additional reflections.

In several cases, the literature review provided different, or even contradictory, interpretations of the same phenomenon; all the points of view are equally included in the report.

Documents the quotations stem from are clearly identified through the COMPASS identification code (e.g. CO_0001) and can be easily detected through the reference list included at the end of this report, thus providing the reader with the possibility to satisfy any complementary need of information.

It is clear that in principle there are so many potential interactions among drivers that the complete coverage of all of these is out of the ultimate scope of COMPASS: the approach followed in Task 3.1 was tailored to the specific purpose of the investigation on potential impacts on mobility and transport, as emerged from the literature. The analysis was therefore specifically focused on highlighting the main aspects that are of relevance for this scope and it reflects some simplifying assumptions due to the need of limiting the complexity of the analysis and to make it compatible with the project objectives.

The review process gave birth to a robust deliverable acting as a compass that helps the reader to surf the wide literature collection by either reading the full report, or consulting individual sections.

Conclusions on main drivers and trends drawn by the authors are proposed in the final section of this part of the report, while a matrix summarising the identified main interactions among driver is shown in Figure 1-96.

## 1.2 THE SOCIAL DOMAIN

### 1.2.1 Social Domain Key Factors and Drivers

➢ *“Whilst it is generally accepted that “social factors” play an important role as “transport drivers”, it is frequently not recognised that the reverse is also the case: transport policy can have a significant impact upon social issues (i.e. upon “social capital”). It follows that social issues need to be put at the centre of transport policy-formulation (and not considered simply as exogenous factors for calculating transport demand), being given the same level of importance as economic and environmental issues.” (Ref: **CO_5048**)*

The term “social” refers to the interaction of people with other people and to their collective co-existence, irrespective of whether they are aware of it or not, and irrespective of whether the interaction is voluntary or involuntary. Social factors include the behavioural and cultural aspects of individuals, health consciousness, demographic aspects as well as characteristics, attitudes, orientations, or needs of people.

Figure 1-2 below summarises the key Social factors and drivers taken into account for the analysis.

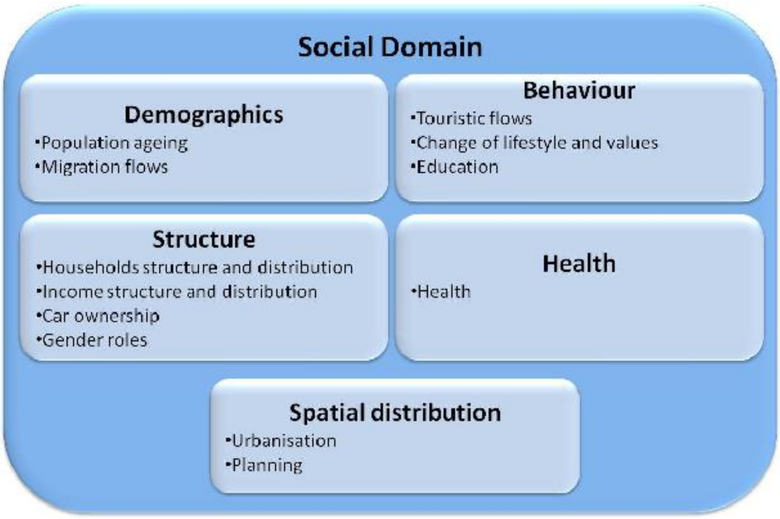



**Figure 1-2 Social domain key factors and drivers**

### 1.2.2 The Demographic Factor

Projecting demographic developments in the next decades is one of the most daunting analytical tasks facing policy makers. A high uncertainty surrounds the projections and this uncertainty grows the longer the projection period: substantial uncertainty remains, for example, on migration flows, the health status of the elderly or on the incidence of disability; therefore the projection results are strongly influenced by the underlying assumptions.

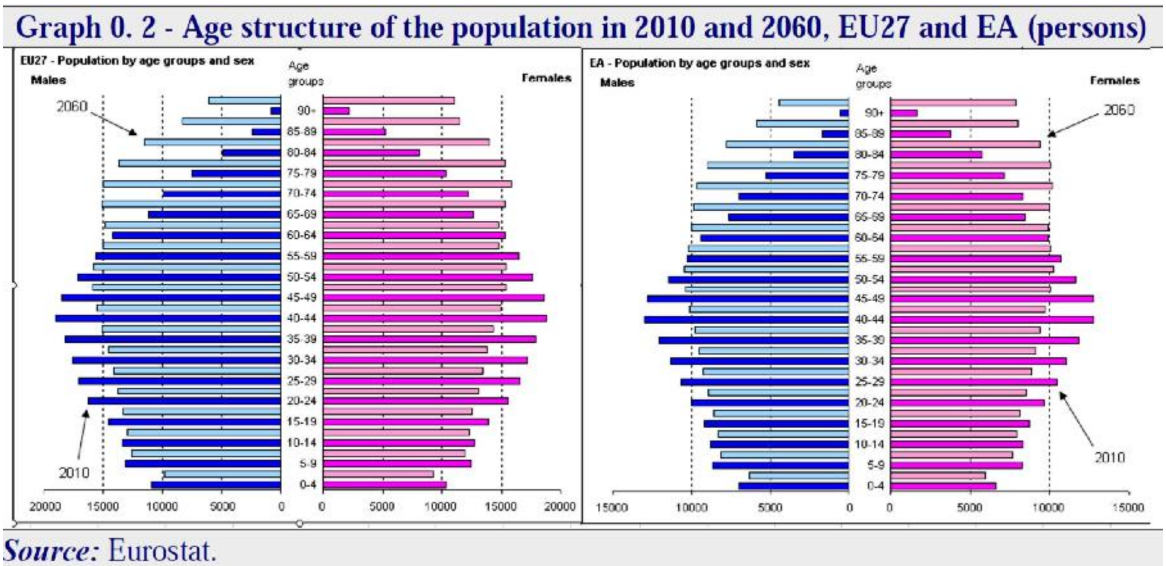
The demographic factor presented in the next pages is mainly derived from EUROPOP2010 population projection convergence scenario, released by Eurostat in April 2011. It is based on assumptions on future trends in fertility, life expectancy and migration in the 27 EU countries and adopts a ‘convergence’ approach, this meaning that the key demographic determinants are assumed to converge over the very long-term[2]. (Ref: **CO_0050**)

[2] As far as fertility and mortality are concerned, it is assumed that they converge to that of the ‘forerunners’. Specifically, fertility rates are assumed to converge to levels achieved by Member States that are considered to be 'forerunners' in the demographic transition. Life expectancy increases are assumed to be greater for countries at lower levels of life expectancy and smaller for those at higher levels, thus following convergent trajectories. In each Member State, immigration and emigration flows assumed to converge, taking also into account the changes in the national age structures. (Ref: CO_0050)

### 1.2.2.1 Population ageing

**Driver description**

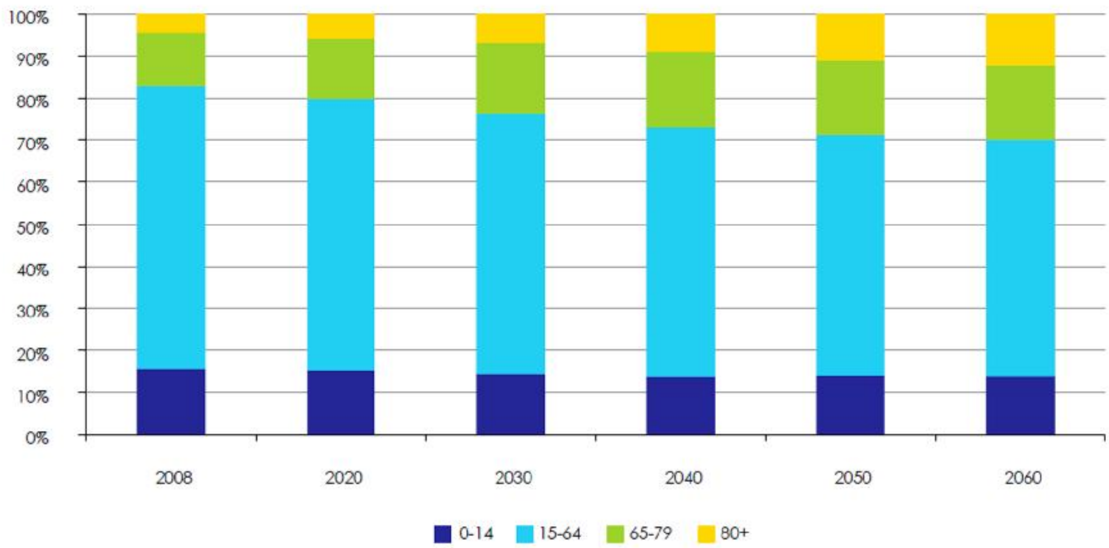
- *"Demographic ageing, i.e. the increase in the proportion of elderly people, is the result of significant economic, social and medical progress as well as public health policies. These have given Europeans the opportunity to live a longer life in relative comfort and security without precedent in our history. However, as was stressed by the Heads of State and Government at their informal Summit at Hampton Court in October 2005, it is also one of the main challenges that the European Union will have to face in the years to come."* (Ref: ***CO_0016***)
- *"The age structure of the EU population will dramatically change in coming decades due to the dynamics of fertility, life expectancy and migration. The overall size of the population is projected to be slightly larger in 50 years time, but much older than it is now. The EU population is projected to increase (from 501 million in 2010) up to 2040 by almost 5%, when it will peak (at 526 million). Thereafter, a steady decline occurs and the population shrinks by nearly 2%. Nonetheless, according to the projections, the population in 2060 will be slightly higher than in 2010, at 517 million."* (Ref: ***CO_0050***)
- *"While the EU population as a whole would be slightly larger in 2060 compared to 2010, there are wide differences in population trends until 2060 across Member States. Decreases of the total population are projected for about half of the EU Member States (BG, CZ, DE, EE, EL, LV, LT, HU, MT, PL, PT, RO and SK). For the other Member States (BE, DK, IE, ES, FR, IT, CY, LU, NL, AT, SI, FI, SE and UK) an increase is projected. The strongest population growth is projected to be found in Ireland (+46%), Luxembourg (+45%), Cyprus (+41%), the United Kingdom (+27%), Belgium (+24%) and Sweden (+23%), and the sharpest declines in Bulgaria (-27%), Latvia (-26%), Lithuania (-20%), Romania and Germany (both -19%)."* (Ref: ***CO_0050***)
- *"The highest shares of old age population are likely to be found in Eastern Germany, North-West of Spain, Italy and some parts of Finland. In Central and Eastern Europe the impacts of ageing will be delayed owing to their younger population and lower life expectancy. However, significant increases in the old age population are expected in the longer term in these regions."* (Ref: ***CO_0016***)
- *"The age structure of the EU population is projected to change dramatically, as shown in the population pyramids presented below. The most numerous cohorts in 2010 are around 40 years old for men and women. Elderly people are projected to account for an increasing share of the population. At the same time, the middle of the age pyramid becomes smaller during the projection period due to below natural replacement fertility rates. As a consequence, the shape of the population pyramids gradually changes from pyramids to pillars. A similar development is projected for the euro area."* (Ref: ***CO_0050***)




Source: The 2012 Ageing Report: Underlying Assumptions and Projection Methodologies. Directorate-General for Economic and Financial Affairs of the European Commission (Ref: **CO_0050**)

**Figure 1-3 Population by age groups and sex (absolute numbers)**

- *"Average life expectancy at birth in the EU is some six years higher for women than men. A girl born in 2008 is expected to live 82.4 years on average; a boy 76.4 years. For 65-year-olds, in 2008 there was an expectation of a further 20.7 years for women and 17.2 years for men." (Ref: **CO_0197**)*
- *"The population aged 15-64 will start to decline as of 2010 in the EU and, over the whole projection period, it will drop by 14 %. The population aged 65 and above will increase very markedly throughout the projection period. This group will almost double, rising from 87.5 million in 2010 to 152.6 million in 2060 in the EU. The number of older people (aged 80 years and above) is projected to increase by even more, almost tripling from 23.7 million in 2010 to 62.4 million in 2060." (Ref: **CO_0050**)*
- *"By 2060, the median age of the European population is projected to be more than 7 years higher than today and the number of people aged 65 or more is expected to represent 30% of the population as opposed to 17 % today." (Ref: **CO_0015**)*




Source: 2009 Ageing Report: Economic and budgetary projections for the EU-27 Member States (2008-2060) (Ref: **CO_2050**)

**Figure 1-4 Projection of changes in the structure of the population by main age groups, EU27**

- *"Recent demographic projections show that in 2060 there will be only two active workers for every pensioner." (Ref: **CO_0015**)*
- *"Ageing has (favourable and less favourable) consequences on the environment through consumption patterns (housing and land use, transport, tourism, food and drugs, etc.) and sensitivity to environmental constraints (e.g. vulnerability to heat-related, illnesses and air pollution effects on respiratory systems). It is associated with population influxes into sunbelts, coastal areas and river valleys, in OECD countries and elsewhere. It has macroeconomic consequences as well, due to public spending and related services – such as pensions, health care, long-term care, education and unemployment transfers – and to age-related trade-offs between current consumption and saving for future generations (ECFIN, 2006). Ageing also affects labour force participation rates, standards of living, urban planning and mobility." (Ref: **CO_5009**)*

### Interactions within the Social Domain

#### *Migration Flows*

- *"A limited, but increasing, number of elderly acquire second homes and/or migrates to other countries, often southern member states with attractive climate and nature. Most spend autumn, winter and spring in the south and the summer in their native country." (Ref: **CO_0125**)*
- *"The population of European countries will continue to age rapidly and the working population will decrease dramatically in almost all nations. These demographic changes will have major*

*implications not only in terms of economic growth, but also for social, cultural and political aspects, and obviously for migration patterns and trends." (Ref: **CO_5027**)*

With an ageing population, the number of disabled elderly people who need care would heavily increase in the EU27; furthermore the growing participation of women in the labour market may constrain the future supply of care provision within households and families. This evidence could boost the current migration flows of foreign people (both intra and inter EU) involved in care provision within families.

#### Households structure and distribution

As the population grows older within a smaller family unit an increasing number of Europeans will be growing old alone without the wider family support structures that still often exist today. In the future an increase in the number of one-person households can be expected.

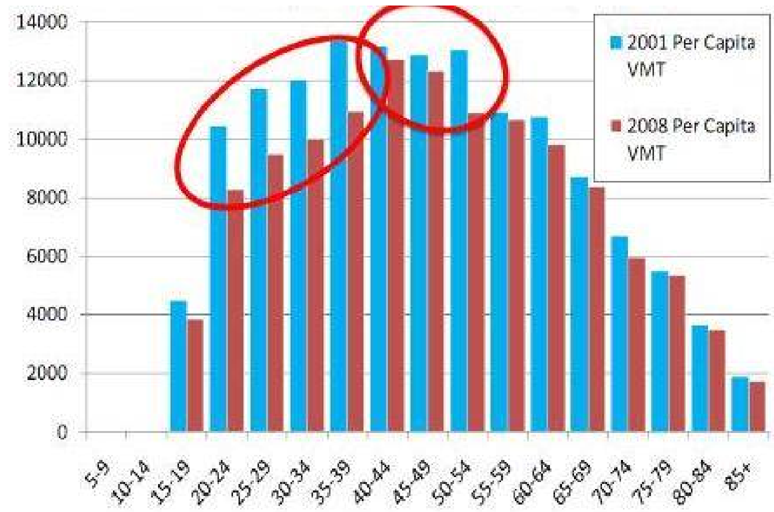
#### Income structure and distribution

Generally, the average income from receiving a state pension is much lower compared to an average income earned by an economically active person. Therefore the ageing population is an important concern from a poverty perspective since aged individuals have lower income and higher health risks than that of other age groups.

- *"Retired people have a lower income than those that are in the workforce." (Ref: **CO_0125**)*

#### Car ownership

- *"A growing share of the elderly holds drivers license and have access to cars, reflecting that habits acquired as young is - partly - sustained in higher ages and leads to gradually increasing daily transport." (Ref: **CO_0125**)*
- *"Age affects travel patterns. U.S. residents born after 1978 drive significantly less than people of the same age did ten years earlier, as illustrated in the figure below. Average annual vehicle miles traveled (VMT) was about 20% less in 2008 than in 2001 for each under 40 age group. This gives further evidence of changes in consumer preferences and lifestyles that are likely to reduce per capita VMT in the future. Figure below also illustrates the substantial declines in per capita VMT that occurs after 55 years of age. When people retire their per capita vehicle travel tends to decline and their demand for alternative modes and more accessible housing location tends to increase (AARP 2005). Although Baby Boomers are likely to drive more than previous retirees, they are unlikely to drive as much as they did during their working years." (Ref: **CO_5047**)*




Source: The Future Isn't What It Used To Be. Changing Trends And Their Implications For Transport Planning. (Ref: **CO_5047**)

**Figure 1-5 Average annual mileage by age**

#### Gender roles

A growing population will inevitably bring an additional burden to women to whom the family care of children and elderly is generally delegated.

- *"Especially in Southern Europe, recent aging demographic trends are accompanied by significant changes of household and family structures, characterized by an increase of single headed households and by the weakening of mutual family and community support networks. As the EU Green Paper on demographic change points out, families (and women within families) will not be able to face this caring challenge alone." (Ref: **CO_0088**)*

### Urbanisation

- *"(...) the use of land in all European towns and cities will become increasingly important as demographic and environmental changes take place. Europe's citizens are living longer and the demand for individual homes for single occupiers is also increasing." (Ref: **CO_0096**)*
- *"Demographic changes play an important role in the re-assessment of suburban areas. The 'baby-boomers', who were mainly involved in the first wave of suburbanisation in European cities during the 1960s and 1970s, are now 60 to 70 years old. This group often owns property designed for the requirements of a one-family household in terms of layout and location. In many cases, this is now inadequate for the next phase of life. This may especially be the case in areas with a poor social and physical infrastructure, where there is less opportunity for self-determined, non-car-orientated mobility. This holds even more true when one considers that it seems increasingly unlikely that public authorities will provide suburban areas with the same level of social and technical infrastructure as they did in the past." (Ref: **CO_0079**)*
- *"Older people are much more orientated towards their specific neighbourhood in fulfilling their day-today needs. Proximity to shops, medical care and other services are of particular importance. At the same time, the 'empty nest' syndrome (experienced after grown-up children have left the house) means higher costs per person and often a larger amount of work per person in looking after and maintaining the property. Therefore, as far as financial considerations allow, this group increasingly starts to look for innercity alternatives. However, for most people, re-location to the inner-city is only possible if their suburban home can be sold at an acceptable price: this might not be possible in certain suburban areas. These circumstances could lead to spatial segregation, with some suburban areas (i.e. those with higher density and better social and physical infrastructure) remaining high-valued neighbourhoods, and others losing value and status." (Ref: **CO_0079**)*
- *"As the trend towards an increasingly ageing population and smaller households continues, it may be anticipated that some slowing down of the movement from cities to suburbs will occur in the coming decades." (Ref: **CO_0028**)*

### Planning

- *"The way that transport services are planned and delivered, the design and maintenance of the pedestrian environment and land use planning policies can all contribute significantly to the problems that disabled and older people face and can limit their ability to regain or retain independent daily living. Transport and land use planning can also play a major part in identifying and delivering solutions." (Ref: **CO_0013**)*
- *"Infrastructure design should not focus solely on technical efficiency and lowest cost. Designs for new roads and future road improvement programmes should at least recognise the inappropriateness of standards based on the abilities of a fit, young adult driver for members of an ageing society and meet the needs of all categories of road users (vehicle occupants, pedestrians, cyclists, motorised wheelchair users, etc.)." (Ref: **CO_0013**)*
- *"The quality of footpath and pedestrian-crossing surfaces and the avoidance of abrupt changes in level and steep inclines are particularly important to older pedestrians. In addition to affecting ease of use, improvements in these areas will also yield safety benefits, allowing older people to shift their concentration from walking to responding to other road users' actions." (Ref: **CO_0013**)*
- *"Transport systems have to be adjusted to the needs of an ageing society, taking account of understandability, readability and coherent signing systems. Transit and buffering times have to be designed for elderly people." (Ref: **CO_5006**)*
- *"Among the likely trends for Europe 2050 we envisage: proximity buses for elderly people and RMP[3]. Speed is not important because their value of time is small, but they want proximity to*

[3] Reduced Mobility Persons

*avoid walking. They may need external elevators or escalators on the street to overcome some heights." (Ref: **CO_5005**)*

#### *Tourist flows*

- *"The ageing population and an increasing concern for health are likely to drive a growth in demand for health tourism product and spa services. There should also be growing interest in cultural tourism and specially designed programmes for older traveller." (Ref: **CO_0023**)*

#### *Change of lifestyle and values*

- *"Lifestyles are progressively changing in Europe, in part influenced by population ageing. Clear indications of increasing mobility and changing consumption patterns now exist in older population groups." (Ref: **CO_1023**)*
- *"(...) current statistics assume that transport outlay on the part of older groups will increase – senior citizens are more mobile than the generations before them. However, little attention is being given to the variety of circumstances and lifestyles that exist in old age just as at other stages of life." (Ref: **CO_5006**)*
- *"Over time the elderly gradually take up the same habits as the younger generations. As the younger, used to high mobility and travelling to other countries, gets older, and as the wealth and health conditions of the elderly population improves, the high mobility habit stays. Consequently an increasing daily mobility and frequent travelling activity can be seen for the wealthier and healthier segments of the elderly. This development is visible in the northern and western European countries, but not particularly visible in the south and eastern European countries with less tradition for travelling." (Ref: **CO_0125**)*

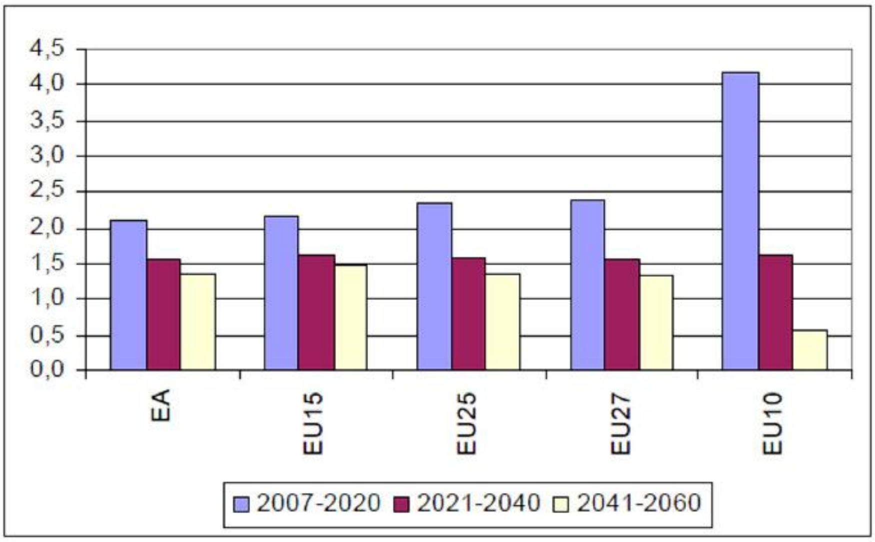
#### *Health*

- *"Ageing leads to increased demand for health and long-term care and rising health care expenditure." (Ref: **CO_0016**)*
- *"The available evidence indicates that the ageing of the population and the extended longevity of people can be expected to lead to increasing numbers of elderly with severe disability and in need of long-term care in some Member States." (Ref: **CO_2050**)*
- *"With an ageing population, the number of disabled elderly people who rely on informal care only would nearly double in the EU27, and increase by more than 120% in seven Member States: the Czech Republic, Ireland, Cyprus, Luxemburg, Poland, Romania and Slovakia." (Ref: **CO_2050**)*

### Interactions with the Economy Domain

#### *GDP trends*

- *"Population dynamics will also be an important driver of consumption and production to 2030 in non-OECD countries. The trend towards ageing of the population, urbanisation and changing lifestyles will also influence the structure of consumption." (Ref: **CO_5009**)*
- *"World population growth is (...) progressively becoming a threat to growth, although in the past it has done most to bolster economic growth. Demographic transition to stable or shrinking populations alongside rising life expectancy is dramatically changing the age structure of societies." (Ref: **CO_0235**)*
- *"Given the decline in labour supply, the annual average potential GDP growth rate for the EU27 is projected to decline from 2.4% in the period 2007 to 2020 to 1.3% in the period 2041-2060." (Ref: **CO_2050**)*




Source: Dealing with the impact of an ageing population in the EU (2009 Ageing Report) (Ref: **CO_0073**)

**Figure 1-6 Projected potential growth rates (annual average growth rates), EU aggregates**

- *“The share of working age population is expected to be particularly low in several of the Finnish, Swedish and German regions. It is noteworthy that the magnitude of decline in the working age population shows significant variations. Around 40 regions will experience a decline of more than 10 % by 2020. Some regions in Bulgaria, Eastern Germany and Poland will be particularly hard hit, with a decline exceeding 25 % by 2020. These regions suffer from a combined effect of low fertility and high out-migration.” (Ref: **CO_0016**)*
- *“The fiscal impact of ageing is projected to be substantial in almost all Member States, with effects becoming apparent already during the next decade. On the basis of current policies, age-related public expenditure is projected to increase on average by about 4 ¾ percentage points of GDP by 2060 in the EU – and by more than 5 percentage points in the euro area. Most of the projected increase in public spending over the period 2007-2060 will be on pensions (+2.4 p.p. of GDP), health care (+1.5 p.p. of GDP) and long-term care (+1.1 p.p. of GDP). Potential offsetting savings in public spending on education and unemployment benefits are likely to be very limited (-0.2 p.p. of GDP for each item).” (Ref: **CO_2050**)*

*Employment*

- *“Demographic ageing is inevitable, but future changes in labour force and population at working age are not only determined by population dynamics. This gives European societies a variety of policy options including rising retirement age, higher labour force participation of women and a pro-active recruitment of migrant labour and skills.” (Ref: **CO_6000**)*
- *“If successful, such policies will inevitably lead to much larger ethno-cultural and religious heterogeneity; higher labour force participation rates would require a radical departure from early retirement which in many EU countries has become a widespread phenomenon.” (Ref: **CO_6000**)*

*Regional differences in economics*

- *“The population ageing process is not spatially uniform (...) as it also happens that large cities with obsolete economic bases are losing population while some competitively-orientated rural areas are increasingly able to attract retirees and the self-employed with a view to further developing their new “residential” economies.” (Ref: **CO_1023**)*
- *“Remote rural regions show a stronger decline in population and a faster ageing process than rural regions close to a city.” (Ref: **CO_0216**)*

*Availability of public and private resources and investments in the transport sector*

- *"A society with a higher ratio of older people will need to devote more public resources to pension payments, health care and nursing. Through its effect on public finances, ageing will put a strain on the supply and maintenance of transport infrastructure and set a limit for funding available to public transport." (Ref: **CO_0015**)*

- *"An ageing population will have a strong upward impact on public spending for long term care. This is because frailty and disability rise sharply at older ages, especially amongst the very old (aged 80+) which will be the fastest growing segment of the population in the decades to come. (...) Public spending on long-term care is projected to double, increasing from 1.2% of GDP in 2007 to 2.3% of GDP in 2060 in the EU as a whole." (Ref: **CO_2050**)*

An ageing population requires also new investments in the transport sector with the purpose to keep elderly as active and independent as possible. This would imply the adoption of a new vehicle design for both the private and public transport sector, the provision of new services expressly tailored for the new needs, the adoption of technologies and devices easy to use given the reduced capabilities.

#### *Energy availability and prices*

- *"The elderly people's demand for energy services depend on the cost of such energy services. Older people have a lower income than the population in general, and the poor part the elderly population can be expected to be particular sensitive towards changes in energy prices." (Ref: **CO_0125**)*

#### *Fiscal policy*

- *"In some European countries, the current fiscal policy would be sustainable if there was no impact of ageing on public finances. It can thus contribute to cover part of the budgetary impact of ageing over the long term by reducing public debt and/or accumulating assets." (Ref: **CO_1004**)*
- *"In addition to the long-term budgetary impact of ageing, the current budgetary position and level of debt can also present a risk to public finance sustainability." (Ref: **CO_1004**)*
- *"The current level of gross debt, while declining, remains well above the reference value and the steady reduction of the debt ratio foreseen in the update is necessary. The European country strategy of putting longer-term concerns at the heart of fiscal policy, including by reducing debt, will undoubtedly alleviate sustainability risks and the 'ageing fund law' reinforces the political commitment by setting legally binding budgetary targets. Furthermore, recent measures aimed at increasing the effective retirement age and the employment ratio should contribute positively to sustainability. However, the current budgetary position may not be sufficient to cover fully the substantial increase in expenditure due to ageing populations, underlining the importance of maintaining large primary surpluses in the coming years." (Ref: **CO_1004**)*

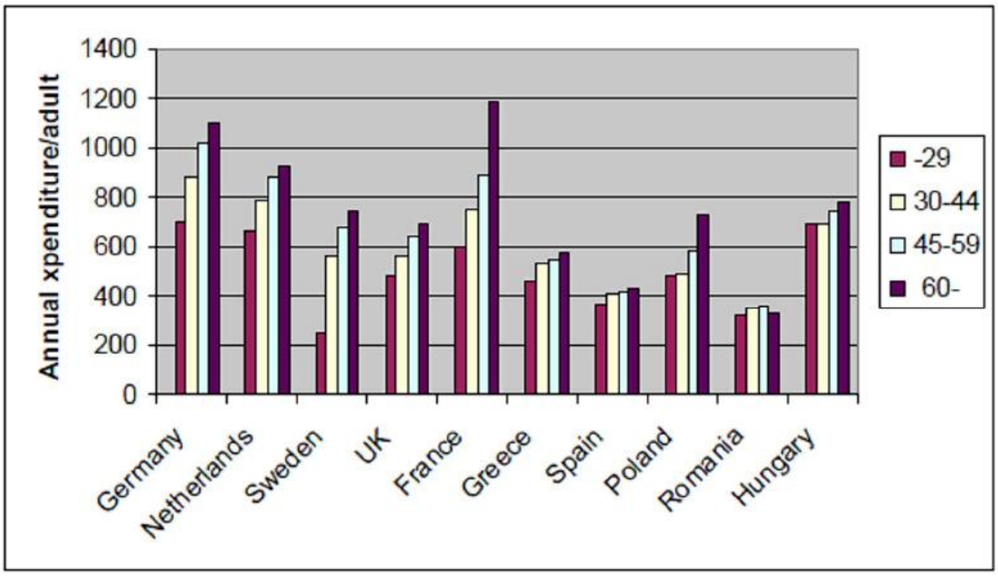
### Interactions with the Environment Domain

#### *Pollution levels and emissions standards*

- *"Population ageing and lower population growth could also have positive effects. Although other factors can be more important (e.g., consumption patterns, heating needs, urbanisation, living arrangements, productivity levels), a smaller population size can lead to a lower use of resources and reduced climate change. Ageing per se can also provide environmental gains to the extent that older individuals commute and consume less than younger individuals. In addition, the distinct income and savings patterns of older individuals can have indirect implications for demand that result in lower environmental emissions." (Ref: **CO_0098**)*

#### *Energy availability, production and consumption*

- *"(...) the ageing of the population is not likely in itself to lead to significant environmental changes or pressures. The elderly generations are generally less mobile, take up new consumption patterns at a slower speed and consume on average the same or less resources than other groups in society. An important exception is the consumption of heat, gas and other fuels, where consumption per person is higher for the elderly than for the rest of the population. This is because elderly have smaller households (often one or two persons) with larger living space in m2 per inhabitant than younger groups leading to larger energy consumption." (Ref: **CO_0125**)*
- *"This hypothesis is supported by Eurostat household budget survey. The figure below presents the annual expenditure on electricity, gas and other fuels per adult in households with different age of the reference person. The annual expenditures to these energy products are largest for the group of households with the reference person above 60, though the level of consumption and level of difference between age groups vary across Europe." (Ref: **CO_0125**)*




Source: Eurostat: Household budget survey.

Source: Environment and Ageing (Ref: **CO_0125**)

**Figure 1-7 Annual household expenditure on electricity, gas and other fuels by age of reference person in selected countries. 2005**

## Interactions with the Technology Domain

### *Technology development in general and innovation diffusion*

- *"Although many older people today are unfamiliar with computer technology, this will change over the next two decades. All age groups will increasingly use of information and communication technology (ICT) in many different ways. New technology will be useful to older people, both in road infrastructure (electronic information signs, route information, navigation systems, etc) and in the public transport systems (smart card, trip planning services, automated information kiosks, etc), provided that the interface is appropriate." (Ref: **CO_0031**)*
- *"Equity and Accessibility for older people and disadvantaged communities is still an important issue and requires further investment and more efficient, speedier implementation of services. The advent of technology means that whole journeys can now be planned, but easy access of disabled, older and disadvantaged groups to this technology must also be considered. Research needs to consider providing this group with user friendly and low cost technologies which can ease the arrangement of such journeys." (Ref: **CO_0032**)*
- *"Europe's changing demographic composition can also present an opportunity for the development of products and services geared to the needs of older people. New technologies can be developed to allow older people to stay autonomous and live longer in their own homes, to transform the delivery of care, inter alia personalizing services in response to patients' unique needs and preferences." (Ref: **CO_0073**)*

### *New vehicle design*

- *"Vehicles used for both public and private transport need to take greater account of the reduced capabilities of the increasing number of older, functionally disabled users and of their mobility aids. Design standards to enable these improvements already exist." (Ref: **CO_0031**)*
- *"Vehicle manufacturers need to improve the usability of vehicles for older people while maintaining vehicles' crashworthiness. Facilitation of entry and exit, more user-friendly controls and displays and greater use of power-assisted devices are areas for improvement." (Ref: **CO_0031**)*
- *"Height of doorframe, width of door aperture, seat height, doorsill height and floor-well depth are design elements of a car that may encumber older drivers and passengers." (Ref: **CO_0031**)*
- *"Further design improvements advocated for older occupants are: Handhold and supports for assistance in entering and exiting the vehicle. While handles are often provided on the passenger's doorframe, similar features are rarely provided for drivers. In the absence of this*

*feature, drivers can get some support by grasping the door window frame or ledge." (Ref: **CO_0031**)*

- *"(...) automotive designers tend to be younger engineers with little personal experience of the problems and difficulties facing older drivers. These engineers need to think about how their grandparents would fare in the models they are designing (Huelke, 2001). The Ford Motor Company is addressing this issue by having their ergonomics engineers in training don a "third-age" suit, which makes the wearer feel physically 30 years older. The suit, which is akin to an astronaut's outfit, mimics restricted body movement, inability to turn the head, stiff fingers and joints and increased sensitivity to glare (Roach, 2000)." (Ref: **CO_0031**)*

#### Advanced Driving Devices

- *"The existence of sensor technology, radio frequency communication-based technology, ad-hoc communication, positioning technology and video image processing technology enables extra information on the driving environment to be collected and interpreted. Examples of such information are distance and/or speed from the vehicle ahead, lateral position of the vehicle on the lane and degree of visibility (e.g. day or night). Integrating them into invehicle driver support systems should decrease human errors, alert the driver as early as possible to an impending danger, warn him/her if there is no driver reaction to the first alert and actively assist or ultimately intervene in order to avert the accident or mitigate its consequences. Warnings should be given in visual or audible formats rather than vibrating format as elderly drivers are less sensitive to vibration." (Ref: **CO_0081**)*
- *"New technologies for improving vehicle control and safety should continue to evolve and be designed and evaluated in light of older drivers' use patterns and functional abilities. Possible developments include navigational aids, in-vehicle collision warning systems, vision enhancement facilities and intelligent cruise control." (Ref: **CO_0031**)*
- *"In-vehicle emergency call ("Mayday") systems promise to be of particular benefit to older people in terms both of increased personal security in the event of vehicle breakdown and earlier treatment of injury in the event of a crash. These systems need to be evaluated, and if deemed beneficial, promoted." (Ref: **CO_0031**)*

#### Information systems and Booking and Payment systems

- *"Information, ticketing and payment systems need to be easily understood and fare structures need to be fair and simple. Many current applications have been developed with capacities of the young internet generation in mind. There are clear opportunities for innovation and the creation of mobility-related services and products that specifically target the older generation and people with reduced mobility." (Ref: **CO_5048**)*

### Impacts on Mobility and Transport

#### Higher transport demand for daily passenger transport

- *"In summary the motorized mobility of the elderly is lower than for the rest of the adult population, both with regards to daily transport and to tourist travels. As for the rest of the population the transport consumption of the elderly tends to increase - but at a lower level than the younger generations. An ageing of the population therefore must be expected to lead to lower transport consumption - and thus less pressure on the environment - but this effect may to some extent be weakened by the apparent increase in travelling by the wealthy and healthy segments of the elderly population in north-western Europe." (Ref: **CO_0125**)*
- *"Ageing will affect mobility through its impact on the labour market. In view of the contemporary ageing trends we can expect a higher rate of persons aged 60+ to remain active in the labour market. Assuming that a) labour market demand grows in the future and b) technological developments are not such that this increase in labour supply can be absorbed by teleworking thus having a neutral impact on mobility, we can expect ageing to generate a higher transport demand for daily passenger transport." (Ref: **CO_2041**)*

#### Reduced overall mobility with a different time profile

- *"The number of daily trips decreases at 65+. Of course this is closely related to a shrinking activity rate. However, surveys show that other reasons, such as the weather, darkness, barriers, missing assistance and lack of money also play a significant role." (Ref: **CO_0079**)*

- *"Older people have a different mobility profile during the course of a day. Whereas motorised traffic usually peaks between 7 a.m. and 9 a.m. in the morning, and between 4 p.m. and 6 p.m. in the evening, the mobility pattern of the 60+ age group varies dramatically." (Ref:* ***CO_0079****)*

#### Reduced travelled distances and time

- *"Mobility patterns of older people are more focused on their particular neighbourhood. Two thirds of all trips made by older people are restricted to their respective neighbourhoods (mainly on foot). Therefore safe, clear, barrier-free routes, with opportunities to rest, are extremely important for ensuring the mobility of older people in all neighbourhoods and all areas of the city." (Ref:* ***CO_0079****)*
- *"A 1989 survey in West Germany (Kloas et al., 1993) illustrates the variability of travel habits by profession - the average person traveled 1.09 h per day, but university students and government employees spent much more time in motion (1.27 and 1.32 h, respectively). German pensioners were less mobile (0.94 h)." (Ref:* ***CO_0001****)*

#### Increased demand for public transport

- *"Ageing results in more difficulties when driving, thus increasing reliance on collective (public) transport." (Ref:* ***CO_5048****)*
- *"Public transport and walking are of high importance for older people. Studies in Germany showed that mobility patterns change significantly at about the age of 65. Whereas personal mobility until the age of 55 is clearly dominated by motorised individual transport, this pattern changes dramatically thereafter, with the percentage of pedestrian traffic rising to 52% in the 85+ age group." (Ref:* ***CO_0079****)*
- *"One particularly poignant question concerns the degree to which the cutbacks in state pension provision will lead to a lower proportion of affluent seniors, and whether the older generation of the future will no longer be able to afford expensive mobility." (Ref:* ***CO_5006****)*
- *"Ageing results in more difficulties when driving, thus increasing reliance on commercial individual transport (taxis and paid drivers)." (Ref:* ***CO_5048****)*

#### Rethinking public transport infrastructures

- *"The ageing of society will also have an impact on the characteristics of the transport solutions that will need to be offered for providing their mobility. Public transport vehicles and infrastructure will need to become more accessible. Pedestrian traffic lights will need to remain on the green stage for longer times to suit the possibilities of people with reduced mobility. This might reduce the capacity of the (urban) infrastructure for road traffic." (Ref:* ***CO_5048****)*
- *"Electric wheelchairs will need to be available at airports and railway stations. Toilets will need to be adapted and made more abundant. Airports, railways and maritime stations will need to have medical services available." (Ref:* ***CO_5048****)*

#### Need for more secure, safe and reliable transport services

- *"An ageing society will place more emphasis on the provision of transport services involving a high level of perceived security and reliability, and which feature appropriate solutions for users with reduced mobility." (Ref:* ***CO_0015****)*
- *"Compared to their share of the population, older people are overrepresented in casualties mainly when using public transport and as pedestrians. This reflects, of course, both their travel characteristics and their physical frailty." (Ref:* ***CO_0030****)*
- *"(...) the decline in capability of elderly drivers has contributed to the fact that - compared to middle aged drivers - elderly drivers are more often involved in traffic accidents, killed or seriously injured in accidents which involve other vehicles." (Ref:* ***CO_0081****)*

#### Changes to the driving infrastructures: development of car design and new support and control systems

- *"The ageing of society provides compelling reasons for improving vehicle design to meet the problems experienced by older people. Because ageing is associated with frailty and increased vulnerability to injury in the event of a crash, older transport users are likely to be the prime beneficiaries of continuing improvements to protect vehicle occupants." (Ref:* ***CO_0031****)*

- *“In-vehicle assistive technologies are available to address elderly drivers’ functional decline and avoidable behaviours, assist elderly drivers with their driving activities and increase road safety.” (Ref: **CO_0081**)*

*Scarcity of labour skills in the transport sector*

- *"A scarcity of labour and skills may arise, further aggravating the shortage of skilled labour already experienced in some segments of the transport sector." (Ref: **CO_0015**)*

*Increasing demand for tourism*

- *“Population ageing and the increasing well-being of the aged will increase flows even more. Residential tourism in Spain, Italy, Croatia is already booming, as Northern Europeans are purchasing second residences there: either retired people spending winters in the south, or liberal professionals spending 3 or 4 days per week thanks to their work flexibility.” (Ref: **CO_5048**)*

*Increase of demand for collective forms of long distance transport by road and air*

- *“Although above a certain age people generally travel less than when they were younger, aged people of today tend to travel more than their parents did. This tendency is expected to continue and is reinforced by improved health, more travelling options and better foreign language skills." (Ref: **CO_0015**)*
- *“Ageing affects the transport system through its impact on the structure and patterns of leisure activities. Contemporary older cohorts are more interested in travelling in their leisure time. This will result in an increase of demand for collective forms of transport by road and air.” (Ref: **CO_2041**)*
- *“However, older people may show more variable habits in terms of mobility than in earlier times, possibly due to higher average income revenues and better health status of the elderly in the more distant future. In addition, even if collective public transport such as rail are not currently preferred by older people, this could change with significant improvements in terms of quality (comfort, accessibility, information) and adapted tariffs.” (Ref: **CO_5048**)*

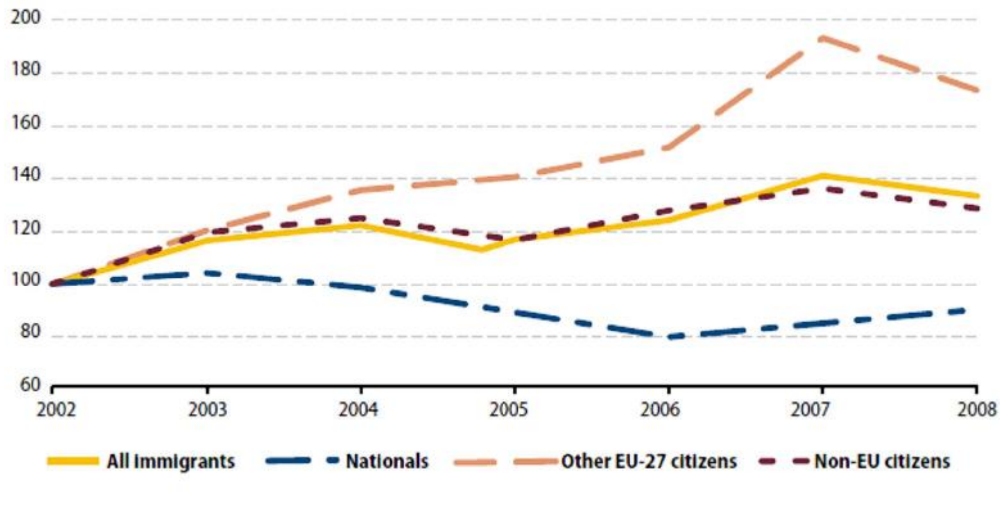
*Increase of demand for road safety*

- *“Factors that are likely to hinder further improvements in road safety are the rising number of vulnerable road users, (...) the growing number of elderly road users and a general increase in mobility demand, particularly in urban areas. All of these issues mean that road safety will remain a major challenge in the coming decade.” (Ref: **CO_0266**)*

#### *1.2.2.2 Migration flows*

**Driver Description**

- *"Migration has become an increasingly important phenomenon for European societies." (Ref: **CO_0066**)*
- *"During 2009, about 3.0 million people immigrated into one of the EU Member States while at least 1.9 million emigrants were reported to have left an EU Member State. The latest figures available reveal a substantial decline in immigration in 2009 as compared with 2008. However, it is difficult to quantify exactly the magnitude of this decline as some countries (including Germany, Austria and the Netherlands) have modified the underlying definitions of migration (...)." (Ref: **http://epp.eurostat.ec.europa.eu/statistics_explained**)*
- *"It should be noted that these figures do not represent the migration flows to/from the EU as a whole, since they also include flows between different EU Member States. However, more than half of the immigrants into the EU Member States, an estimated 1.6 million people in 2009, were previously residing outside the EU."*
  *(Ref: **http://epp.eurostat.ec.europa.eu/statistics_explained**)*
- *"Immigrants to EU Member States have a wide variety of origins." (Ref: **CO_0066**)*
- *"A particular distinction must be made between intra-EU migration and migration from outside of the EU. Subject to some transitory restrictions on citizens of new Member States, EU citizens have the right to live and work in other EU Member States. (Similar arrangements are in place for citizens of the other EEA countries and Switzerland.) EU citizens are not subject to limits on the numbers that may be admitted, and are exempt from restrictions as to duration of residence and access to the labour market that may be applied to third country nationals (persons who are no citizens of an EU Member State)." (Ref: **CO_0066**)*
- *"The number of EU‑27 citizens migrating to a Member State other than their own country of citizenship increased on average by 12 % per year during the period 2002–08, and peaked in 2007." (Ref: **CO_0066**)*



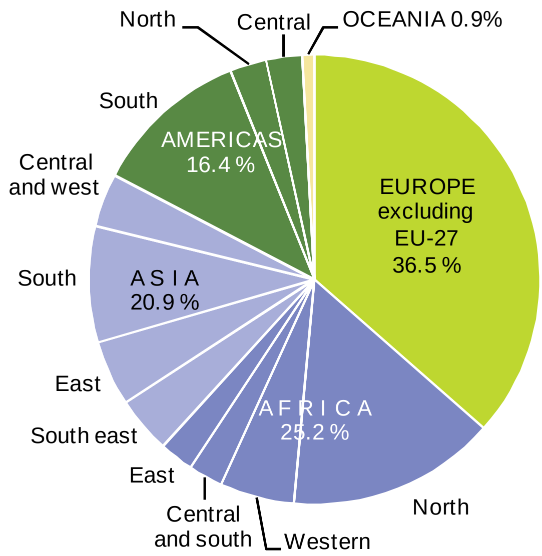

*Source:* Eurostat (online data code: migr_imm1ctz) and Eurostat estimates

Source: Migrants in Europe. A statistical portrait of the first and second generation (Ref: **CO_0066**)

**Figure 1-8 Relative change in migration inflows to EU Member States by citizenship groups, EU‑27, 2002–08 (%)**

- *"Intra-European migration flows are (...) very diverse. They comprise retirees from northern European regions moving south to the Mediterranean regions as well as East-European workers in search of jobs moving to West-European countries. In the context of European integration and of the development of corporate enterprises, intra-European mobility in the service sector is also growing. The same is also true in the case of students. East-west migration flows related to the recent EU enlargements have largely been underestimated, causing in some cases scarcity problems for qualified manpower in the immigrants' countries of origin. The intensification of* *intra-European migration flows in the decades to come is highly probable in a context where national borders will become weaker while regional disparities remain significant and the number of retirees increases." (Ref: **CO_1023**)*

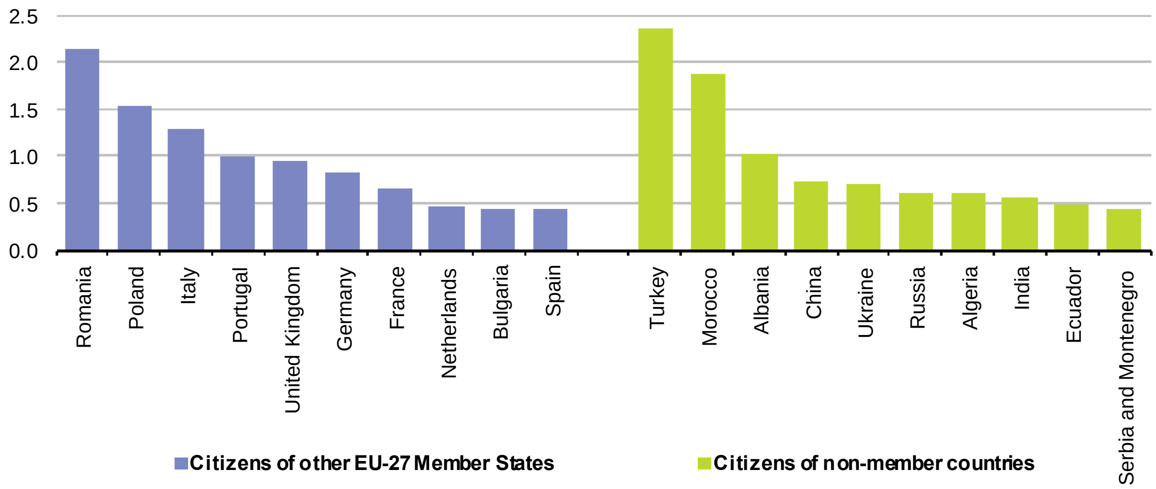
- *"In 2010, a breakdown of the population by citizenship in the EU-27 showed that 20.1 million were citizens of a non-EU27 country (4% of the total population)." (Ref: **CO_0086**)*
- *"Looking at the distribution by continent of origin of third country nationals living in the EU, the largest proportion (36.5 %) were citizens of a European country outside the EU-27 (see Figure below), a total of 7.2 million people; among these more than half were citizens of Turkey, Albania or Ukraine. The second biggest group was from Africa (25.2 %), followed by Asia (20.9 %), the Americas (16.4 %) and Oceania (0.9 %). More than half of the citizens of African countries that were living in the EU were from North Africa, often from Morocco or Algeria. Many Asian non-nationals living in the EU came from southern or eastern Asia, in particular from India or China. Citizens of Ecuador, Brazil and Colombia made up the largest share of non-nationals from the Americas living in the EU."*
  *(Ref: http://epp.eurostat.ec.europa.eu/statistics_explained)*




Source: Migration and migrant population statistics: tables and figures YB2012 (Ref: **CO_0085**)

**Figure 1-9 Citizens of non-member countries resident in the EU-27 by continent of origin, 2010**

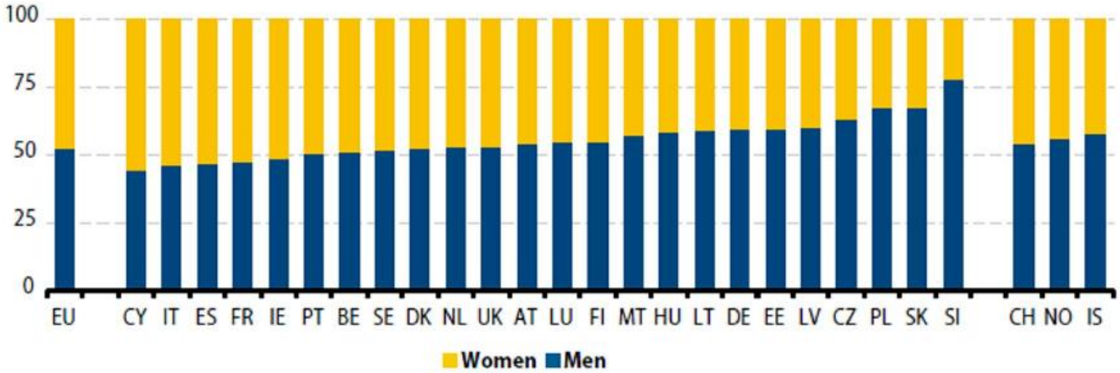
- *"The citizenship structure of the population of non-nationals living in the EU varies greatly between Member States; it is influenced by factors such as labour migration, historical links between origin and destination countries, and established networks in destination countries. Turkish citizens made up the biggest group of non-nationals (see Figure below) living in the EU in 2010, comprising 2.4 million people, or 7.2 % of all non-nationals. The second largest group was Romanians living in another EU Member State (6.6 % of the non-national population), followed by Moroccans (5.7 %). The group of non-nationals living in the EU with the most significant increase over the period from 2001 to 2010 was Romanians, their numbers increasing seven-fold from 0.3 million in 2001 to 2.1 million by 2010. The number of Polish and Chinese citizens also increased significantly during this period, and citizens from both of these countries figured among the ten largest non-national groups in 2010."*
  *(Ref: http://epp.eurostat.ec.europa.eu/statistics_explained)*




Source: Migration and migrant population statistics: tables and figures YB2012 (Ref: **CO_0085**)

**Figure 1-10 Main countries of origin of non-nationals, EU-27, 2010 (million)**

- *"In 2008, there were more men than women in migration flows to and from EU Member States in general. Around 48 % of immigrants were women. By contrast, Cyprus, Italy, Spain, France and Ireland reported that women outnumbered men among immigrants (Figure below). In Cyprus, this was mainly due to women with Filipino, Sri Lankan and Vietnamese citizenship, whereas in Italy and Spain women outnumbered men in the biggest group of immigrants (with Romanian citizenship in the case of Italy, and Moroccan citizenship in the case of Spain)." (Ref: **CO_0066**)*




(¹) Immigration data for EL and RO are limited to non-nationals only and are therefore not included; immigration data for BG highly underestimate non-nationals and are therefore not included.

*Source:* Eurostat (online data code: migr_imm1ctz)

Source: Migrants in Europe. A statistical portrait of the first and second generation (Ref: **CO_0066**)

**Figure 1-11 Immigrants by gender, EU−27 and EFTA, 2008 (%)**

- *"Patterns of migration flows can change greatly over time, with the size and composition of migrant populations reflecting both current and historical patterns of migration flows." (Ref: **CO_0066**)*
- *"Migrants' choice of destination may be influenced by a variety of interrelated factors including the presence of established communities from a particular country of origin living in a destination country (for example, Iraqi-born people seeking international protection in Sweden), and historical links between countries, related sometimes to the dissolution of previous states (such as between Russia and Latvia, or between the Czech Republic and Slovakia). Patterns of migration may also reflect past colonial and linguistic links, as seen in the long history of migration from the Indian subcontinent to the United Kingdom, in migration between Ireland and*

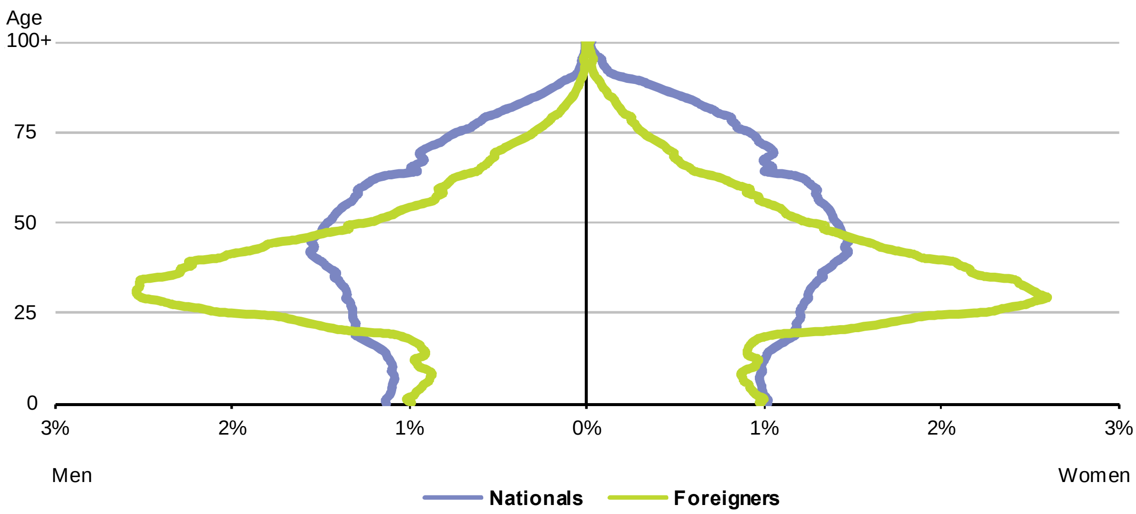
*the United Kingdom, between Brazil and Portugal and between Ecuador and Spain and in migration from Suriname to the Netherlands." (Ref: **CO_0066**)*

- *"Whereas migration used to be seen predominantly as a one-off movement leading to permanent resettlement, recent migration is more fluid, thanks to improved transport and communication networks. Migrants today may make consecutive stays in different countries, or alternate residence between countries." (Ref: **CO_5027**)*
- *"Future trends in migration are perhaps the hardest to anticipate, as they depend from future events across the world ranging from economic and social factors to political developments and family ties." (Ref: **CO_2050**)*
- *"The global economic crisis has slowed emigration in many parts of the world, although it does not appear to have stimulated substantial return migration. With economic recovery and job growth, most experts expect this slowdown to be temporary." (Ref: **CO_5029**)*
- *"For the EU as a whole, annual net inflows are projected to increase from about 1,018,000 people in 2010 (equivalent to 0.2% of the natural EU population) to 1,217,000 by 2020 and thereafter declining to 878,000 people by 2060." (Ref: **CO_0050**)*
- *"The cumulated net migration to the EU over the entire projection period is 55 millions, of which the bulk is in the euro area (42 millions)." (Ref: **CO_0050**)*
- *"Net migration flows are projected to be concentrated to a few destination countries: Italy (15.4 millions cumulated up to 2060), Spain (10.9 millions) and the UK (8.6 millions). For countries that are currently experiencing a net outflow (BG, EE, LV, LT, MT and RO), this is projected to taper off or reverse in the coming decades." (Ref: **CO_0050**)*
- *"In a trend perspective and in a context where the Union's competence in immigration matters remains limited, the evolution will be characterised by continuing, although rather contained, illegal immigration." (Ref: **CO_1023**)*

## Interactions within the Social Domain

### *Population ageing*

- *"An analysis of the age structure of the resident population shows that, for the EU-27 as a whole, the non-national population was younger than the national population. The distribution by age of non-nationals shows, with respect to nationals, a greater representation of adults aged between 20 and 47; this feature is evident when looking at the corresponding population pyramids (see Figure below). In 2010, the median age of the EU-27 total population was 40.9 years, while the median age of non-nationals living in the EU was 34.4 years)"*
  *(Ref: http://epp.eurostat.ec.europa.eu/statistics_explained)*




Source: Migration and migrant population statistics: tables and figures YB2012 (Ref: **CO_0085**)

**Figure 1-12 Age structure of the national and non-national populations by sex, EU, 2010 (%)**

Given the lower median age of migrants, and their higher fertility rates, migration flows can mitigate the speed of European population aging. However, international migration alone will almost certainly not reverse the ongoing trend of population ageing experienced in many parts of the EU.

- *“Most experts assume that immigrants will only partly compensate for the declining native population and work force.” (Ref: **CO_6000**)*
- *“Studies reveal that in order to offset the population decline, immigration to Europe should double in the coming years, i.e. 1.8 million per year to 2050, rather than the 950,000 per year recorded from 1995 to 2000.” (Ref: **CO_5027**)*

#### *Household structure and distribution*

Migration could have a twofold impact on household structure and distribution if measured from the perspective of the origin country or from the one of the hosting country. If considering the origin country, in several cases migrants, especially at the beginning of their experience, left households in the origin country that they usually support via remittances. Furthermore in case of women migrants, they usually left their children home with grandparents taking care of them. This implies a change in the structure and size of the household of the origin country. If looking at the hosting country, migrants generally live in urban areas and, in order to mitigate the cost of living in such expensive areas, tend to form new populated households.

#### *Income structure and distribution*

- *“The differences in the labour market situation of foreign-born and native-born persons are almost certain to be reflected in median income levels. (...) In 2008, for almost all Member States, the median annual equivalised disposable income for the foreign-born population was considerably lower than that for native born persons.” (Ref: **CO_0066**)*
- *“Lower income levels also go hand in hand with less favourable housing conditions, in particular with regard to overcrowding.” (Ref: **CO_0066**)*
- *“Remittances sent by migrants are a remarkably high component of international capital flows. Through remittances, migration can thus directly and indirectly increase income and consumption in the home area and, if the poor receive at least some remittances, decrease poverty in the home area. If the poor receive most remittances, not only poverty but also inequality will decrease. Yet, migration does not necessarily lead to a significant increase in income or reduction in poverty and inequality in home areas. Remittances may not be sufficient to compensate for the loss of local income previously earned by the migrant.” (Ref: **CO_0095**)*

#### *Car ownership*

- *“In general immigrants have lower economic standards than the domestically born in the same country, and consequently the access to cars is generally lower. The purchase of a car and getting a driver’s license are costly, and consequently it takes time for immigrants to accumulate the resources needed to get car access. Car access is lower among female than among male immigrants, and this difference is greater than the difference in car access among domestically born women and men.” (Ref: **CO_4033**)*
- *“Many of the immigrants had access to a car and a driver license in the country of origin, and many would like to have a car and a driver license in the future. If they could drive or be driven as a passenger, many thought that they would be less likely to use energy efficient transport modes in the future. In sum, the immigrants interviewed have an energy efficient way of travelling today, but the challenge seems to be to maintain this travel behaviour in case they attain a driver license and a car.” (Ref: **CO_4033**)*

#### *Urbanisation*

- *“New immigrants in recent decades have tended to flock to urban areas, altering the composition of large cities. These cities have become the visible face of globalisation. In the Netherlands, for example, more than 60 % of all immigrants and their children live in the Western conurbation of the Randstad (which comprises Amsterdam, Rotterdam, The Hagueand Utrecht); in Amsterdam nearly half the population is of immigrant origin. The situation is similar in other large European cities. At the same time, the newcomers are distributed unevenly over the city’s districts and wards, concentrated more in some areas than others.” (Ref: **CO_5027**)*
- *“Many socially deprived areas – often with a high share of immigrants – are located in the urban fringe.” (Ref: **CO_5027**)*

*Tourist flows*

- *"(...) prosperous places like London and Paris attract vast numbers of tourists, while some of these tourists become subsequently temporary or permanent migrants in the host country. So, tourism encourages migration. Conversely, migrants travel back to their home countries for short visits and their friends and relatives visit them in the host country. Therefore, migration boosts tourism. Thus, migration and tourism tend to become mutually interacting geographic phenomena whose importance is rapidly growing. Migration – related tourism seems to become an important segment of global tourism." (Ref: **CO_0092**)*
- *"The empirical result (...) shows that as the stock of immigrants increase from a certain country ceteris paribus the number of VFR[4] visits from that particular country rises. The regression also points out that GDP per capita, which determines the ability to travel, has a positive impact on VFR visits. Next, the distance is, as expected, negatively related to VFR visits and the total number of visits. There is no significant impact of distance on the total duration of VFR visits, since long distance VFR trips are made less frequently, but when they are made the duration per trip is longer." (Ref: **CO_0092**)*

*Health*

- *"Migration inside and between countries is likewise increasing (...). These migrations increase the opportunity for diseases to spread rapidly between populations and may result in the re-introduction of infectious diseases to areas where they had been eradicated (or significantly reduced)." (Ref: **CO_0275**)*

### Interactions with the Economy Domain

*GDP trends*

- *"The contribution of immigrants to the EU economies has been substantial. In the period 2000–2005, third country immigrants to the EU accounted for more than a quarter of the overall rise in employment and for 21% of the average GDP growth in the EU-15. This growing migrant labour share consisted of both highly qualified jobs in the expanding sectors of the economy but also of many jobs requiring a mix of lower skills." (Ref: **CO_0086**)*

*Employment*

- *"Migration could play an important role in mitigating the effect of ageing on the labour market." (Ref: **CO_0015**)*
- *"By 2030, it is estimated that some 200 million immigrants will be needed to fulfil the needs of the economic system, or else Europe's economy will not survive." (Ref: **CO_5048**)*
- *"(...) it is estimated that in order to compensate for the reduction of the population of working age, the current flow of immigrants will need to be tripled within the next four decades" (Ref: **CO_5027**)*
- *"Better recognition at EU level of skills and qualifications from third countries would mean that people can fully use their potential in their jobs. More geographically flexible labour markets would allow migrants to change employers, possibly located in different Member States, more easily. Such mobility should preserve their residence rights and lead to a better matching of labour market supply and demand." (Ref: **CO_0086**)*
- *"There is the possibility that jobs will be filled by "invited workers", who come to Europe to work for a period of time and then return to their origin countries. The dynamics of this phenomenon are related on border permeability policies, as weak borders allow people to enter and leave easily, whilst strong borders encourage people to stay due to the difficulty in re-entering later on." (Ref: **CO_5048**)*
- *"More recently, certain migrant worker policies have focused on attracting highly skilled or educated migrants. Although the definitions of the target group of migrants have differed between countries, this approach has been seen in several national programmes (such as in Denmark, Germany, Sweden and the United Kingdom), and now forms the basis of the EU Blue Card Scheme." (Ref: **CO_0066**)*

[4] Visiting Friends and Relatives

- *"With regard to the health sector, for example, as already announced in the "Agenda for New Skills and Jobs", the Commission intends to put forward by 2012 an action plan in order to address the shortage of health professionals in the EU." (Ref: **CO_0086**)*
- *"Immigration flows from outside Europe are expected to continue to grow (United Nations, 2005), as they will contribute to fill employment gaps, especially in lowskilled jobs." (Ref: **CO_5048**)*

*Regional differences in economics*

Migration is not spatially uniform and therefore a high concentration of migrants in certain regions can contribute more to the local economies, thus increasing the regional differences. This phenomenon is further intensified if considering working migration that is usually polarised towards prosperous regions.

### Interactions with the Environment Domain

No particularly relevant interrelationships have been found.

### Interactions with the Technology Domain

No particularly relevant interrelationships have been found.

### Impacts on Mobility and Transport

*Poor information available on travel behaviour of immigrants*

- *"The travel behaviour of immigrants and the attitudes of immigrants toward different travel modes are scarcely researched in Europe. Analysis of this topic is difficult since the country of birth or questions concerning nationality are not included in the national travels surveys in European countries." (Ref: **CO_4033**)*

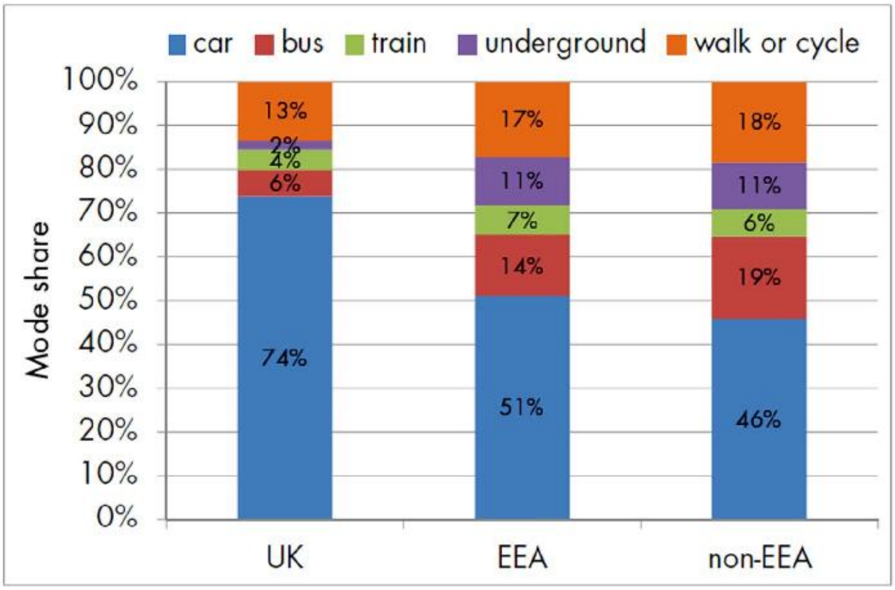
*Lower travelled distances*

- *"In general immigrants have fewer cars than the domestically born populations, and they travel less in general. Trips are fewer and travel distances by car are shorter among immigrants than among the domestically born populations. The differences between the immigrants and the domestically born seem to be greater for women than for men and greater for newly arrived immigrants than for immigrants who have stayed longer in their new country." (Ref: **CO_4033**)*
- *"Different mobility patterns and lower car availability lead to different distances travelled. For instance the average German man travels four times further per day than the average Italian woman living in Germany. This is an indication of the relative importance of local neighbourhoods for migrants." (Ref: **CO_0079**)*

*Increasing demand for public transport services*

- *"The poorer car access among immigrants leads to more walking and more use of public transport among immigrants than among the domestically born. However, bicycle riding appears to be more popular among the domestically born than among the immigrants especially than among immigrant women." (Ref: **CO_4033**)*
- *"It is much less common for non-EEA[5] migrants to travel to work by car than UK nationals (46 percent of non-EEA migrants compared with 74 percent of UK nationals). Instead, more of them take the bus to work (19 percent of non-EEA migrants compared with 6 percent of UK nationals). More of them use underground (11 percent of non-EEA migrants compared with 2 percent of UK nationals). More of them also walk or cycle (18 percent non-EEA compared with 13 percent of UK nationals). Also, it is slightly more common for non-EEA migrants to take the train to work; however, the difference (6 percent of non-EEA migrants compared with 4 percent of UK nationals) is not statistically significant. The chart also suggests that EEA and non-EEA migrants have a similar pattern in mode choice." (Ref: **CO_0094**)*

[5] EEA European Economic Area




Source: The impact of migration on transport and congestion (Ref: **CO_0094**)

**Figure 1-13 Mode choice in UK by nationality. Annual Population Survey, Oct 2009–Sep 2010**

- *"With regard to migrants' impacts on public transport, an area that is important but difficult to quantify is crowding. (...) Crowding issues are specific to the mode of public transport. Notably, it is more difficult for rail and underground to address crowding issues by expanding capacity because additional infrastructure is costly and takes a long time to build. For buses, crowding may be less of an issue as bus operators can respond by providing more buses relatively easily and quickly. In fact, the increased patronage on buses is generally seen as a positive outcome." (Ref: **CO_0094**)*

*Increasing travel demand towards extra European countries (China; Asia etc)*

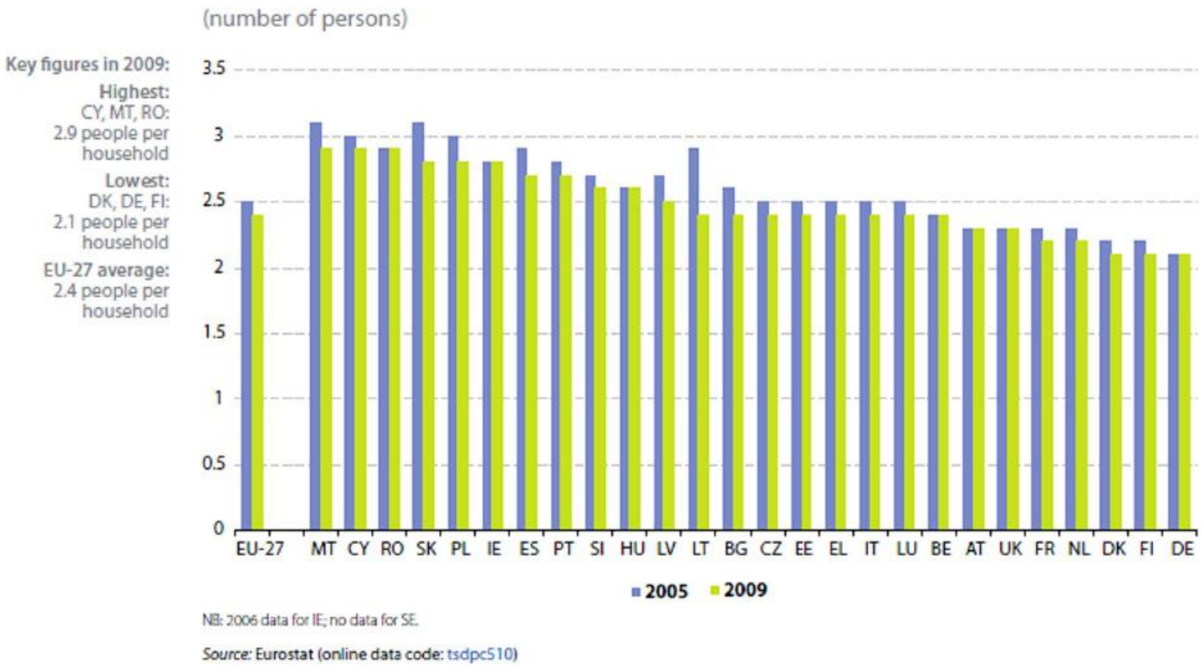
- *"Migrants, generally young and mainly living in urban areas, will further intensify Europe's ties with neighbouring regions, by creating cultural and economic links with their country of origin. These links will entail more movement of people and goods." (Ref: **CO_0015**)*

### 1.2.3 The Social Structure Factor

#### *1.2.3.1 Household Structure and Distribution*

**Driver description**

- *"Another social indicator of potential relevance for mobility is household size and typology as household arrangements (and more specifically whether people live alone or in larger families) influence mobility patterns and, especially, motorisation." (Ref: **CO_2041**)*
- *"European men and women are having children later in their lives because they have more life choices combined with highly effective means of controlling their fertility. (...) The increased participation in higher education and training that has occurred in most European nations (...), as well as accrual of qualifications to meet the demands of modern economies, have lead to an extension of the period of dependency in the third decade of life. Consequently, the time span of the transition to adulthood, from leaving education, entering the labor market and marrying and becoming parents has become more protracted" (Kiernan, 2003, p. 30)." (Ref: **CO_2018**)*
- *"Family size is declining both because of the fall in fertility rates and because fewer generations are living together under the same roof. The two-generation family and cohabiting couple has become the norm for private life, with the result that family solidarity is being placed under strain, especially in caring for older people. In addition, the increase in the number of women in employment observed everywhere, although at different speeds and intensity across countries, is contributing to the spread of dual-earner families." (Ref: **CO_0083**)*




Source: Sustainable development in the European Union (Ref: **CO_0197**)

**Figure 1-14 Average number of people per household, by country**

- *"The increase in single households is a common phenomenon in European cities. In particular, the numbers of households with a single adult under the age of 35, and between 35 and 64 years, are both increasing. The number of trips per person varies according to household size, with single households usually making the highest number of trips. The rising number of young single households, together with the growing number of active older people, partly explains the strong rise in journeys associated with leisure activities which can be witnessed in many cities." (Ref: **CO_0079**)*
- *"Single-adult households among the 65+ age group are most common in the Nordic and North-Western groups of countries (where divorce is relatively common and where it is relatively unusual for older people to live with children or other relatives) and least common in the Southern countries (where divorce rates remain low, and where it is common for older people to live with adult children). Couple-only households where at least one partner is aged 65 or over*

*are most common in the Southern European countries (low divorce rates) and least common in Eastern Europe (high divorce rates, and a high incidence of multigenerational households)." (Ref: **CO_0084**)*

Among the new and rare family forms, the growing phenomenon of "Commuter Families" has to be taken into account, especially given its impact on mobility patterns. Commuter families are generally couples which do not live in the same household. These might be also families with children. Unfortunately current statistical data does not allow for a complete description of this phenomenon. The data of the Gender and Generation Survey (GGS) provide a first database to describe, at least to some extent, this family form, even though it is not possible to differentiate specific details, e.g. how long the partnership lasts or how often the partner is commuting.

### Interactions within the Social Domain

#### *Income structure and distribution*

- *"Household structures have changed profoundly over the past decades in OECD countries. There are more single-headed households with and without children today than ever before; their share among working-age households has increased in all OECD countries, on average from 15% in the late 1980s to 20% in the mid-2000s. Smaller households are less able to benefit from the savings associated with pooling resources and sharing expenditures. A trend toward smaller households therefore is likely to increase earnings and income inequality." (Ref: **CO_0157**)*

#### *Car ownership*

- *"Household structure is an important driver for the overall mobility of the population. A household is a typical unit owning a car or having access to a car, with the household members sharing the car. The general tendency has been a decrease in household size, and UN projections envisage (United Nations, 2003) a further decrease in EU 27 from 2.4 in 2005 to 2.1 in 2030. These figures indicate that, irrespective of an almost constant total population, there will be an increase in number of households. If the current trends in household car ownership continue, an increase in the car fleet may be estimated." (Ref: **CO_5048**)*

#### *Urbanisation*

- *"Re-urbanisation is facilitated by the decline of household size – single or two persons households have a higher propensity to locate in the urban centres." (Ref: **CO_5048**)*
- *"During the next two decades demand for large-lot housing will decline slightly, but demand for small lot and attached housing will approximately double; these trends are likely to increase urbanization in two ways: more redevelopment of existing urban neighbourhoods, and suburbs developing into towns and cities." (Ref: **CO_5047**)*
- *"Major factors affecting households' choices of residence are the affordability of available properties, the match between neighbourhood amenities and their lifestyle aspirations, and the cost and convenience of travelling to work." (Ref: **CO_0260**)*
- *"Households make choices between residential areas taking into account the price of housing and the price of commuting between the work place and home. When travel costs fall below a certain threshold and income reaches a certain level the rate of sprawl quickens, and unsurprisingly sprawl is more common in regions where incomes are high and commuting costs are low." (Ref: **CO_0028**)*
- *"In the inner city, poor quality neighbourhoods often house a mix of unemployed people, the elderly poor, single young people and minority ethnic groups, often suffering from the impacts of the selective nature of migration and employment loss." (Ref: **CO_0028**)*
- *"The socio-economic character of suburban and peripheral areas is typified by middle and upper income families with children, who have the necessary mobility and lifestyle to enable them to function effectively in these localities. However, the suburban experience for other groups, including the young and old, who lack mobility and resources can be very different and can reduce social interaction. Furthermore, large segments of urban society are excluded from living in such areas." (Ref: **CO_0028**)*

*Planning*

- *"Housing market demand analysis based on consumer preference surveys indicates that during the next two decades demand for large-lot housing will decline slightly so current supply is sufficient to meet future needs, but demand for small lot and attached housing will approximately double." (Ref: **CO_5047**)*

## Interactions with the Economy Domain

*Employment*

- *"Unemployment has been and still is falling, and employment both of men and women has been increasing. The proportion of lone parents in employment has been rising. The proportion of households without a person in employment is also falling, though it remains high." (Ref: **CO_0176**)*

## Interactions with the Environment Domain

*Energy availability, production and consumption*

- *"Changes in lifestyle associated with urban sprawl contribute as well to increases in resource use. (...) people are living increasingly in individual households, which tend to be less efficient, requiring more resources per capita than larger households. For instance, a two person household uses 300 litres of water per day, two single households use 210 litres each. A two person household will use 20 % less energy than two single person households. The number of households grew by 11 % between 1990 and 2000, a trend that increases land use and acts as a driver for expansion of urban areas. The general trend is for greater consumption of resources per capita with an associated growth in environmental impact. This adds pressure to the fact that about 60 % of large European cities are already overexploiting their groundwater resources and water availability." (Ref: **CO_0028**)*

## Interactions with the Technology Domain

No particularly relevant interrelationships have been found.

## Impacts on Mobility and Transport

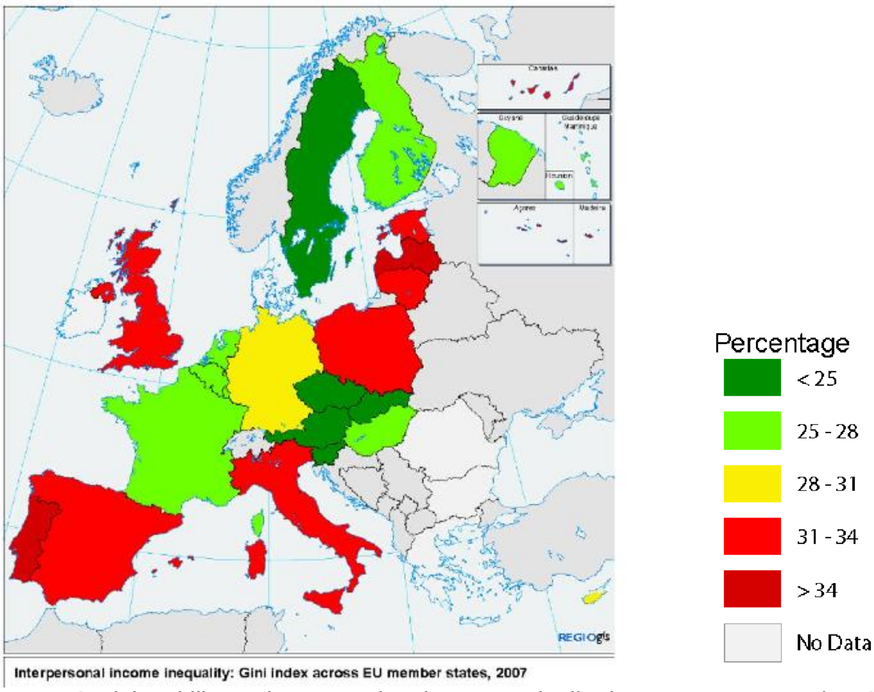
*Higher traffic densities in urban and suburban environments*

- *"Changing household structures result in the decrease of the average household size. This results in lower car occupancy. Assuming that (a) the motorisation rate continues to increase and (b) car-sharing schemes do not increase in significance, we can expect the changing household structures to lead to higher traffic densities in urban and suburban environments." (Ref: **CO_2041**)*

#### 1.2.3.2 Income Structure and Distribution

**Driver description**

- *"Income distribution reflects the nature and extent of inequalities in the income of individuals or households in a given society or subgroups within society. The concept may also be applied to geographical units." (Ref: **CO_5054**)*
- *"Measurements of income distribution include poverty measures, either identified as absolute or relative poverty. Absolute poverty measures the number of people living below a certain income threshold or the number of households unable to afford certain basic goods. Relative poverty, which is related to the concept of income inequality, measures the extent to which a household's financial resources fall below an average level of income threshold for that economy." (Ref: **CO_5054**)*
- *"There are many ways to characterise income distribution and inequality (...) Aggregate measures such as the Gini coefficient and the Atkinson family of inequality measures summarise income inequality in society in a single number. (...) The Gini-coefficient is perhaps the most popular measure of inequality. The coefficient varies between 0, which reflects complete equality and 1, which indicates complete inequality (one person has all the income or consumption, others have none)." (Ref: **CO_5054**)*




Source: Social Mobility and Intra-Regional Income Distribution Across EU Member States (Ref: **CO_5054**)

**Figure 1-15 Interpersonal income inequality: Gini idex across EU member states, 2007**

- *"The main source of income for individuals and households in the EU is earnings from employment." (Ref: **CO_5026**)*
- *"EU-15 countries have greater spatial inequality in per capita income and unemployment rates, two common indicators of individual living standards in high-income countries." (Ref: **CO_5028**)*
- *"Inequality in earnings has risen in the majority of member states in recent decades. In particular labour's share of value added has fallen especially among the low paid. This means that employment no longer provides a guarantee against poverty and exclusion. One third of working adults are in poverty, implying the need to strengthen policies aimed at working poor." (Ref: **CO_5026**)*
- *"Furthermore, an increasing proportion of European workers have experienced a decline in total income – wages plus social contributions." (Ref: **CO_5026**)*

- *"As findings from INEQ, EQUALSOC, and LoWER3 show, both earnings and incomes inequalities have increased in recent decades for most EU states. The level of inequality varies between different MS. For example, inequality declines marginally in Belgium but rises significantly in the UK. The main source of rising inequality for many states is the increased share of income accruing to more affluent households, those in the top quintile – (the top 20 % of incomes)." (Ref: **CO_5026**)*

| | Mid 1970s | Mid 1980s | Mid 1990s | Mid 2000s |
|---|---|---|---|---|
| Austria | | 0.236 | 0.238 | 0.265 |
| Belgium | | 0.274 | 0.287 | 0.271 |
| Czech Republic | | 0.232 | 0.257 | 0.268 |
| Denmark | | 0.221 | 0.215 | 0.232 |
| Finland | 0.235 | 0.207 | 0.228 | 0.269 |
| France | | 0.300 | 0.270 | 0.270 |
| Germany | | 0.257 | 0.272 | 0.298 |
| Greece | 0.413 | 0.336 | 0.336 | 0.321 |
| Hungary | | 0.273 | 0.294 | 0.291 |
| Ireland | | 0.331 | 0.324 | 0.328 |
| Italy | | 0.309 | 0.348 | 0.352 |
| Luxembourg | | 0.247 | 0.259 | 0.258 |
| Netherlands | 0.251 | 0.259 | 0.282 | 0.271 |
| Norway | | 0.234 | 0.256 | 0.276 |
| Poland | | | | 0.372 |
| Portugal | 0.354 | 0.329 | 0.359 | 0.385 |
| Slovakia | | | | 0.268 |
| Spain | | 0.371 | 0.343 | 0.319 |
| Sweden | 0.212 | 0.198 | 0.211 | 0.234 |
| United Kingdom | 0.282 | 0.325 | 0.354 | 0.335 |
| United States | 0.316 | 0.338 | 0.361 | 0.381 |

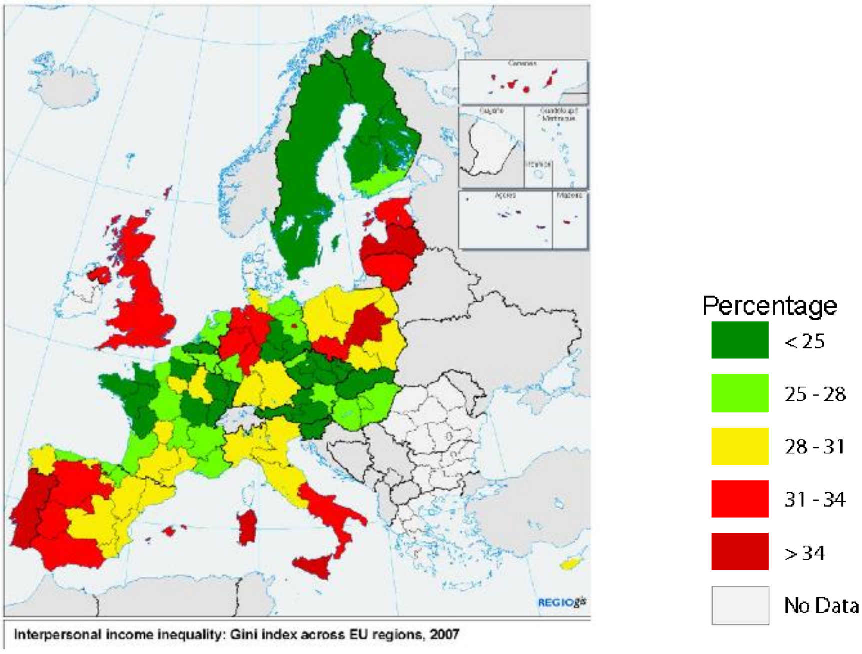
Source: Adapted from OECD (2008) op.cit.

NB: Norway and the US are included for comparison; see definition of Gini Coefficient in Box 1.1.

Source: Why socio-economic inequalities increase? Facts and policy responses in Europe (Ref: **CO_5026**)

**Figure 1-16 Trends in household income inequality (Gini coefficient)**

- *"The projects show that a combination of factors (including economic restructuring associated with the move towards a knowledge economy, labour market change and redistributive policies of welfare states) account for these increases in inequality in the last two to three decades."* (Ref: **CO_5026**)
- *"Hoffmeister (2006) found in a study of European countries that more than a fifth (21.6%) of overall inequality was attributed to the income gap between the western and eastern halves of the EU. The differences between countries (within the areas) account for only 1.3 percent, and the differences between the regions (within the countries) for less than 1 percent of overall inequality. Three quarters of the inequality was attributed to income differences between people living in the same NUTS1 region." (Ref: **CO_5054**)*




Source: Social Mobility and Intra-Regional Income Distribution Across EU Member States (Ref: **CO_5054**)

**Figure 1-17 Interpersonal income inequality: Gini index across EU regions, 2007**

- *"In Europe, 17 families out of 100 were considered at risk of poverty in 2007. In addition to this conventional form of poverty, new forms of social exclusion and poverty are emerging: "infrastructure-poor" (eastern Europe); "feminisation of poverty", mainly among single, immigrant mothers (southern Europe); "immigrant poverty" (central Europe and other countries); "young people at risk of poverty" (eastern Europe); "the vulnerable elderly" (eastern and western Europe), among other forms." (Ref:* ***CO_5027****)*
- *"Cities in particular have many low-income communities – this trend will increase as much of the world's future population growth will be occurring in Asian and African cities." (Ref:* ***CO_5018****)*
- *"In some countries that recently joined the EU, the level of urban poverty is underestimated. A World Bank study found that peri-urban dwellers, homeless and internally displaced people and refugees are consistently underrepresented or omitted entirely from surveys. The appearance of forms of slums in the periphery of big cities is a new – and still not well recognised or documented – phenomenon. The World Bank study found that most poverty analyses fail to differentiate among urban settlement types, and as a result, "the better off capital cities conceal the degree of poverty in secondary cities." (Ref:* ***CO_5027****)*
- *"Passenger traffic is very much related to both personal income and travel time. People are willing to travel, and are disposed to spend a certain amount of their income (i.e. 10 to 15% of their personal income) and of their time (i.e. 1h per day) for travel." (Ref:* ***CO_5048****)*
- *"For passengers, the key element in transport is its cost in relation to people's personal income. If personal income rises, rising transport costs are not a substantial problem." (Ref:* ***CO_5048****)*

## Interactions within the Social Domain

### *Migration flows*

- *"Migrants move for higher wages, greater education opportunities, or a better quality life." (Ref:* ***CO_5028****)*
- *"The pool of potential migrants is likely to remain large given prevailing wage differentials between poor and rich countries, three to four times those triggering the mass migration of Europeans to North America in the late-nineteenth century." (Ref:* ***CO_5028****)*

### *Households structure and distribution*

- *"Using the 2005 EU-SILC data, Lelkes et al. (2009) examined the distribution of (net) household incomes in all 27 EU Member States and analysed the determining factors of inter-personal* *income inequality. Decomposing total income inequality by population subgroups using the MLD[6] index, the authors investigated the impact of the following factors on income distribution: age of the head of the household; household structure; the education and the employment status of the head of the household; work intensity of the household[7]; and, the degree of urbanisation in the household's place of residence. Four categories for the age of household head were used: 18–35 years; 36–49 years; 50–64 years; and, over 65 years. Household structure was grouped into five categories: a) households with a working-age head (between 18 and 64 years of age) with no children; b) with one child; c) with two children; d) with three or more children; e) households with a retirement-age head. The 'work intensity' of the household was defined taking into account the total number of months worked by all household members compared with the number of total workable months. The results of the decomposition show that with the exception of few countries, differences in the ages of household heads accounted for less than 5% of total inequality. Such differences in age were more important in the Nordic countries (DE, FI and SE) as well as CY and EE where there are significant income differences between different age groups, particularly between those of working age and retired. The authors suggest that the explanatory power of household structure (with children or no children) is relatively high in CZ, CY and IE. Differences in the number of children account for 8% of the total inequality in CZ and 8% in the UK, where the average income of the families with three or more dependent children is less than two-thirds of the mean income of childless households. The income differentials by household structure are explained by the differences between households headed by a working-age person or by a retired person. However, in contrast, Brandolini, A. and G. D'Alessio (2001) concluded that differences in population structure (household size; age and sex of household head) do not explain many of the large differences in income inequality observed across countries." (Ref: **CO_5054**)*

#### Car ownership

- *"Income is an important factor for car ownership and thus for the level of trip making overall, and for motorised trip making in particular." (Ref: **CO_5048**)*
- *"Observed that households that rely exclusively on non-motorized modes of transport and public transportation spend only about 3 to 5 percent of their income on travel; that percentage rises to 10 to 15 percent for people who own at least one motor vehicle." (Ref: **CO_0059**)*
- *"Per capita automobile ownership and mileage tend to increase rapidly over the range of $3,000 to $10,000 (2002 U.S. dollars), when vehicle ownership increases twice as fast as per-capita income, but at higher income levels growth rates levels off and eventually reach saturation. International analysis indicates that per capita automobile ownership peaks at about $21,000 (1996 U.S. dollars) annual income, and levels off or even declines with further wealth. Using U.S. data, Holtzclaw found that vehicle travel increases strongly with annual income up to about $30,000, but then levels off and declines slightly with incomes over $100,000." (Ref: **CO_5047**)*
- *"As incomes rise, there will be a shift towards a demand for transport. In 2005, vehicle ownership was about 11 cars per 1,000 capita in China and about 6 cars per capita in India, compared with a global average of 111 cars per 1,000 capita. Recently, car ownership rate in China has been growing at a rate of 12% per year, while in India it has been growing at 9% per year." (Ref: **CO_0159**)*

#### Urbanisation

- *"Urban economists have long understood that several fundamental forces drive the spatial growth of cities. These forces include the growth in household income (which raises the demand for living space), the reduction in commuting costs due to transport improvements (which eases suburban access) and rising city populations." (Ref: **CO_4014**)*
- *"Increasing urbanisation (an increasing weight of the urban relative to the rural population within a region) is negatively associated with income inequality (Rodríguez-Pose, and Tselios, 2009a). However, different results were found by Hoffmeister (2006) who examined income differences between people living in the same (NUTS1) region across the EU. The regions characterised by high levels of interpersonal income inequality in Europe are usually the ones that incorporate the capital of a country or regions marked by high rates of agglomeration (such as Ostösterreich in*

[6] Mean Log Deviation
[7] Work intensity of the household is defined taking into account the total number of months worked by all household members, related to the number of total workable months

*AT, Hamburg and Berlin in DE, London in the UK, Centralny in PL). One of the explanations for this contradiction could stem from the fact that increasing weight of the urban relative to the rural population means a decreasing income inequality for the whole of the population in a region, but this does not apply to the disparities within the working population which may increase (Rodríguez-Pose, and Tselios, 2009a). Urbanisation might increase the local economic prosperity and income per capita for the local population but at the same time, it can trigger a higher earnings dispersion between the skilled employees and the less skilled, those who work in the advanced industries versus the more traditional, low paid industries." (Ref: **CO_5054**)*

- *"There is a strong correlation between poverty and urban mobility, but its extent is not sufficiently well known or quantified. The time and money that the poor must spend meeting basic mobility needs keeps low-income families from accumulating the assets that would lift them out of poverty." (Ref: **CO_0163**)*

*Planning*

- *"Mobility systems must work for rich and poor alike, to ensure no-one is shut off from goods, services and employment opportunities. There are currently 4 billion people around the globe on low incomes[8]." (Ref: **CO_5018**)*
- *"One of the most significant transport challenges the world faces is how to offer reliable, safe, and affordable choices of transport to an expanding number of poor people. The income-transport gap is the gap between those that can afford transport choices and those with no transport choices. Dealing with the income-transport gap will be essential in the megacities of the future, in order to help manage pollution and environmental degradation." (Ref: **CO_0159**)*

*Tourist flows*

- *"As millions of people are to become "middle-class" in Asia in the next 20 years, Europe will become a theme park for extra-EU visitors: between 300 and 600 million Asian tourists will be travelling yearly to Europe. This estimate implies a large growth of transcontinental flights, especially towards consolidated tourist areas such as Paris and London, but also towards Italy, Barcelona and Berlin." (Ref: **CO_5048**)*

*Change of lifestyle and values*

- *"The stimulus provided by cheap air links to the real estate business of secondary housing. Increasingly, medium to high-income households have been buying second residences outside their home countries. Commonly, the households are from the wealthier European countries (notably the United Kingdom) that have turned their attentions to Southern Europe, which is considerably cheaper and has much better weather conditions all year round. The Northern European households travel regularly (on a weekly basis or twice per month), using LCA cheap fares, to their secondary residences located in Southern Europe to spend a weekend. Naturally, this business has stimulated the real estate business in these regions." (Ref: **CO_5037**)*

*Education*

- *"Educational inequality (unequal distribution of education level completed) is associated with higher income inequality within a region (Rodríguez-Pose, and Tselios, 2009a). Analysing income data at national level Lelkes et al. (2009) demonstrate that education in general accounts for income inequality to a greater extent than age and household structure: differences in education can account for up to 30% of income inequality in PT and around 20% in HU. In LT, PL, CY, LU and SI, education seems to matter at both lower and upper ends of the distribution." (Ref: **CO_5054**)*

*Health*

- *"Low-income households are often more exposed to environmental pollution than middle- and high-income households and thus are also more vulnerable." (Ref: **CO_5009**)*

### Interactions with the Economy Domain

*Availability of public and private resources and investments in the transport sector*

- *"Just as wealthier consumers tend to purchase more expensive vehicles for greater performance, comfort and prestige, wealthier cities tend to invest in higher quality public transit*

[8] WRI, The Next Four Billion: "Low-income" is defined as earning less than $3,000 in local purchasing power.

*systems that offer superior service. In developed countries, cities with higher incomes tend to have better transit systems which result in higher per capita transit ridership rates." (Ref: **CO_5047**)*

*Fiscal policy*

- *"In order to reduce the inequality which is one of the causes of the crisis tax policy must be used more vigorously, for example, by raising the top tax rate and reintroducing the wealth tax." (Ref: **CO_0235**)*

### Interactions with the Environment Domain

*Pollution levels and emissions standards*

- *"Using US data, Huntington (2005) found that, after allowing for (...) technology shifts, the positive relationship between emissions per head and income per head has remained unchanged." (Ref: **CO_2024**)*

### Interactions with the Technology Domain

*Technology development in general and innovation diffusion*

- *"Technological changes at the regional level create demand for innovative products, better human capital and skilled labour. Therefore, technological change is usually associated with greater earnings inequality. Perugini and Martino (2006) show that the technology-driven innovation (strongly correlated with R&D expenditure) is positively associated with income inequality." (Ref: **CO_5054**)*

*New vehicles design*

- *"Everyone in the mobility sector will have to design tailored mobility solutions that meet these poor people's needs." (Ref: **CO_5018**)*
- *"Worldbike is an international network of professionals in the bicycle industry, who work on creating affordable bike transportation and income-generating opportunities for the poor. The Chop'N Drop bike is an open-source design, which is shipped to small-scale manufacturing facilities or skilled individuals in the developing world, who then construct the bike locally." (Ref: **CO_5018**)*

### Impacts on Mobility and Transport

- *"Another social factor of potential relevance for transport policy has to do with the distribution of economic resources and the level of inequality. Household income correlates strongly with GDP per capita and could be thought of as a proxy to the latter for the estimation of transport demand. The average values of household income or GDP per capita, however, say little about how the latter is distributed within the population. As economic measures increase in importance in the transport policy domain and given the gradual deregulation of public transport services, the assessment of levels of inequality is likely to gain in significance for transport politics." (Ref: **CO_2041**)*

*Increased demand and mileage*

- *"(...), transport accounts for a certain percentage of each person's disposable income, and this percentage seems to remain rather stable but at different levels in different countries. Since transport is becoming less expensive, relative to most people's revenue, and faster, transport demand is growing in terms of number of trips and total length, even though the natural and cultural thresholds may remain basically stable." (Ref: **CO_5048**)*
- *"Studies have shown that TTB[9] per traveler is typically higher at lower incomes (Roth and Zahavi, 1981). (A ``traveler'' is defined in travel surveys as someone making at least one motorized trip on the day of the survey.) The poor face more constraints on their choice of living locations and transport modes and thus find it more difficult to optimize travel times. The share of travelers to total population is lower in low-income societies (...)." (Ref: **CO_0001**)*
- *"(...) the time spent in motorized modes ($TTB_{mot}$) rises with income and mobility as people shift from slow non-motorized modes to motorized travel." (Ref: **CO_0001**)*

[9] Travel Time Budget

- *"On average, people spend a constant share of money on traveling; rising income leads nearly directly to rising demand for mobility, which we demonstrate historically. A person also spends a constant share of time for travel on average; as total mobility rises, travelers shift to faster modes to remain within the fixed travel time budget of 1.1 h per person per day. In addition to these constant budgets, travel behavior is also affected by the path dependence of infrastructures, landuse constraints, and the development of niche markets." (Ref: **CO_0001**)*
- *"(...) the rise in TMB[10] from 3-5 to 10-15% with increasing motorization might allow for more rapid growth in mobility because a larger fraction of income is devoted to travel. In practice, it appears that rising travel money budgets are offset completely by the rising unit cost of travel as travelers shift from public modes (bus, railroads) to private automobile. Thus even at low mobility, there is a direct relationship between rising income and rising mobility." (Ref: **CO_0001**)*
- *"The world's population reached 6 billion in 2000 and will be around 9 billion in 2050. Coupled with rising incomes this will lead global mobility to expand strongly through 2050. If infrastructure and energy prices allow, there will be around 3 to 4 times as much global passenger mobility (passenger-kilometres travelled) as in 2000 and 2.5 to 3.5 as much freight activity, measured in ton-kilometres." (Ref: **CO_4024**)*

#### Increased demand for faster transport modes

- *"The fixed travel money budget requires that mobility rises nearly in proportion with income. Covering greater distances within the same fixed travel time budget requires that travellers shift to faster modes of transport. The choice of future transport modes is also constrained by path dependence because transport infrastructures change only slowly." (Ref: **CO_0001**)*
- *"Studies show that income is closely related to people's value of time, in other words, how much in monetary terms people think their time is worth. Transport services which allow a reduction in journey time (e.g. cars, high-speed rail and aviation) are therefore strong candidates for growth from this respect." (Ref: **CO_5031**)*

#### Increased demand for air transport

- *"Economic factors, in particular disposable income, air ticket price and price of competing modes (e.g. high-speed rail) are often regarded as key determinants of air traffic demand (see Hanlon, 2007)." (Ref: **CO_5031**)*
- *"For example, in the UK, the statistics provided by the Civil Aviation Authority (CAA) indicate a strong relationship between the frequency of leisure flying and the socio-economic characteristics of passengers with higher income households as well as singles, childless couples, and those with properties abroad taking more flights." (Ref: **CO_5054**)*
- *"IATA (2008) calculates that for a 1 % rise in income (typically measured in GDP per capita), demand for air travel in developed economies increases by 1.5 % for short haul, and 1.7 % for long haul." (Ref: **CO_5031**)*
- *"Air travel probably continues to increase at high incomes." (Ref: **CO_5047**)*
- *"The growth in income is likely to put an upwards pressure on demand for air travel, especially with regards to leisure travel. A downturn in the economy with a reduction in income would have the opposite effect, which is currently being observed temporarily as a result of the global economic slowdown." (Ref: **CO_5031**)*

#### Poverty complicates mobility

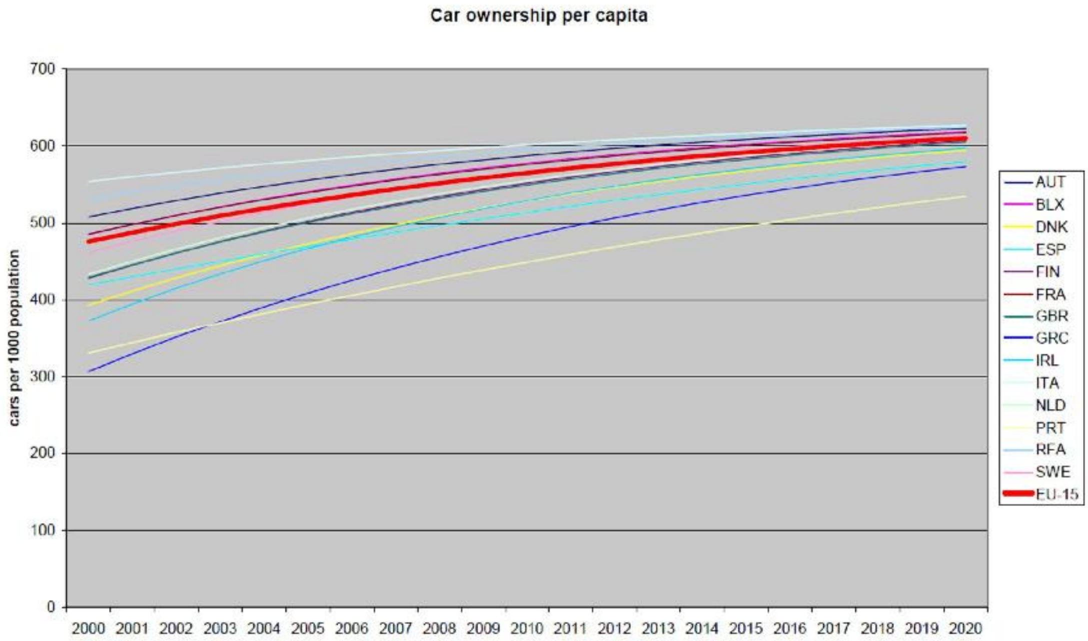
- *"Poverty complicates mobility and lack of transport options complicates poverty. The poor do not travel less, they just travel under worse conditions. Lack of transport options hamper access to employment, as well as contribute to weakened social networks." (Ref: **CO_0163**)*

[10] Travel Money Budget

#### *1.2.3.3 Car Ownership*

**Driver description**

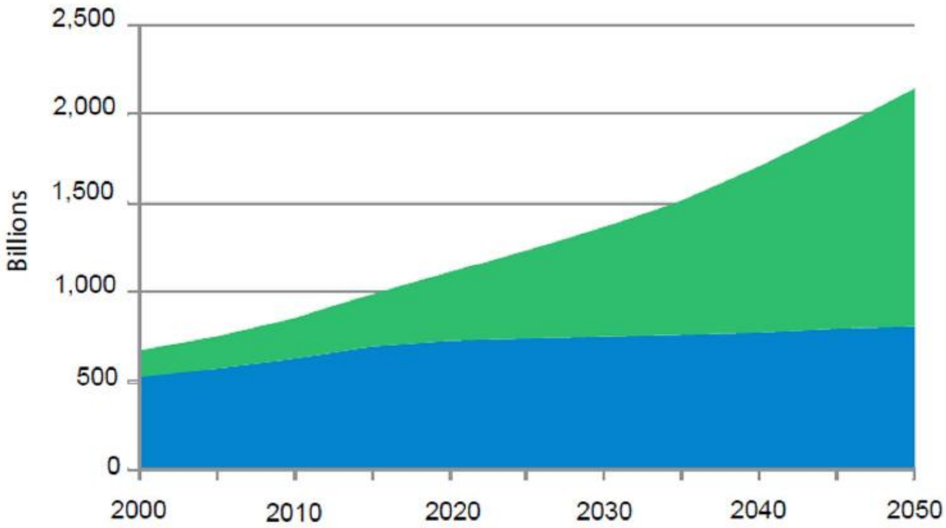
- *"The 20th century was the age of the car. It became a status symbol for those who had it, and an aspiration for those who could not afford it." (Ref: **CO_5018**)*
- *"Ownership rates increased significantly during the 70s, and for lower-income households during the 80s, but flattened and declined in some classes during the 90s. The period of growth in per capita vehicle ownership rates coincided with Baby Boomer's peak driving years, significant growth in the portion of women employed outside the home, rising wages, low fuel prices, cheap credit and suburbanization. Most of these factors have peaked and many are now reversing." (Ref: **CO_5047**)*
- *"International data indicates that vehicle ownership growth rates started to decline after 1990 in most wealthy countries such as Denmark, Germany, France, Italy, Finland, Sweden and the U.K., and appear likely to level off at a point lower than the U.S. peak of 0.75 vehicles per capita. Millard-Ball and Schipper (2010) and Newman and Kenworthy (2011) found similar patterns in other industrialized countries (Australia, Canada, various European countries, and the U.S.)." (Ref: **CO_5047**)*
- *"In 2000, marked differences in car ownership rates still existed between countries: Greece had the lowest ownership with about 280 passenger cars per 1000 inhabitants and Luxembourg the highest with more than 610. The European average reached about 468 cars per 1000 inhabitants, a 19.7% increase since 1990. Variations in income levels and fuel prices, and different tax regimes for the purchase, ownership and use of cars, are part of the explanation for these differences." (Ref: **CO_6004**)*
- *"According to the model's baseline projections, car ownership levels in the EU-15 are expected to continue increasing but, especially after 2015, will probably reach saturation at values between 600 and 650 cars per 1000 inhabitants (see figure below). (Ref: **CO_2015**)*




Source: Trends in vehicle and fuel technologies - Scenarios for future trends (Ref: **CO_2015**)

**Figure 1-18 Projected car ownership per capita in EU-15**

- *"Robust growth in car ownership may be tempered by congestion and lack of parking space in large cities." (Ref: **CO_0284**)*
- *"With shifting consumption patterns in developing and transitional countries, growth in vehicle ownership in non-OECD countries is expected to make up close to three-fifths of the global vehicle fleet by 2050; at the moment the non-OECD fleet is a quarter of the global fleet." (Ref: **CO_2017**)*




Source: Hybrid Electric Vehicles (Ref: **CO_2017**)

**Figure 1-19 Global Growth in Light Duty Vehicles[11] A tripling of the non-OECD fleet is foreseen by 2050**

## Interactions within the Social Domain

### *Households structure and distribution*

- *"Car ownership is an important determinant of passenger travel behaviour and it is fundamentally interconnected with residential location and decision-making regarding motorised trips. A number of travel surveys have conceded that persons in households located centrally in urban areas have fewer motorised trips than persons located in peri-urban areas." (Ref: **CO_5048**)*
- *"The most substantial changes in vehicle ownership occurred during the late 1960s through 1990, a period when a significant number of women entered the workforce, the number of licensed drivers increased rapidly, and disposable income grew. The average household in 1969 had 3.16 persons and 1.16 vehicles. Average household size in 1990 dropped to 2.56 persons, while the number of vehicles increased to 1.77 per household, exceeding the number of licensed drivers per household." (Ref: **CO_4012**)*

### *Urbanisation*

As mentioned above, car ownership plays a fundamental role with residential location. Thus it is clear that car ownership is a determinant factor in urbanisation sprawl, allowing people to commute for longer distances.

### *Planning*

- *"(...), while the historical patterns in vehicle ownership rates suggest that growing wealth is a powerful determinant of vehicle demand, policymakers may be able to slow the expansion of the vehicle stock through tax policies, promotion of public transport, and appropriate urban planning – an important area for future research." (Ref: **CO_2038**)*
- *"Over the very long run - five decades or more – societies face a fundamental choice about how their mobility patterns will develop. Some hold that in order to make mobility sustainable, people will have to be induced to live in significantly more dense agglomerations. According to this view, only by doing this will it be technologically and financial feasible to rely on public transport to a much greater degree than is generally the case today. To produce this change in living patterns, different forms of "carrots" (urban planning aimed at making such patterns more desirable) and "sticks" (making motor vehicle ownership much more expensive and complex) will be necessary." (Ref: **CO_1030**)*

[11] Cars, minivans, SUVs

*Change of lifestyle and values*

- *"Social values influence people's behaviour in many ways. As countries grow richer, people's values towards freedom of movement, environmental protection, and leisure time increase as well. The implications for transport demand depend on the magnitude and balance of these changes. Whilst the preference for free movement may push people to own larger and faster cars, awareness of environmental problems may work in the other direction." (Ref: **CO_5031**)*
- *"As motor vehicle ownership grew, travel costs declined and households dispersed, people organized their lives around increased mobility. The greatest growth in motorized travel has involved non-commute personal trips, including shopping, social and recreational travel, and family/personal business, (...)." (Ref: **CO_5047**)*
- *"The greatest issue of uncertainty is the degree to which consumer preferences will continue to favour automobile travel. During the Twentieth Century, automobile transport and suburban housing were considered exciting and glamorous. There are signs that consumer attitudes are changing." (Ref: **CO_5047**)*
- *"A confluence of events - environmental worries, a preference for gadgets over wheels and the years-long economic doldrums - is pushing some teens and twentysomethings to opt out of what has traditionally been considered an American rite of passage: Owning a car." (Ref: **CO_5047**)*
- *"The car-sharing sector is growing in Europe for a number of reasons; including freedom from car ownership and implied costs, ease of use, inability to own a car outright, environmental awareness, and choice of vehicles." (Ref: **CO_0159**)*

*Health*

- *"Low car ownership is inevitably associated with a high proportion of vulnerable road users – pedestrians, cyclists and motor cyclists – who account for most of the fatalities, and have much higher fatality rates per km travelled. Casualties are projected to rise if the world proceeds further down the high-mobility path, because in very low car ownership countries (0–10 cars per 1000 persons), a doubling (say) of road vehicles – and thus vehicle occupants – only marginally reduces the number of vulnerable road users." (Ref: **CO_0007**)*

### Interactions with the Economy Domain

*Employment*

It can be expected that car ownership plays a certain role in facilitating employment opportunities, especially in those situations where public transport alternatives are not so numerous (e.g. small towns and rural areas).

*Availability of public and private resources and investments in the transport sector*

- *"Declining per capita vehicle ownership rates also has implications for transportation finance. Real (inflation adjusted) per capita fuel tax revenues are declining, so either tax rates must increase, alternative revenue sources must be provided, or transport investments must be reduced." (Ref: **CO_5047**)*
- *"(...) developing countries will face the challenge of building the infrastructure (roads, bridges, fuel delivery, etc.) needed to support the growth in vehicle ownership." (Ref: **CO_2038**)*

*Fiscal policy*

- *"Many governments tax vehicle purchases and most levy an annual tax on vehicle ownership or charge for an annual permit to drive on the roads." (Ref: **CO_2017**)*
- *"Several factors are taken into consideration while creating vehicle taxes. (...) In Denmark, ownership tax is based on the fuel economy, whereas in Germany, it depends on emission standards. In Sweden and the Netherlands, vehicle gross weight and fuel type are the criteria used to impose vehicle ownership tax. Vehicle ownership tax in France and the United Kingdom is based on CO2 emissions. In most European countries, vehicle ownership taxes depend on the engine model, the engine capacity, the fuel type, and the vehicle age or vehicle gross weight (Hirota et. al., 2003)." (Ref: **CO_0212**)*

### Interactions with the Environment Domain

*Pollution level and emission standards*

- *"The speed of vehicle ownership expansion in emerging market and developing countries has important implications for transport and environmental policies, as well as the global oil market." (Ref: **CO_2038**)*
- *"(...) many of the environmental concerns associated with the greater use of vehicles could presumably be strengthened by our projections, especially since future vehicle ownership growth will mostly take place in developing countries that have so far been able to deal with the environmental issues less successfully than advanced economies (World Bank, 2002)." (Ref: **CO_2038**)*
- *"Reducing emissions from motor vehicles is an important component of an overall strategy for reducing air pollution, especially in cities in developing and transitional countries where population and vehicle ownership are growing rapidly." (Ref: **CO_2017**)*

*Scarce resources of fossil fuels*

- *"Private cars represent the dominant transport mean in road transport, accounting for 55.9% of total energy consumed in road transport in 2005.(...) Energy consumption by buses accounted for 1.5% of total energy in road transport in 2005 and motorcycles accounted for 3.3%." (Ref: **CO_1029**)*
- *"(...) the future strong growth in the vehicle stock in developing countries will lead to significant increases in oil demand from the transport sector. We project annual worldwide growth in highway fuel demand to be in the range of up to 2.5-2.8%." (Ref: **CO_2038**)*

### Interactions with the Technology Domain

No particularly relevant interrelationships have been found.

### Impacts on Mobility and Transport

*Difficulties in predicting a significant increase in trips generation*

- *"Statistics are abundant showing that household car ownership or car availability is positively correlated with trip generation (Kostyniuk and Kitamura 1986b; Levinson 1976; Supernak 1983), although the effect of car ownership may be exaggerated because trips by non-mechanized modes are not included in the analysis. Whether or not trip generation increases further if household car ownership continues to increase needs to be critically examined." (Ref: **CO_0196**)*
- *"It is logical that if an overall increase in household car ownership is primarily due to an increase in the number of cars owned by multi-car households, then its impact on trip generation may be limited." (Ref: **CO_0196**)*

#### *1.2.3.4 Gender Roles*

**Driver description**

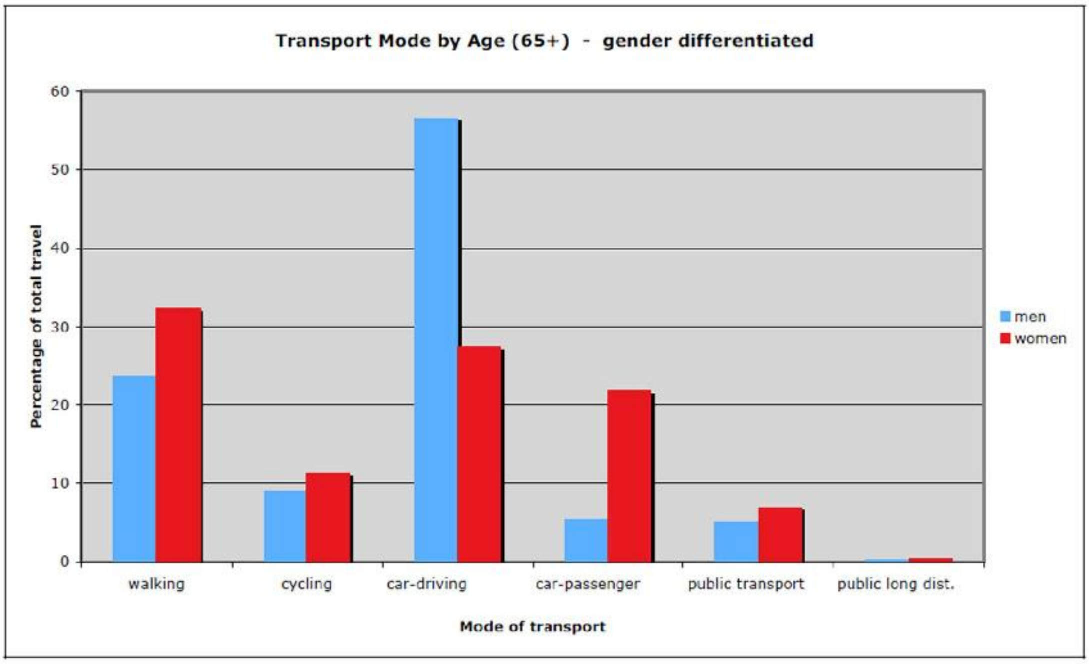
- *"Gender, based on the biological construct of male and female, differentiates economic and social roles and responsibilities. Gender is an integral part of the broader social context interacting with class, race, ethnicity, income, education, religion, and geographic location. Gender defines how men and women are expected to act, dress, and behave; this includes travel behavior and patterns. (Ref:* ***CO_0163****)*
- *"The definition of gender roles and responsibilities varies from place to place and changes over time and between generations. This makes it difficult to assume an overriding general definition of roles and responsibilities." (Ref:* ***CO_0163****)*
- *"The lives of girls and women have changed dramatically over the past quarter century. Today, more girls and women are literate than ever before, and in a third of developing countries, there are more girls in school than boys. Women now make up over 40 percent of the global labor force. Moreover, women live longer than men in all regions of the world." (Ref:* ***CO_0161****)*
- *"Gender disparities still remain in many areas, and even in rich countries." (Ref:* ***CO_0161****)*
- *"Although women have entered the labor force in large numbers across much of the developing world in the past quarter century, this increased participation has not translated into equal employment opportunities or equal earnings for men and women. Women and men tend to work in very different parts of the "economic space," with little change over time, even in high-income countries. In almost all countries, women are more likely than men to engage in low-productivity activities. They are also more likely to be in wage or unpaid family employment or work in the informal wage sector." (Ref:* ***CO_0161****)*
- *"Despite labour force participation, women continue to bear a disproportionate share of household work, and this uneven distribution of labour is implicated in the division of labour in the labour market and at home." (Ref:* ***CO_0165****)*
- *"In Spain, women account for more than 90 per cent of the total number of employees in this sector, domestic work representing the largest single area of female employment. Moreover, the employment rate in this sector has inverted its decreasing trends since 1994 and since the beginning of this decade has grown faster than the female employment rate in all other sectors. Belgium is estimated to have around 20,000 domestic workers, 89 percent of whom are women. In Austria, more than 95 percent of the 8,900 domestic workers officially accounted for in 2005 are female. In the Netherlands, 25 per cent of elderly persons are estimated to engage paid domestic help. In Italy, the National Institute for Social Security (INPS) calculated a total number of more than 460,000 employees in domestic work in 2006, 87.5 per cent of whom women and 73 per cent foreigners. Another recent Italian research confirming data produced by the Statistical Institute (ISTAT) claims that the actual number could largely pass one million workers." (Ref:* ***CO_0088****)*
- *"Greater gender equality can enhance productivity, improve development outcomes for the next generation, and make institutions more representative." (Ref:* ***CO_0161****)*

**Interactions within the Social Domain**

***Population ageing***

- *"Since 1980, women are living longer than men in all parts of the world. And, in low-income countries, women now live 20 years longer on average than they did in 1960." (Ref:* ***CO_0161****)*
- *"In the next 30 years, the number of people over 65 years of age will double and those over 80 will treble in the member and associate member countries of the European Conference of Ministers of Transport (ECMT). It has also been highlighted that older people will increasingly expect to maintain the high level of mobility they have grown accustomed to previously, though this will be more difficult as they age. More people will retain their driving licences as long as possible and licence holding will be more prevalent amongst older people, especially older women." (Ref:* ***CO_0162****)*
- *"(...) even as one gets older the gender difference in travel patterns between men and women are maintained." (Ref:* ***CO_0162****)*

- *"In Germany also the differences in travel patterns between older men and women is clearly set out. The chart below sets out the travel differences between men and women over the age of 65. Women are bigger users of walking, public transport and travelling as a car passenger than men within this age group." (Ref: **CO_0162**)*




Source: Women and Transport (Ref: **CO_0162**)

**Figure 1-20 Transport mode in Germany for men and women over 65 years old**

- *"In relation to elderly women, one theme that has been taken up is the tendency of elderly women to give up driving to a greater extent than their male counterparts." (Ref: **CO_0165**)*
- *"Elderly women form a distinct group facing mobility difficulties, since they will at some point begin to reduce their driving, lowering their mobility. Particularly elderly women living alone will be vulnerable, having few alternatives to driving." (Ref: **CO_0165**)*

### *Migration flows*

- *"In Western Europe, as in many other parts of the world, domestic work has the characteristic of attracting a large and increasing number of female migrants. (...) They provide essential service to the countries of destination and contribute to the wealth of their aging societies and to the sustainability of their welfare and employment systems." (Ref: **CO_0088**)*
- *"In spite of migrant women generally showing a generally lower participation rate in the labour force compared to their male counterparts and female nationals, evidence show that an increasingly high share of these women find an occupation as a domestic or care worker. The majority of domestic workers in Europe are foreign born." (Ref: **CO_0088**)*
- *"In Germany, for example, the number of foreign women working as domestic workers rose by nearly 75 per cent between 1993 and 2003. In Spain and Greece, the number of women in this sector is reported to have multiplied by 11 and 6 times respectively over the same period. In France, half of the female immigrant workers and one out of three immigrants employed as low-skilled workers are reported to be in domestic work. The Italian National Social Security Institute (INPS) reports that 73 per cent of the total numbers of domestic workers in 2006 were foreigners, 87.5 per cent of whom were women. In general terms, migrant women are reported to be four times as many as native women in the household sector." (Ref: **CO_0088**)*
- *"Labour force participation rates for migrant women tend to be higher in Southern European countries, where migrant women are highly represented among domestic workers. These are the same countries where national women's participation rate in the labour force has rapidly increased over the last decade. This could at least in part confirm the correlation between national women's insertion into the labour market and the outsourcing of care work to migrant domestic workers." (Ref: **CO_0088**)*

- *"Today, women tend to migrate at a stage of their life when they have concluded their educational path and they have a family of their own who they provide for and support through their migration process." (Ref: **CO_0088**)*

*Households structure and distribution*

- *"Studies on women's travel patterns suggest the importance of women's domestic responsibilities for their travel patterns, and an important focus is married/single women with children (...) Embedded in women's travel patterns are the transportation problems of their children. This means that if women continue to bear a disproportionate share of chauffeuring and other responsibilities, then travel differences will not disappear. Single mothers in particular are a very vulnerable group, even if they have moderate incomes. They face disproportionate pressure to alter their activities and travel patterns, because they are economically disadvantaged and because they have less assistance in balancing employment with household and childcare responsibilities." (Ref: **CO_0165**)*

*Income structure and distribution*

- *"Women are more likely than men to work as unpaid family laborers or in the informal sector. (...). Women entrepreneurs operate in smaller firms and less profitable sectors. As a result, women everywhere tend to earn less than men." (Ref: **CO_0161**)*
- *"Women's greater domestic responsibilities coupled with their weaker access to household resources have significant consequences for their transport and travel status. The lower the income of a household the more probable it is that women within that household will experience greater transports deprivations as compared with men." (Ref: **CO_0161**)*
- *"Poor women and men do not travel less; they just travel under more duress and in worse conditions. They lack real options and the ones available are usually under-resourced, undercapitalized, and over-utilized. Women are usually the last to have access to the most modern and expensive (higher status) forms of transport." (Ref: **CO_0163**)*

*Car ownership*

- *"Men are the first to use a vehicle in a household, and when possible to motorize. Women will use the vehicle that is left behind." (Ref: **CO_0163**)*
- *"In the richer countries, even poor people own a used car, whereas in a majority of developing countries, only a handful of the wealthiest can afford to own and maintain a car. When it comes to female vehicle ownership rates, the rates become even lower. About 75% of women in the United Kingdom have no or restricted access to a car, while with men it is only 15% with no or restricted access to a car." (Ref: **CO_0163**)*
- *"Car ownership and access to transport were associated with higher perceived quality of life. The effects of car ownership and access were independent of wealth. There was some evidence that the relationship between driving and quality of life was stronger for men than for women." (Ref: **CO_4006**)*

*Planning*

- *"(...) in most countries, women participate less in formal politics than men and are underrepresented in its upper echelons." (Ref: **CO_0161**)*
- *"Indeed as a profession, transport planners have failed to produce systematic methodologies which incorporate gender analysis for the purpose of urban development and planning. At present it would be fair to argue that there are no systematic gender inclusion procedures for transport either in terms of the training of professionals, in terms of the participation of users or in terms of the design and planning of transport systems, transport services and transport equipment." (Ref: **CO_0161**)*
- *"Decision-makers are still not sensitive enough to women's transport needs and patterns. Multi-trip chains, buying groceries and accompanying services (children, elderly) are often still the duties of women. Therefore, multimodal transport services, nearby opportunities and children and youth-friendly transport facilities have to be designed to support women." (Ref: **CO_5006**)*

*Change of lifestyle and values*

- *"Women are more vulnerable users of public space in general and this affects how they use public space, including transport. (...) Women will change their transport behaviour and have their transport options constrained if they perceive urban transport systems or travel to be unsafe. Thus, women will make the decision not to travel at night, not to get out at a particular spot, to take a longer route home if it is safer." (Ref: **CO_0163**)*

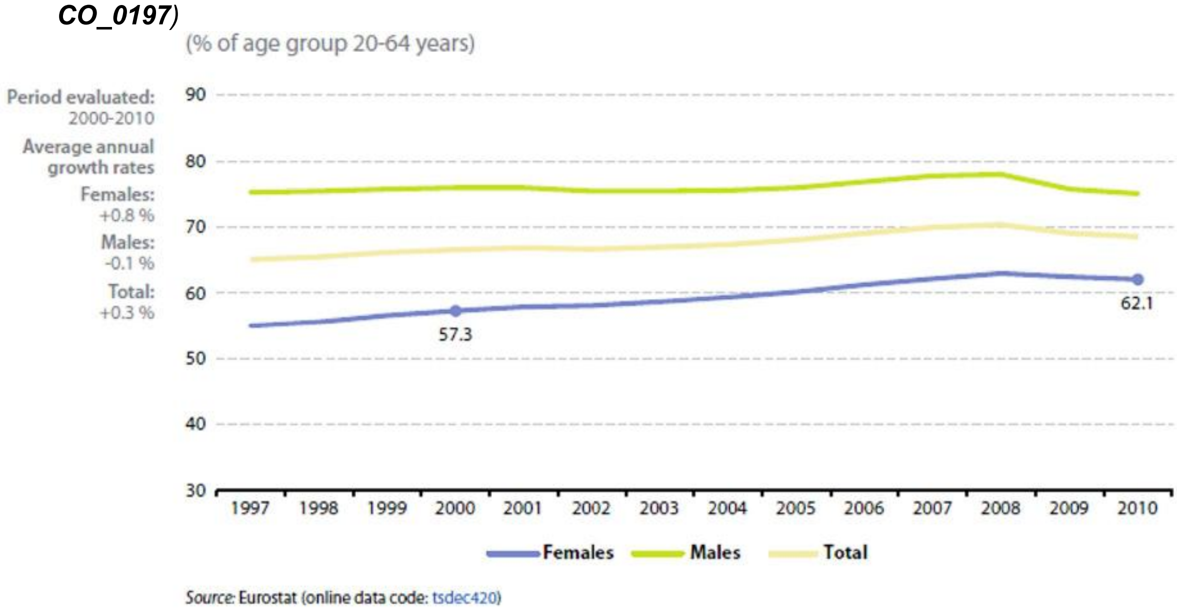
*Education*

- *"Gender gaps in primary education have closed in almost all countries. In secondary education, these gaps are closing rapidly and have reversed in many countries, especially in Latin America, the Caribbean, and East Asia - but it is now boys and young men who are disadvantaged. Among developing countries, girls now outnumber boys in secondary schools in 45 countries and there are more young women than men in universities in 60 countries." (Ref: **CO_0161**)*

### Interactions with the Economy Domain

*Employment*

- *"Women now represent 40 percent of the global labor force, 43 percent of the world's agricultural labor force, and more than half the world's university students. Productivity will be raised if their skills and talents are used more fully." (Ref: **CO_0161**)*
- *"[In Europe] Over the period 2000 to 2010, female employment rose steadily from 57.3 % to 62.1 %, narrowing the gender gap. Considerable differences remain between Member States." (Ref: **CO_0197**)*




Source: Sustainable development in the European Union (Ref: **CO_0197**)

**Figure 1-21 Employment rate, by gender, EU-27**

- *"Within the EU, marked disparities are found concerning female employment rates between the northern and southern European countries, ranging from 71% for women as a percentage of total population of working age (15–64) in Sweden to 39.6% in Italy (...)." (Ref: **CO_0083**)*
- *"Women are underrepresented in transport" (Ref: **CO_5019**)*
- *"The transport sector remains male-dominated; few women are employed in the sector except in travel service occupations (e.g. as travel agents). The great majority of transport drivers and operatives are male, as are those employed in vehicle trades (e.g. as car mechanics). Women are also under-represented in professional and managerial positions within the sector, or in transport-related public bodies; hence their influence over the decision-making process is also very limited." (Ref: **CO_0162**)*
- *"Gender considerations should also be taken into account, to facilitate women's access to transport jobs." (Ref: **CO_0015**)*

- *"In several EU countries there is also room for higher female labour force participation which would require adaptations in the educational and child care systems allowing mothers to continue their careers." (Ref: **CO_6000**)*

## Interactions with the Environment Domain

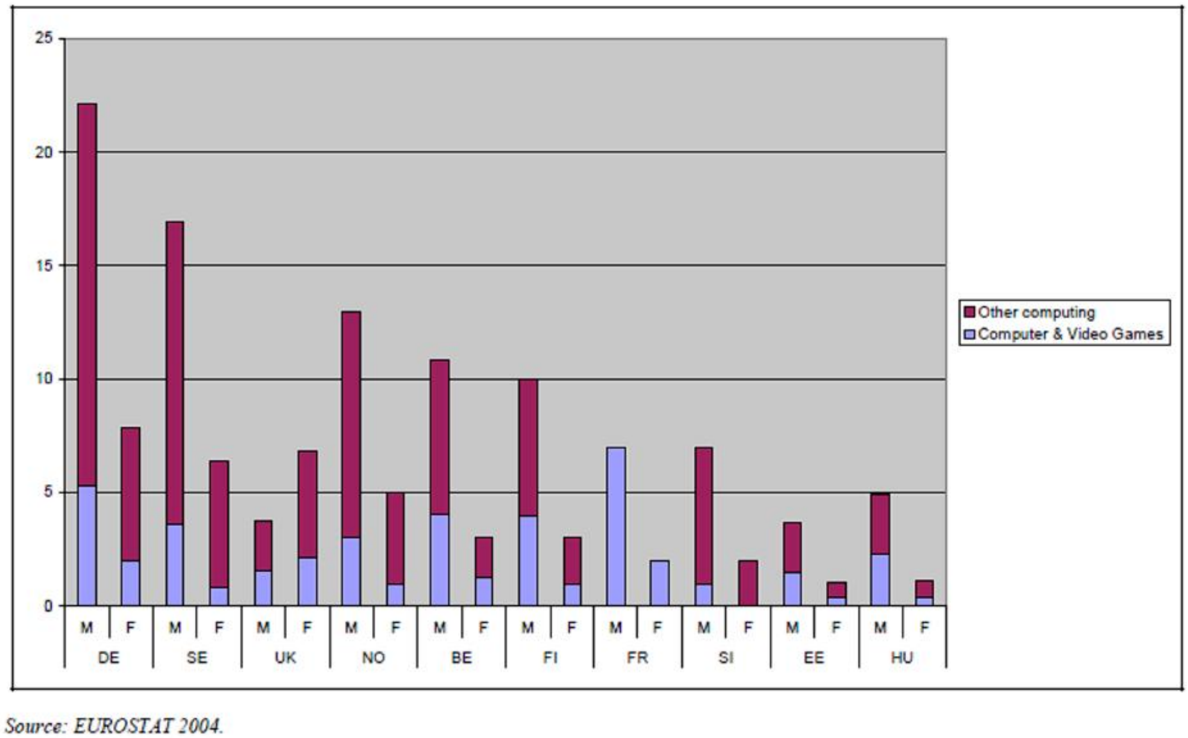
### *GHG mitigation*

- *"Given the serious environmental impacts of mobility patterns in wealthy nations, not least in terms of greenhouse gas emissions, it is crucial to study mobility in the combined normative perspectives of gender mainstreaming and environmental sustainability." (Ref: **CO_0165**)*
- *"Polk (2003, 2004) compares men's and women's travel patterns as well as their attitudes towards environmental issues and willingness to change behaviour in Sweden. She draws on large-scale travel surveys and attitude surveys. Her results suggest that women were more environmentally concerned and more critical of auto-mobility than men were, that women were more positive towards proposals that reduce the environmental impact of car use and that women express more willingness to reduce their use of the car than men. In general, there are not large differences between men and women, however women consistently showed more support of ecological issues and were more prepared to participate in ecologically benign activities such as reducing car use." (Ref: **CO_0165**)*
- *"In her study Hjorthol (...) explores the cultural perceptions that men and women give to public and private means of transport, and she bases her study on a large-scale survey amongst inhabitants in Oslo, the capital of Norway. She shows how the two different types of transport have different cultural values with men and women. Women seem to be more positive than men towards public transport and believe that public transport gives them access when and where they want to travel. In contrast, men see the car as enabling freedom in time and space, and also the car is a masculine mastering project; men's work with and maintenance of the car can be seen as an important arena for their identity. In contrast, women see the car in functional terms. These results suggest in parallel with Polk's results that women's cultural values of transport make them more conducive to using public forms of transport, and therefore they have potential for accommodating environmentally friendly transport practices." (Ref: **CO_0165**)*

## Interactions with the Technology Domain

### *Technology development in general and innovation diffusion*

- *"Use of technology is gendered however and data from the European Harmonised Time Use surveys show that men may view technology use as a hobby or leisure pursuit more than a utilitarian activity to aid activity scheduling, maintain social contacts or replace activities for which travel would be otherwise involved. This is shown in Figures below." (Ref: **CO_0162**)*




Source: Women and Transport (Ref: **CO_0162**)

**Figure 1-22 Time Use of Computer games and other computing activity by gender across European States**

- *"Yet new informatics technologies are available which readily permit the capture and harnessing of gender data for transport and travel systems which better service women and most particularly low income women. Instead of standing and waiting with children at poorly serviced and poorly supervised unsafe bus stops, low income women could through new technology call demand responsive services to get them to hospitals in time with efficiency benefits for the overall urban system." (Ref: **CO_0162**)*
- *"Many EU supported research developments taken together show us a path through which the development of in-home communication technologies connected to the services of local public transport operators could help reduce the time poverty of low income women. In-home networked terminals have very low communications costs; they would permit women to make reservations, on both routine and crisis services, giving exact details of the journeys which they need to make to meet their survival needs." (Ref: **CO_0162**)*
- *"Tele-strategies are fast solutions to women's time problems: women's local constraints can be greatly ameliorated by access to the information highway. Functions which could only previously be performed by being physically present in dispersed urban locations can now be accomplished by communicating through information technology: reserving medical appointments and cancelling them with the immediate print out of the information in hand; electronic banking and money transfers; electronic shopping and delivery of goods; tele-working; virtual conferencing with school authorities; electronic voting; electronic distance education for sick or disabled children." (Ref: **CO_0162**)*

## Impacts on Mobility and Transport

### *Different mobility patterns over time and space*

- *"The multi-purpose trip is a typical characteristic of women's mobility behaviour, especially for employed women with children, who tend to combine trips for shopping, taking children to kindergarten/school etc." (Ref: **CO_0079**)*
- *"Generally, when compared to men, women in urban areas tend to take more and shorter trips at more varied times. These trips are more expensive in terms of in time and money." (Ref: **CO_0163**)*

- *"Women tend to make more off-peak trips, traveling to more disperse locations. Since women are more likely to be employed as informal workers, their destinations are not necessarily concentrated in the Central Business District (CBD) or in one or two main areas." (Ref: **CO_0163**)*
- *"As more women than men work as domestic servants, their travel times can be much earlier or later than the typical work day around which most transit is planned." (Ref: **CO_0163**)*
- *"Men consistently travel further distances than women, but women make the same or fewer trips." (Ref: **CO_0165**)*
- *"(...) women spend less time on travel than men. On average, it was found that men travel 13 minutes more than women do per day." (Ref: **CO_0162**)*

*More need of private transport...*

- *"Women's travel to work patterns are still dominated by the use of private transport and, even when they have high levels of access to public transport, the use of private transport is essential in order to allow them to negotiate the complexities which face them when seeking to link home and work. Many of these complexities have been exacerbated by the spatial mismatch between the areas that women live and the jobs and services which are available to them." (Ref: **CO_0010**)*
- *"In countries with greater gender equality, more women are mobile, more women work outside the home, and they utilize more types of transport. The emergence of more women working outside of the home could have a profound effect, especially in countries that currently have low motorization rates. Additionally, changes in views about women driving in specific countries/regions of the world could have a very significant impact on transport patterns." (Ref: **CO_0159**)*

*...but lower possibility to afford it*

- *"Generally, women have a lower incidence of vehicle use, and a higher incidence of walking. This is partly a reflection of lack of money to afford to buy vehicles or pay for services. This reinforces women's time poverty." (Ref: **CO_0079**)*
- *"Women undertake more trips on foot in their neighbourhood related to the satisfaction of everyday needs. As women still perform the bulk of household and caring work, they are often accompanied by children and older people, who are the slowest traffic participants." (Ref: **CO_0079**)*

### 1.2.4 The Spatial Distributor Factor

#### *1.2.4.1 Urbanisation*

**Driver description**

- *"Historically, the process of rapid urbanization started first in today's more developed regions. In 1920, just under 30 per cent of their population was urban and by 1950, more than half of their population was living in urban areas. In 2007, high levels of urbanization, surpassing 80 per cent, characterized Australia, New Zealand and Northern America. Europe, with 72 per cent of its population living in urban areas, was the least urbanized major area in the developed world." (Ref: **CO_1015**)*
- *"According to United Nations forecasts, by 2050 nearly 70 % of the global population will live in cities, up from around 50 % today. The figure for Europe is higher still: some 83 % of the population – nearly 557 million – are expected to live in cities by 2050. This shift will bring a new set of challenges for city authorities: how to provide the urban population with sufficient water, energy, transport and waste services, and manage infrastructure in a sustainable way." (Ref: **CO_5027**)*
- *"The growth of urban populations is an important driving force behind urban expansion. However, in Europe, it is not the main factor. More significant is the trend for European cities to become much less compact. Since the mid-1950s, European cities have expanded on average by 78 %, whereas the population has grown by just 33 %." (Ref: **CO_0096**)*
- *"Recent urban expansion in OECD countries (...) is now largely driven by urban sprawl. Urban sprawl can clearly be seen by the fact that urban land expansion has been faster than population growth." (Ref: **CO_5009**)*
- *"(...) in Europe today, even where there is little or no population pressure, a variety of factors are still driving sprawl. These are rooted in the desire to realise new lifestyles in suburban environments, outside the inner city." (Ref: **CO_0028**)*
- *"Urban expansion on a wider front is driven by economic growth and restructuring, new employment opportunities, growth of transport infrastructure, population growth and household change, as well as a decline of traditional rural economies. There are also more intangible factors, such as cultural values, lifestyles, social segregation, and urban/rural attitudes and perceptions." (Ref: **CO_0097**)*
- *"The models of urban expansion demonstrate clearly the reach of the city in dependence on the technological level of the transportation infrastructure. Given the need to reach the city centre within 30 minutes from home, the first sprawl was possible by the invention of the horse-railway, which allowed an urban perimeter of 10 kms (r=5 kms). The tram extended the radius to seven kilometres. With metro (r=12 kms) and rapid train systems (r=20 kms) after World War II it was possible to allow urban sprawl, orientated to the rail tracks, to an urban perimeter of 40 kms." (Ref: **CO_0036**)*
- *"Rural–urban migration and the transformation of rural settlements into towns and cities have been important determinants of rapid urban growth but there has also been a general convergence in lifestyles between urban and rural areas as advances in transportation and telecommunication have caused distance and time to collapse. Urban functions are being spread over larger and larger geographic areas so that the traditional distinction between urban and rural areas is becoming increasingly redundant for many purposes." (Ref: **CO_0087**)*
- *"Urban areas and their hinterland are today not two discrete spaces; they overlap and interlink in a complex system of economic and social interactions." (Ref: **CO_5051**)*
- *"The residential communities in the periphery are no longer complementary quarters to the core city, but have gained independence and autochthonous qualities, they have become multifunctional living areas. And with emancipation the outskirts gained self-consciousness in an architectural sense as well." (Ref: **CO_0036**)*
- *"Current urban development – at least in Western Europe - has been characterised also by the shift of business activities to suburbs." (Ref: **CO_0034**)*
- *"From around 1960 onwards, the European retail sector has experienced an important development at the urban peripheries and in suburban areas. This evolution was basically*

*spurred by the considerable emigration flux towards the outskirts of the agglomerations (suburbanisation of houses and workplaces), the increasing economies of scale in the retail sector, the changes in the shopping behaviour of consumers, problems in city centres (congestion, parking, high ground prices, scarcity of parcels and buildings), the intention of urban planning to improve services in the urban agglomeration and, finally, the internationalisation of the retail sector (with the increasing presence in our cities of hypermarkets Carrefour, IKEA etc.)." (Ref: **CO_0034**)*

- *"Urban sprawl as a dominant trend in post-war European and North American cities is not expected to disappear in the coming years. However, for objective and subjective reasons the increase in urban sprawl may diminish. (Objective reasons include increasing cost of land due to land scarcity; subjective reasons include increasing appreciation of city life)." (Ref: **CO_0079**)*
- *"(...) there is some evidence that urban sprawl has already reached its peak in many cities. Cities are either already experiencing a slowdown of outward migration, or they are expecting one. This means that there is at least the potential for inner-city areas to become more attractive to new target groups (e.g. high-income households, families, older people etc.)." (Ref: **CO_0079**)*
- *"As a main consequence of urbanisation, per capita urban land consumption is increasing, including the land that has been converted from rural to urban use to provide for jobs, recreation and entertainment, shopping, parking, transportation, storage, government services." (Ref: **CO_5048**)*

## Interactions within the Social Domain

### *Car ownership*

Living in urban areas, generally congested and with developed public transport services, allow inhabitants to re-think their mobility behaviour and to abandon the usage of car. Thus it can be expected that urbanisation could be a driver for the reduction of car ownership rates.

- *"The car-free, urban lifestyle is held in the highest regard and offers an alternative to the hegemony of the car." (Ref: **CO_0004**)*

On the other side, especially in those situations where public transport services are inadequate to satisfy the needs, urban sprawl can be considered as a factor in boosting private mobility and contributing to the increase of car ownership rates.

- *"The EU project SCATTER has listed the widely accepted negative effects of urban sprawl as follows: (...) increase in the use of private cars, traffic congestion (...)." (Ref: **CO_5027**)*

### *Planning*

- *"Urban sprawl inhibits the development of public transport and solutions based on the development of mass transportation systems, and the provision of alternative choices in transportation that are essential to ensure the efficient working of urban environments." (Ref: **CO_0028**)*
- *"Currently we are on a pathway to ever increasing urban sprawl, and in some cases megacities merging with neighbouring cities and towns. These mega-regions, formed by megacities that stretch hundreds of kilometres – sometimes across state borders – form vast belts of high population density and economic power and create huge challenges for governance and mobility. However, this trend is not inevitable and it is possible to reverse it. For example, many urban planners and transport officials today advocate replacing low density car-centric cities and zoned land use with denser, integrated urban villages based around mixed land use, public transport and walkability." (Ref: **CO_5018**)*
- *"Three aspects, however, receive too little mention or none at all: a) the potential that nonetheless exists in urbanisation – with specific reference here to the setting-up/improvement of effective public and private transport systems – is one of the main tasks facing urban regions in the future. b) Sustainable, resource efficient housing development and the integration of urban and traffic planning continue to be weak aspects of national planning legislation. c) Revitalisation and reurbanisation as an opportunity: as far as residential mobility goes, the potential of towns and cities with regard to their density of service providers represents an important aspect of the 'back to the city' trend being observed in parts of Europe." (Ref: **CO_5006**)*

- *"Mistakes of the past such as urban and suburban sprawl and an automobile-based society should not be repeated. We need a new sustainable design, mass transit, high density, lots of walking for a safe, high quality urban environment." (Ref: **CO_5019**)*

*Change of lifestyle and values*

- *"In general, urban populations have a less direct perception of "nature" than rural residents, and typically have higher consumption levels." (Ref: **CO_5048**)*
- *"A new sustainable mobility freedom concept could take off, especially in the urban environment, with a greater attention of people towards active travel (walking and cycling), combined with the use of high quality public transport and information services, as the main way to ensure freedom of movement." (Ref: **CO_5048**)*

*Education*

- *"On the other hand, the urban population may have a greater level of environmental awareness, due to greater access to education and information." (Ref: **CO_5048**)*

*Health*

- *"(...) urban sprawl produces many adverse environmental impacts that have direct impacts on the quality of life and human health in cities, such as poor air quality and high noise levels that often exceed the agreed human safety limits." (Ref: **CO_0028**)*
- *"Slum populations in urban areas are particularly exposed to disease, suffering from poor air quality and heat stress, and with limited access to clean water." (Ref: **CO_2024**)*
- *"Increasing urbanisation, especially in China and South Asia, as well as ageing of the population (since the elderly are generally more susceptible to air pollution) could be potential contributors to this phenomenon." (Ref: **CO_5009**)*

**Interactions with the Economy Domain**

*Employment*

- *"Efficiently operating cities attract investment and jobs." (Ref: **CO_0260**)*

*Availability of public and private resources and investments in the transport sector*

- *"In the U.S., road networks as well as public transit systems are subsidized, with revenues from user fees falling well short of the combined operating and capital costs of the systems. Such subsidies, which are common in other countries as well, reduce the cost of travel within cities, potentially encouraging their spatial expansion. This conclusion is not immediate, however, because transport subsidies must be supported by general tax revenue. As a result, while a subsidy reduces the direct cost of using the transport system, it raises the general tax burden, reducing disposable incomes. The first effect causes a city to expand, while the second (by reducing the demand for space) causes it to contract." (Ref: **CO_4015**)*
- *"From an economic perspective urban sprawl is at the very least a more costly form of urban development due to: increased household spending on commuting from home to work over longer and longer distances; the cost to business of the congestion in sprawled urban areas with inefficient transportation systems; the additional costs of the extension of urban infrastructures including utilities and related services, across the urban region." (Ref: **CO_0028**)*
- *"Sprawl also increases the length of trips required to collect municipal waste for processing at increasingly distant waste treatment plants and this is expected to continue as household waste grows 3–4 % annually." (Ref: **CO_0028**)*
- *"The EU project SCATTER has listed the widely accepted negative effects of urban sprawl as follows: (...) higher costs of public services, especially transport (...)." (Ref: **CO_5027**)*
- *"(...) investment in public transport infrastructure is only economically justifiable if housing and employment density is sufficient within the catchment area of the stops. As a result, a consensus is emerging between researchers and urban planners on a density pertinence threshold for public transport of approximately 30 inhabitants/ha." (Ref: **CO_0208**)*
- *"Transportation investment that acknowledges the unique history, architecture, and ecology of a site can ensure that historic structures, archaeological remains, and wildlife habitats are preserved. (...) This means planners and developers must be careful to avoid damaging or*

*destroying objects of archaeological or historic significance in the path of new transportation facilities." (Ref: **CO_0206**)*

#### Intensified competition for scarce resources use

- *"This growing global population also has an increasing taste for resource-intensive goods such as meat and cars. The result is exploding global demand for water and land for crops, livestock, domestic use and biofuels; fossil fuels to power transport or production; and minerals, metals and forests for manufacturing. All of these resources are already heavily exploited, and many face the possibility of severe depletion or even exhaustion in the first half of the century. Scarcity will lead to competition and high, volatile resource prices – it seems likely that the age of cheap oil and cheap energy is over, for example. This will have a knock-on effect on the cost and availability of transport and other goods and services essential to everyday needs in cities." (Ref: **CO_5018**)*
- *"The consumption of land and soil are of particular concern as they are mostly non-renewable resources. In contrast to changes in agricultural land use, the development of farmland for new housing or roads tends to be permanent and reversible only at very high costs." (Ref: **CO_0028**)*

### Interactions with the Environment Domain

#### Climate change impacts

- *"Sprawl related growth of urban transport and greenhouse gas emissions have major implications for global warming and climate change, with the expectation of increasingly severe weather events in the coming years and increased incidences of river and coastal flooding." (Ref: **CO_0028**)*
- *"Cities are themselves sources of global warming: they are "heat islands", significantly warmer than the surrounding countryside. The main reason for this is the way the land surface is modified by urban development; waste heat from energy use is a secondary cause." (Ref: **CO_0091**)*

#### GHG mitigation

- *"The use of energy within a city, and the associated GHG emissions, is dependent on both the form of urban development, i.e. its location and density, and also its design. In this respect, the twin challenges of urban sprawl and the growth of informal urban settlements are especially problematic." (Ref: **CO_0147**)*
- *"The great challenges of our time are concentrated in the large cities, from where more than half the total worldwide greenhouse gas emissions originate." (Ref: **CO_0284**)*
- *"Buildings are responsible for more than 40 per cent of energy use in OECD countries and at a global level they account for about 30 per cent of GHG emissions according to UNEP's Sustainable Building and Construction Initiative." (Ref: **CO_0091**)*
- *"Buildings can last for decades, even centuries, and it is projected that more than half of existing buildings will still be standing in 2050. As such, the environmental impacts of buildings constructed today will continue for years to come." (Ref: **CO_5009**)*
- *"There is great potential for cost-effective GHG emission reductions from buildings, with the right incentives and building codes." (Ref: **CO_5009**)*

#### Noise levels and emissions standards

- *"Urbanization, growing demand for motorized transport and inefficient urban planning are the main driving forces for environmental noise exposure." (Ref: **CO_0127**)*

#### Pollution levels and emissions standards

- *"The level of air pollution exposure in the densely developed centres of cities may often be at higher levels than the suburbs due to the greater concentrations and slower movement of traffic." (Ref: **CO_0028**)*
- *"Twenty per cent of the EU urban population lives in areas where the EU air quality 24-hour limit value for particulate matter (PM10) was exceeded in 2009 (figure below). For EEA-32 countries*

*the estimate is 39%. EU urban exposure to PM10 levels exceeding the WHO AQG[12] is significantly higher, comprising 80–90 % of the total urban population." (Ref:* ***CO_0129****)*

- *"Seventeen per cent of the EU urban population lives in areas where the EU ozone target value for protecting human health was exceeded in 2009 (figure below). For EEA-32 countries the estimate is also 17 %." (Ref:* ***CO_0129****)*
- *"Twelve per cent of the EU urban population lives in areas where the annual EU limit value and the WHO AQG for NO2 were exceeded in 2009 (figure below). For EEA-32 countries the estimate is also 12 %." (Ref:* ***CO_0129****)*
- *"The EU urban population exposed to SO2 levels exceeding the WHO AQG is significantly higher, amounting to 68–85 % of the total urban population (figure below)." (Ref:* ***CO_0129****)*

| Pollutant | EU reference value | Exposure estimate (%) | WHO AQG | Exposure estimate (%) |
|---|---|---|---|---|
| $SO_2$ | Day (125) | 0.3–2.3 | Day (20) | 68–85 |
| $NO_2$ | Year (40) | 7–19 | Year (40) | 7–19 |
| $PM_{10}$ | Day (50) | 18–40 | Year (20) | 80–90 |
| Pb | Year (0.5) | < 1 | Year (0.5) | < 1 |
| CO | 8-hour (10) | 0–2 | 8-hour (10) | 0–2 |
| $O_3$ | 8-hour (120) | 16–50 | 8-hour (100) | > 95 |

Colour coding of exposure estimates, fraction of urban population exposed to concentrations above the reference level:

| | | | |
|---|---|---|---|
| < 10 % | 10–50 % | 50–90 % | > 90 % |

**Note:** The reference levels included comprise EU limit or target levels and WHO air quality guidelines (AQG). The averaging period is shown and the reference levels in brackets are in μg/m³ except for CO which is in mg/m³.

For some pollutants EU legislation allows a limited number of exceedances. This aspect is considered in the compilation of exposure in relation to EU air quality limit and target values.

The comparison is made for the most stringent EU limit or target values set for the protection of human health. For $PM_{10}$ the most stringent standard is for 24-hour mean concentration.

This estimate refers to a recent three-year period (2006–2008) and includes variations due to meteorology, as dispersion and atmospheric conditions differ from year to year.

Source: Air quality in Europe ð 2011 report (Ref: **CO_0129**)

**Figure 1-23 Percentage of the urban population in the EU exposed to air pollutant concentrations above the EU and WHO reference levels**

- *"Traffic-related air pollution is still one of the most pressing problems in urban areas." (Ref:* ***CO_0229****)*

### *Energy availability, production and consumption*

- *"There is a general correlation between energy consumption (in gigajoule per inhabitant) and urban density (in inhabitants per hectare). This allows to distinguish several kind of cities, like the American ones, the European ones and the Asian ones." (Ref:* ***CO_5027****)*
- *"Evidence shows that there is a significant increase in travel related energy consumption in cities as densities fall." (Ref:* ***CO_0028****)*
- *"The diversification of energy sources, fuel types, and vehicles will be greatest in urban environments where the transport and distance requirements are more compatible with diversified energy types and new energy distribution infrastructures." (Ref:* ***CO_5034****)*
- *"Electricity use is already growing more quickly relative to other energy carriers as a result of continuous urbanisation" (Ref:* ***CO_1009****)*

### *Scarce resources of fossil fuels*

- *"The EU project SCATTER has listed the widely accepted negative effects of urban sprawl as follows: (...) increase in fuel consumption and air pollution (...)." (Ref:* ***CO_5027****)*
- *"Increased average trip length and suburb to suburb trips increase fuel consumption and related emissions of air pollutants and greenhouses gases." (Ref:* ***CO_5048****)*

[12] Air Quality Guidelines

*Scarce resources of raw materials*

- *"Urban sprawl has also produced increased demands for raw materials typically produced in remote locations and requiring transportation." (Ref: **CO_0028**)*
- *"Land use change also alters water/land-surface characteristics which, in turn, modify surface and groundwater interactions (discharge/recharge points), to the point that a majority of the small watersheds affected by urban sprawl show hydrological impairment. If the capacity of certain territories to maintain the ecological and human benefits from ground water diminishes, this could lead to conflicts due to competition for the resource." (Ref: **CO_0028**)*

## Interactions with the Technology Domain

*Technology development in general and innovation diffusion*

- *"Urban centres are the locations of "nodal" interactions that contribute to rapid developments in knowledge, science and technology. Indeed, urban contexts are richer in cognitive dimensions than rural contexts, if only because urban contexts contain more people and a greater range of ideas within a dense setting." (Ref: **CO_5048**)*
- *"Certainly, ICT-based innovation will be a prominent feature of our lives, particularly in increasingly networked cities, where the ability to be permanently connected could bring better access to goods, services and other people with less need for physical transport." (Ref: **CO_5018**)*
- *"The peri-urban is also a place of innovation and increasing employment in the service and IT sectors: 25% of peri-urban regions are classified as 'highly innovative." (Ref: **CO_0097**)*

*Traffic management systems*

- *"Cities will be obliged to apply ever-stricter air quality legislation, and to reduce transport-related CO2 emissions in line with increasingly stringent European and global targets. Greater priority will be placed on policies for the prevention and avoidance of congestion, which will inevitably include measures such as access control and road charging to manage the level of demand. Incentives and sanctions will favour low-impact collective and individual modes of passenger transport, while special attention will be paid to goods delivery, with new provisions for truck routing, loading, parking and the associated logistics services." (Ref: **CO_0261**)*

*Information systems*

- *"Another mega-trend that is setting the scene for innovation needs in transport is urbanisation.(...) This process will need adjustment and planning, as urban areas increasingly need to manage the demand profile. The key to this are Intelligent Transport Systems (ITS) that provide great possibilities, for example to monitor networks, provide incentives (namely through charges), provide traveller information and enable use of in-vehicle devices." (Ref: **CO_0284**)*

*Pollution abatement and monitoring*

- *"Up to now cities that wanted to calculate their GHG emissions either followed their own path or adopted an inventory tool designed for business. ICLEI-Local Governments for Sustainability has now released a draft International Local Government Greenhouse Gas Protocol with two parts: the Emissions Analysis Protocol provides guidance on making an inventory of greenhouse gas emissions and reporting them, and the Measures Analysis Protocol provides guidance on quantifying the emission reduction benefits of mitigation policies and projects. The Protocol goes hand-in-hand with an on-line software tool to plan, monitor and report on GHG emissions and to be released towards the end of 2008 for use by local governments around the globe." (Ref: **CO_0091**)*
- *"Currently most carbon sequestration initiatives at the urban level relate to tree-planting schemes, and the restoration and preservation of carbon sinks." (Ref: **CO_0147**)*
- *"In order to study the influence of the different canyon geometries on the street level concentrations, OSPM model results were computed (...) The highest street increments are observed in the narrow canyon case which due to its configuration has the effect of trapping the air pollutants inside the street. This results in high street level concentrations. Assuming the same amount of vehicles per day in the square and wide cases, the $PM_{10}$ street increments are found to be lower by 33% and 67% compared to the concentrations in the narrow canyon. (...) The model results show that (...) the allowed number of daily $PM_{10}$ exceedances (35 days per*

*year according to the 2005 limit value defined in Directive 1999/30/EC) is exceeded in almost all cities in the narrow canyon, in 14 cities in the square canyon and in half the cities in the wide canyon case." (Ref:* ***CO_0229****)*

### Energy efficiency

- *"Along with population size, key activity drivers of energy demand in building are rate of urbanization, number of households, per capita living area, persons per residence, and commercial floor space. As population becomes more urbanized and areas become more electrified, the demand for energy services such are refrigeration, lighting, heating and cooling increases." (Ref:* ***CO_0105****)*
- *"Energy intensity trends in residential space conditioning are affected by climate, building thermal integrity, and the heating and cooling equipment." (Ref:* ***CO_0105****)*
- *"The greatest energy saving potential lies in buildings. The plan focuses on instruments to trigger the renovation process in public and private buildings and to improve the energy performance of the components and appliances used in them." (Ref:* ***CO_0198****)*
- *"[Energy labels] will also soon be in place for buildings EU-wide, with energy efficiency certificates for each property. (Ref:* ***CO_0269****)*

## Impacts on Mobility and Transport

### Increased dependence upon private transport due to urban sprawl

- *"Decentralization of cities has been facilitated by the car in combination with efficient public transport. This has resulted in a substantial growth in trip lengths and the development of travel patterns that are dispersed rather than concentrated on the city centre. This in turn increases car dependence and reduces the possibilities of promoting efficient public transport. So transport has acted both as the facilitator of change and as a limiting factor on its resolution." (Ref:* ***CO_4017****)*
- *"Urban sprawl reinforces the need to travel and increases dependence upon private motorised transport to do so, leading in turn to increased traffic congestion, energy consumption and polluting emissions. These problems are most acute where residential densities are low and where daily activities (home, work, shopping) are widely separated. There is a sharp increase in car use where land use densities fall below 50-60 people per hectare." (Ref:* ***CO_0096****)*
- *"(...) there is an important relationship between the urbanisation driver and daily commuting patterns. Indeed, one of the consequences of urban sprawl is an increasing dependence on the automobile for intra- and inter-metropolitan travel. Urban sprawl entails building extensive transportation systems because houses are increasingly far away from workplaces and commercial centres. This new constructed infrastructure, in return, spurs further urban sprawl – investments made in new motorways or road connections attract new development along the improved transport lines. Growing car ownership and the concentration of work and shopping in out-of-town locations have resulted – and may continue to result - in continuing increases in journey length for all purposes, but particularly for commuting." (Ref:* ***CO_5048****)*
- *"The new peripheral retail centres are the result of two tendencies, namely the introduction of new retail techniques - self-service and hard discount – and, secondly, the appearance of shopping centres, combinations of retail businesses and warehouses. If the malls are located away from populated areas, e.g. in rural areas nearby highway connections, it is unlikely that public transport links can be provided at a reasonable cost." (Ref:* ***CO_0034****)*
- *"At any rate, if the current trends in the increase of peripheral retail centres continue, a growing transport demand by car is expected." (Ref:* ***CO_0034****)*

### Congestion in urban areas increases with city size

- *"Congestion in many urban areas has been increasing in its duration and intensity. On average, speeds in cities have been declining by 5% per decade (EFTE 1994) and the severity of congestion increases with city size." (Ref:* ***CO_4017****)*

### Increasing attitude for public transport, cycling and walking in urban areas

- *"Growing medium-sized urban regions provide a viable passenger base for a functioning public transport system. The challenge lies in complementing the urban structure in a manner that* *allows the mobility and transport needs of new residents and functions to be efficiently met through public transport." (Ref: **CO_0004**)*

- *"Public transit and walking transport increase as an area becomes more urbanized." (Ref: **CO_5047**)*


Source: The Future Isn't What It Used To Be. Changing Trends And Their Implications For Transport Planning (Ref: **CO_5047**)

**Figure 1-24 Urbanisation impact on mode split**

- *"On shorter journeys, it may be possible to increase the modal share of non-motorised modes, particularly as levels of urbanisation and congestion increase (EC, 2011d). Currently, cycling and walking account for approximately 13 % of urban pkm in Europe, but best-practice examples show this share can be much higher (EC, 2011d)." (Ref: **CO_5030**)*
- *"<In the past 100 years, the automobile has shaped the city rather than cities shaping the automobile. In the future the opposite will be the case: cities will start to shape mobility.> Chris Borroni-Bird, Director of Advanced Technology Vehicle Concepts, GM" (Ref: **CO_5018**)*

#### *Diffusion of integrated services in urban areas*

- *"The mobility mixes of urban dwellers differ widely and range from cars to public transport and bicycles. Here, integrated services enjoy a great potential. The Fraunhofer Society highlights first and foremost services located "between" cars and public transport, e.g. car sharing models or demand-driven public transport without fixed routes." (Ref: **CO_0005**)*
- *"Recognizing that the deeper integration of the urban mobility system is a requirement to achieve greater energy efficiency and provide better accessibility, the roadmap identifies the research needed to enable the integration of the key components of the system, in particular on information, payment and pricing, network management, urban freight, interchanges." (Ref: **CO_5034**)*

#### *1.2.4.2 Planning*

**Driver description**

- *"Planning is a rational decision making process that starts analyzing the system (and understanding its behaviour), and efficiently assigning some resources according to some objectives in a future scenario. Good planning is based on systematic processes of generation and appraisal of alternatives to meet the objectives." (Ref: **CO_5005**)*
- *"A clear physical delineation between urban and rural zones does not mean that urban and rural development issues should be treated separately. On the contrary, there needs to be a coordinated and integrated approach that involves all relevant planning authorities (...) as well as other stakeholders and their organisations. Strong planning legislation and an open governance process are key to this approach." (Ref: **CO_5027**)*
- *"Many public services have been progressively centralised with a view to increasing efficiency. The distances between citizens and service providers (schools, hospitals, shopping malls) have been on the increase. Firms have followed the same trend by keeping a smaller number of production, storage and distribution centres. When taking land-use planning or location decisions, public authorities and companies should take into account the consequences of their choices in terms of travel needs of clients and employees in addition to the transport of goods." (Ref: **CO_0015**)*
- *"Transport, urban planning, business, public services, energy and food supply can no longer be considered in isolation. We need to create truly integrated systems where people have choice, flexibility and seamless connectivity. When people travel, they should be able to connect much more smoothly and quickly between different modes of transport. Increasingly, there will also be a need to supplement this physical connectivity with online connectivity: the ability to check information before, and during, travel will allow people to optimise their journeys, and perhaps even substitute a degree of physical movement with virtual access to lifestyle needs." (Ref: **CO_5018**)*
- *"A Sustainable Urban Mobility Plan is a Strategic plan designed to satisfy the mobility needs of people and businesses in cities and their surroundings for a better quality of life. It builds on existing planning practices and takes due consideration of integration, participation, and evaluation principles." (Ref: **CO_0101**)*
- *"Sustainable mobility for people and goods in urban environments is one of the most challenging tasks in the development of the cities of tomorrow. Delivering an energy efficient, reliable and integrated transport system, is therefore fundamental and must be integrated in all urban developments." (Ref: **CO_5034**)*
- *"Some key principles of sustainable urban development, such as land use integration and minimum density of building, ensure a critical mass of mobility demand (in turn facilitating a good supply of urban public transport) while also promoting self-restraint in a local environment that may be achievable with ecomobility and traffic pacifying measures." (Ref: **CO_5005**)*
- *"Development of the public transport system must be made a spearhead goal of transport policy in both national decision-making and decision-making in urban regions." (Ref: **CO_0004**)*
- *"Public transport should be designed to be competitive with private vehicles in door-to-door time and quality (reliability, comfort, etc.)." (Ref: **CO_5005**)*
- *"Promote non-motorised transport as full and adequate transport modes on a social and economic level that merit privileges and positive discrimination in urban and other dense structures." (Ref: **CO_5006**)*

**Interactions within the Social Domain**

***Households structure and distribution***

- *"(...) urban planning has to ensure that inner-city neighbourhoods meet the requirements of these potential new inhabitants (e.g. high-income households, families, older people etc.), while at the same time avoiding unwanted gentrification." (Ref: **CO_0079**)*

*Urbanisation*

- *"Active urban redevelopment and renewal policies in many urban areas seem to be having some success in reversing the depopulation and decay of urban centres." (Ref:* ***CO_5048****)*
- *"Economic inefficiency is also associated with the market orientated planning regimes that frequently generate sprawling urban areas. Market orientated land use allocations driving urban expansion and the transformation of economic activity often result in the abandonment of former industrial areas. As a result, there are many derelict or underused former industrial zones throughout Europe. In Spain about 50 % of sites contaminated from past industrial activities are located in urban areas (1999), and in Austria it is estimated that abandoned industrial sites cover about 2 % of all urban areas (2004)." (Ref:* ***CO_0028****)*
- *"Containing urban areas or setting a clear spatial boundary between urban and rural land, coupled with integrated spatial or territorial policies and strategies, are the most important means for managing urban growth." (Ref:* ***CO_5027****)*

*Change of lifestyle and values*

- *"Although planning and technology can do a lot to improve mobility, many of our future challenges are shaped by people's values, behaviour and preferences. As well as switching from cars to more low-carbon vehicles, cities need to think about ways in which mass behaviour and social norms can be influenced to get people to think beyond their current patterns of travel and ways of living. In fact, because of increasing urbanisation, cities need to be the key players in promoting low-carbon, healthier lifestyles. The most effective governments and businesses will engage in early planning to influence lifestyles rather than simply relying on additional road infrastructure and modes of transport." (Ref:* ***CO_5018****)*
- *"(...) decision-makers and developers must have the will to concentrate development into units of sufficient size so as to ensure the front-loaded supply of good public transport services to residents in areas of new development. If the residents of new areas are allowed to grow accustomed to passenger car use because public transport is not yet available, changes in travel behaviour are much more difficult to effect at a later stage through improvements in public transport services." (Ref:* ***CO_0004****)*

*Health*

- *"(...) health and social concerns also need to be integrated into the design and management of urban polices. Urban planning which takes account of urban poverty and health issues will promote the accessibility of the poor to basic environmental services as well as to green space, which will eventually contribute to social cohesion as well." (Ref:* ***CO_5009****)*

### Interactions with the Economy Domain

*Employment*

- *"(...) the siting of employment, retail and leisure centres outside urban areas, for instance around motorway junctions, undermines the economic viability of the city centre as a commercial district, encourages car use and excludes citizens who do not have access to a car from these jobs and services." (Ref:* ***CO_0096****)*

*Regional differences in economics*

- *"A functioning public transport system strengthens the competitiveness of the urban region and of business." (Ref:* ***CO_0004****)*

*Availability of public and private resources and investments in the transport sector*

- *"The State and municipalities must allocate sufficient human and financial resources to the development and maintenance of a system responsible for passenger transport throughout the region." (Ref:* ***CO_0004****)*
- *"The city is portrayed as selecting its transport system from along a continuum of money cost/time cost choices. A road network has a high money cost, which includes the cost of automobile operation, but a low time cost, while a slow but resource-efficient public transit system has the opposite characteristics." (Ref:* ***CO_4015****)*

## Interactions with the Environment domain

### *Climate change impacts*

- *"Planning rules and regulations balance a complex range of economic, social, and environmental objectives. However, their design and implementation can have important implications for mitigating climate change and also has the potential to influence the resilience to the impacts of climate change, for example, in the management of flood risks or water scarcity" (Ref: **CO_2024**)*
- *"In many cities throughout developing countries, populations continue to grow in the absence of effective urban planning, resulting in living conditions that exacerbate climate change impacts and development in areas at risk from sea-level rise, flooding and coastal storms." (Ref: **CO_0147**)*
- *"Urban governance and planning can improve resilience to climate change impacts through targeted financing of adaptation, broad institutional strengthening, and minimizing the drivers of vulnerability. Urban areas with weak governance systems – as a result of political instability, exclusion of climate change from the political agenda, or lack of governmental resources – are especially vulnerable to climate change impacts." (Ref: **CO_0147**)*

### *GHG mitigation*

- *"Densification of land use may be the most effective way to reduce the use of GHG intensive modes of travel. Research shows that residents in more densely populated areas and in areas with better mixes of land uses tend to emit far less GHG emissions from their travel. They tend to walk more, use public transportation more and drive less. Policies aimed at increasing density and influencing local governments to make land use development and zoning decisions based on likely impact on GHG emissions, could be highly effective at reducing emissions." (Ref: **CO_0148**)*
- *"Commitments to GHG-reduction: Local authorities will be obliged to optimise and renew their communal fleets (green fleets) and introduce mobility management measures to mainstream TDM[13] and climate protection measures." (Ref: **CO_5006**)*

### *Energy availability, production and consumption*

- *"Urban design and land use planning regulations have the potential to facilitate a less energy intensive society, while balancing a range of wider economic and social objectives." (Ref: **CO_2024**)*

## Interactions with the Technology Domain

### *Technology development in general and innovation diffusion*

- *"Public transport objectives are defined in the shared visions and strategies that are implemented in all activities in the urban region, from city planning to financial planning and urban development. An innovative operating environment should be created for the development of private sector services. This shares innovation process, where the objectives for cooperation between public and private sector have distinct roles. The process advances from ideas and plans based on user requirements and anticipation of technology through new product concepts to the deployment and monitoring of new services and modes of operation. Monitoring seeks to obtain information about e.g. matters relating to the effectiveness of development efforts and passenger approval."(Ref: **CO_0004**)*

### *Pollution abatement and monitoring*

- *"The major contribution of urban emissions to urban scale pollution was confirmed which showed the need to address the design of air quality abatement strategies on an urban scale." (Ref: **CO_0229**)*

## Impacts on Mobility and Transport

### *The potentials in the strict relationship between planning and transport system should be enhanced*

- *"The integration of spatial planning, transport and environmental policies is particularly crucial because they are so closely related. Land use policies need to take account of travel time, car dependency, greenfield use, access to goods and services, air pollution, noise, greenhouse gas*

[13] Transport Demand Management

*emissions and energy consumption. Spatial policies sometimes influence transport variables much more than transport policy itself does." (Ref:* ***CO_5009****)*

- *"Travel demand can be reduced which in turn can reduce transport intensity in many of the subsectors by integrated land-use planning, high-density development, and improved public transit." (Ref:* ***CO_5046****)*
- *"The City and County of Lyon, for example, has developed a dedicated city planning strategy by which permissions for new buildings will only be granted for already existing neighborhoods or directly adjacent to public transport lines, to limit the need for individual cars." (Ref:* ***CO_0284****)*

***Key role of planning in developing adequate public transport networks***

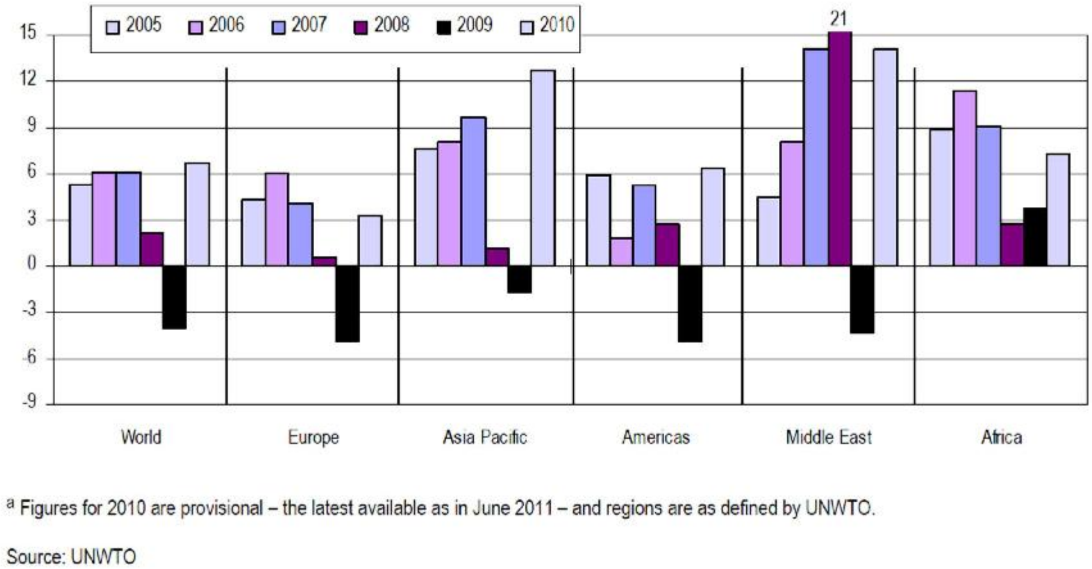
- *"In addition, land use controls such as restrictions on the availability and pricing of parking spaces, the use of pedestrian zones and parks, and land use zonal strategies (including congestion charging), have the potential to support integrated public transport to reduce the use of private motor vehicles." (Ref:* ***CO_2024****)*
- *"It is particularly important to anticipate future needs correctly because transport planning decisions can be self-fulfilling. For example, if we expect automobile transport to be dominant, we will devote most transportation resources to expanding roads and parking facilities, and locate destinations for automobile access, creating the predicted travel patterns. Because roadway capacity expansion is costly and tends to fill with generated traffic, such projects could consume virtually any allocation of resources. However, if we expect demand to become more diverse we will implement different policies, helping to create a more balanced transport system." (Ref:* ***CO_5047****)*
- *"If the urban network is Rapid Transit-based, with adequate coverage throughout the central area and close suburbs, having at least one station close to each major activity zone with good connectivity among lines requiring no more than one transfer and convenient transfer between lines, then the urban network is called 'ubiquitous' and most of the travellers' needs may be fulfilled in a sustainable manner. The Paris Metro network is an example of this. It covers the entire urban area well: no point within the central city is more than 500 m from a metro station. Munich, Madrid and some other capital cities also have many elements of the ubiquitous network pattern." (Ref:* ***CO_5004****)*

## 1.2.5 The Behaviour Factor

### *1.2.5.1 Tourist flows*

#### Driver description

- *"The last few years have proved extremely challenging for the travel and tourism industry worldwide, not least in Europe. The second half of 2008 and 2009 saw the worst global economic recession since the 1930s and, although several key economies in Europe had started to register growth by mid-2009, the growth remained fragile, with the region overall suffering a 5% decline in arrivals and a 13% fall in receipts over the full 12 months of the year. Admittedly, arrivals did bounce back in 2010, but the modest 3% increase in arrivals recorded meant that the total lagged 2008's peak by more than 10%. And Europe's international tourism receipts continued to decline in 2010 (albeit by only around 1%), falling to well below 2007's level." (Ref: **CO_0168**)*
- *"Figure below shows the annual trends in international tourist arrivals worldwide by destination region, as published by the World Tourism Organization (UNWTO) in June 2011." (Ref: **CO_0168**)*

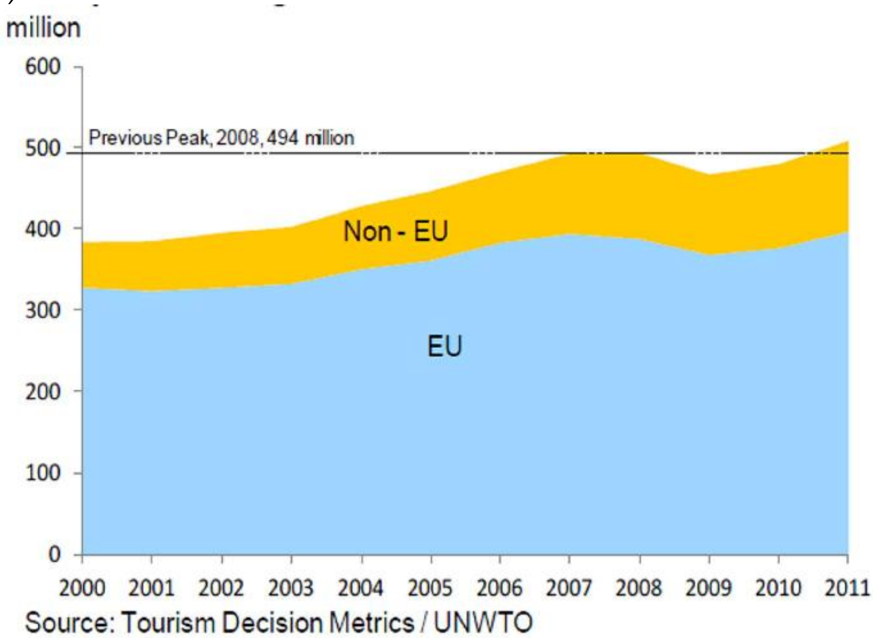



Source: European Tourism Insights 2009-10 (Ref: **CO_0168**)

**Figure 1-25 Growth in international tourist arrivals by world region, 2005-10 (% change over previous year)**

- *"The graph gives the impression that the results for Europe were only slightly worse than those for the rest of the world. This is a little misleading: because of the importance of Europe in world tourism (it accounted for 52% of global arrivals in 2009), the world total is heavily influenced by Europe. Asia Pacific, Africa and the Middle East continued to perform substantially better through 2007-09 than Europe, and the totals for the Americas disguise the fact that, while international arrivals lagged in North America (for different reasons in the individual countries), those in Central and South America generally prospered." (Ref: **CO_0168**)*
- *"The general consensus is that Europeans reacted to the crisis between 2008 and 2010 by travelling closer to home for their holidays (often staying within their home countries), sacrificing secondary holidays in order to maintain their primary holidays, curtailing their lengths of stays and spending, and booking late in order to take advantage of last-minute offers (often spending plenty of time on the internet to find the best of those offers). (Ref: **CO_0168**)*
- *"Business travel was particularly badly affected by the financial and economic crisis. Companies reacted quickly by curtailing business travel (and especially incentive and conference travel). (Ref: **CO_0168**)*
- *"(...), the recession was associated with something that had not been seen for many years: a decline in air travel. According to the ETM, outbound trips by air in Europe fell by 8% in 2009 and recovered by just 4% in 2010." (Ref: **CO_0168**)*

- *"(...), a recovery in long-haul arrivals has been increasingly evident since 2010, reflecting the greater prosperity in other regions of the world. Depending on the nature of individual destinations, they may have enjoyed recoveries or large increases from the USA, Canada, Japan, China, India, Brazil, the Middle East and other emerging markets." (Ref: **CO_0168**)*
- *"Travel to European destinations in 2011 has exceeded the prior peak set in 2008." (Ref: **CO_0167**)*




Source: European Tourism: Trends & Prospects Quarterly Report - Q4/2011 (Ref: **CO_0167**)

**Figure 1-26 Europe: Overnight Visitor Arrivals**

- *"Impressively, 22 of 23 reporting countries show international visitor growth in 2011, ranging from 3% in the UK to more than 20% in Latvia and Lithuania. And 24 of 26 countries show gains in hotel occupancy in 2011." (Ref: **CO_0167**)*
- *"While the travel recovery has been quite robust, signs of eroding gains began to appear, as expected, in the second half of 2011." (Ref: **CO_0167**)*
- *"Not surprisingly, travel to European destinations has slowed in recent months. The combination of fiscal austerity and financial market stress brought about by the Eurozone debt crisis is affecting both consumer and business behaviour. And (...), the spectre of a global recession is not an insignificant risk as even emerging markets have begun to slow." (Ref: **CO_0167**)*
- *"In 2011, Europe generated USD518.7bn in visitor exports. In 2012, this is expected to grow by 0.4%, and the region is expected to attract 503,865,000 international tourist arrivals. By 2022, international tourist arrivals are forecast to total 627,744,000, generating expenditure of USD674.9bn, an increase of 2.6% pa." (Ref: **CO_0166**)*
- *"In recent years, domestic and intra-regional tourism, especially in emerging economies such as China, Thailand, India, Korea and Mexico, have grown rapidly and according to WTTC[14] forecasts, Chinese demand for travel and tourism will quadruple in value in the next ten years. At present China ranks a distant second, behind United States, in terms of demand, but by 2018 it will have closed much of the gap." (Ref: **CO_5048**)*
- *"Three main reasons trigger off these flows: 1.Business; 2.VFR/Visiting friends and relatives: In this respect, the search of roots is very strong (for instance travelling to/from former communist countries); 3. Culture, leisure and enjoyment: in developed and in developing countries, tourism is part of a way of life and the newcomers to tourism era seem to expect similar types of holidays as the "old tourists." (Ref: **CO_5036**)*
- *"Russians are now the ninth biggest spenders in the world on tourism abroad, according to UNWTO, with international travel expenditure up a massive 34% in 2010 (as against a drop of*

[14] World Travel & Tourism Council

*12% in 2009). Russian outbound trip volume was just under 21 million in 2008 and was estimated at 23-24 million in 2010 – after falling in 2009 and staging a solid recovery the following year. Holidays account for about 74% of total trip volume." (Ref: **CO_0166**)*

- *"European destinations that have seen exceptional growth from Russia in the past couple of years (in addition to Turkey) are: (in both years) Estonia; (in 2009) Montenegro; and (in 2010) Austria, Belgium, Croatia, Cyprus, the Czech Republic, Greece, Italy, Latvia, Lithuania, Malta, Poland, Serbia, Slovenia, Spain and the UK." (Ref: **CO_0166**)*
- *"The destinations that have most benefited from the growing demand from Russia have been those offering visa-free travel, or at least visas on arrival." (Ref: **CO_0166**)*
- *"Recently, it has become obvious that the way a visa is delivered can either facilitate these tourism flows or hinder them considerably. For example, the introduction of the Biometric Visa for the USA in 2006 resulted in a 30 to 40% decrease of European visitors; whereas Europe is currently losing market share among Chinese international travellers: the European Commission is aware of this and has taken steps." (Ref: **CO_5036**)*
- *"China was one of the few leading outbound travel markets around the world that continued to show positive growth through the recession, with trip volume rising 4% in 2009 and 20% in 2010. As a result, the market ousted the UK from third place among the world's top tourism spenders in 2010, with a 26% increase in expenditure on travel and tourism abroad (in US dollar terms), to US$54.9 billion." (Ref: **CO_0166**)*
- *"Europe now receives some 3.8 million Chinese annually – 200,000 more than the Japanese count. The number is clearly higher if measured in terms of cumulative arrivals in different European destinations, since the Chinese still tend to visit multiple destinations on one trip." (Ref: **CO_0166**)*
- *"Although the level of interest in Europe as a 'dream' leisure destination is high, and some growth is forecast, demand over the foreseeable future will continue to be relatively low and compromised by cost. The Chinese are surrounded by destinations with which they have greater cultural affinity, which are easier to travel to and offer excellent value for money." (Ref: **CO_0166**)*
- *"Although an estimated 50% of all Indian outbound trips are for business rather than leisure, according to IPK International's World Travel Monitor, the market has confirmed its earlier promise by nearly tripling in terms of outbound trip volume over the last ten years. In 2010, Indians made 11.8 million trips abroad, 8% more than in 2009, roughly unchanged over 2008." (Ref: **CO_0166**)*
- *"Few European destinations have provided figures for arrivals from India in 2009 and 2010 – the market still does not appear to be monitored in detail by the majority of ETC Members. However, it is clear from these few that India has been generating increases in tourist numbers, even for the mature European destinations that are finding it difficult to attract larger numbers from their traditional markets." (Ref: **CO_0166**)*
- *"The best performers in the Indian market – in terms of percentage growth in arrivals and/or nights – appear to have been Austria, Belgium, Cyprus, Finland, Germany, the Netherlands, Poland, Slovakia, Sweden Switzerland and the UK." (Ref: **CO_0166**)*
- *"The Indian leisure traveller is now more open to exploring newer destinations, according to the latest edition of the Nielsen India Outbound Monitor. And many of these are in Asia. This could be detrimental to Europe's prospects. Destinations such as China, the Maldives, Indonesia, the African continent, and even neighbouring Bangladesh, have witnessed a significant increase in interest among Indian travellers as destinations they plan to visit in the future." (Ref: **CO_0166**)*

## Interactions within the Social Domain

### *Migration flows*

- *"(...) migration and tourism tend to become mutually interacting geographic phenomena whose importance is rapidly growing. Migration – related tourism seems to become an important segment of global tourism." (Ref: **CO_0092**)*

*Change of lifestyle and values*

- *"In many European markets, domestic and cross-border travel is still more popular than longer-haul trips. Consumers book at the last minute and search the internet intensively for offers and bargains, and they remain very price-sensitive. Length of stay and spending per night have both declined; all-inclusive and fully independent travel (FIT) arrangements have both become popular. And the luxury and economy segments have both recovered, at the expense of the middle ground." (Ref: **CO_0168**)*
- *"As people travel more, they also become more aware of the culture and environment of the places they travel to, and they reflect more on their own experience and lifestyle." (Ref: **CO_0168**)*
- *"Demand for well-being, health & fitness and stress management products is growing in the developed economies. However competition is also growing in some areas of Europe as private capital is injected into the upgrading of old style health and spa facilities." (Ref: **CO_0023**)*
- *"As medical services get more expensive in Europe, so Europeans will travel to Asia and other more reasonably priced destinations for a wide range of medical services. Equally, the highly developed medical services available in Europe represent an opportunity to develop incoming tourism in specific niche markets. There will be also a growing intra European medical tourism market as a result of longer waiting lists and insurance companies looking to cut costs." (Ref: **CO_0023**)*

*Education*

- *"Cultural tourism is growing in Europe, but there is little evidence to suggest that festival market is expanding through increased interest in culture among existing consumers. The major driver of increased consumption is likely to be rising education levels. This suggests that new consumers will come from areas where education and personal wealth are improving, such as Central and Eastern Europe and Asia." (Ref: **CO_0023**)*
- *"Travelling depends highly on purchasing power – especially in the currency of the destination – and on the level of instruction. The latest developments have showed a parallel increase of mass tourism and of "de luxe" tourism; as a whole, except for a niche market of European senior citizens, the length of stay is short: from 2 days to 2 weeks." (Ref: **CO_5036**)*

## Interactions with the Economy Domain

*GDP trends*

- *"[In Europe] The direct contribution of Travel & Tourism to GDP in 2011 was USD612.8bn (2.8% of GDP). This is forecast to rise by 0.3% to USD614.4bn in 2012.This primarily reflects the economic activity generated by industries such as hotels, travel agents, airlines and other passenger transportation services (excluding commuter services). But it also includes, for example, the activities of the restaurant and leisure industries directly supported by tourists. The direct contribution of Travel & Tourism to GDP is expected to grow by 2.6% pa to USD791.9bn (2.8% of GDP) by 2022." (Ref: **CO_0166**)*

*Employment*

- *"Tourism is said to be the world's largest employer. In 2001, the International Labour Organisation (ILO) estimated that globally over 207 million jobs were directly or indirectly dependent upon tourism." (Ref: **CO_5048**)*
- *"[In Europe] Travel & Tourism generated 9,937,000 jobs directly in 2011 (2.7% of total employment) and this is forecast to grow by 0.4% in 2012 to 9,980,500 (2.7% of total employment). This includes employment by hotels, travel agents, airlines and other passenger transportation services (excluding commuter services). It also includes, for example, the activities of the restaurant and leisure industries directly supported by tourists. By 2022, Travel & Tourism will account for 11,262,000 jobs directly, an increase of 1.2% pa over the next ten years." (Ref: **CO_0166**)*

*Regional differences in economics*

- *"The Low Cost Airlines (LCA) activity has a significant share of passenger travel for leisure purposes, the main economic sector to benefit is tourism. LCA's business model leads these companies to choose regional airports, which are, in many cases, located in depressed and* *underdeveloped economic regions. Moreover, these regions are commonly unknown to most people, and by flying to them and advertising those on their websites LCAs improve regions' visibility." (Ref: **CO_5037**)*

- *"The impact on regional economies derived from air transport corresponds to the increase in employment in activities directly related to air transport, such as: airlines; handling, maintenance and catering companies; airports; shopping within airports; or parking facilities. It is estimated that 1000 jobs are created for every million passengers through an airport. Indirect effects, which correspond to the increase in employment and economic activity in the region as a result of the increase in flows of people, for tourism and business purposes." (Ref: **CO_5037**)*

#### Foreign trade, globalisation

- *"Thanks to globalization ('global village'), many families have moved from their original home to other countries – a development which especially affects the levels of VFR (visits to friends & relatives) movement." (Ref: **CO_0023**)*

#### Fiscal policy

- *"Climate mitigation studies conclude that policies may increase costs of tourism and reduce its economic growth in case of carbon taxes or oil price increases, though other studies find no significant impacts or believe that second order effects like a mode shift from aviation to the car, may even increase overall emissions when taxing aviation." (Ref: **CO_0187**)*
- *"Reducing the number of medium and long haul trips may hypothetically be achieved in different ways: high taxes on air travel, issuing a system of personal travel budgets or capacity restrictions within the (air) transport sector. The question is whether tourists will simply cancel their long haul trips when confronted with such measures and spend their money outside the tourism industry or if they will choose a closer destination." (Ref: **CO_0187**)*

### Interactions with the Environment Domain

#### Climate change impacts

- *"[In Europe] most tourism trips are domestic or between neighbouring countries. However the environmental impacts are mainly generated by long-haul tourism." (Ref: **CO_0186**)*
- *"(...) tourism is not developing sustainably with respect to climate change." (Ref: **CO_0187**)*
- *"Tourism related emissions are expected to continue to grow through the end of this century, and emission reductions of more than 80% are required to avoid 'dangerous' climate change. The main drivers for the environmentally unsustainable development of tourism are the increasing number of tourism trips and, on top of that, an increase of average travel speed caused by an increasing use of air transport, and resulting in an increase of average distances travelled." (Ref: **CO_0187**)*
- *"Climate change is one of the biggest long-term issues facing the tourist industry, and it could lead to the loss of many destinations whose appeal depends on their natural environment. Many low-lying coastal regions are at risk from rising sea levels – as is already evident in the case of Venice." (Ref: **CO_0023**)*

#### GHG mitigation

- *"Several studies have shown that in the 2050s, tourism related greenhouse gas emissions will be larger than global emissions and will surpass the global emission ceiling that safeguards against 'dangerous' climate change. Proposed mitigation of tourism's greenhouse gas emissions focuses mainly on technological improvements such as improving the energy efficiency of accommodations and transport modes, using low carbon fuels (mainly bio-fuels for aviation and electric cars for road transport), and off-setting the emissions through funding reductions in other sectors. Using these measures, the sector envisages reducing total emissions by 50% by 2035, but this ambition is deemed un-realistic, unless a strong change in tourism transport modes and distances is effected." (Ref: **CO_0187**)*

### Interactions with the Technology Domain

#### Technology development in general and innovation diffusion

- *"The internet will drive the next generation of travel / tourism product distribution methods." (Ref: **CO_0023**)*

*Booking and Payment systems*

- *"Experienced travellers are well versed in the organisational aspects of their trips and the reservation/booking systems that service them. And they well demand higher quality experiences and service at all levels of expenditures" (Ref: **CO_0023**)*
- *"New electronic payment systems will be developed, secure credit cards, e-pursues, etc. these will make it easier to transfer money and overcome concerns about excessive transfer charges, exchange rates, and the security of moving money on line." (Ref: **CO_0023**)*

## Impacts on Mobility and Transport

*Travelling by car will remain the most preferred alternative for tourists*

- *"The car remains the primary means of travel for tourists – travel by car in industrial countries accounts for more than 70% of all tourism journeys. The cultural necessity for car transport that has developed in most countries means that consumers and oil companies will search for alternative fuels in the face of rising oil prices, with the result that car travel will continue to dominate in the medium and long term as well." (Ref: **CO_0023**)*

*Demand for air travel will probably increase, though a slowdown in pace should be expected*

- *"New destinations are being created through improved accessibility, such as the development of new airports. The development of budget airlines is also changing travel patterns in Europe very rapidly." (Ref: **CO_0023**)*
- *"For air travel there will be continuing amalgamations between long-haul carriers, whilst low-fare operators will continue to seek more secondary destinations. The increasing costs of fuels, security and airport charges may eventually slow the pace of growth." (Ref: **CO_0023**)*

*Expected increase in rail mode*

- *"For rail travel, government investment in new high speed lines will eventually bring lower prices, improving services and increasing speed." (Ref: **CO_0023**)*
- *"(...) for shorter trips, rail will become a significant competitor to air travel." (Ref: **CO_0023**)*

*Travels by coach and by cruises will probably have to face some constraint*

- *"For coach travel the main problem will be pressure on parking and access to city centres. Cheap air travel prices could also influence coach travel negatively." (Ref: **CO_0023**)*
- *"In the cruise market growing demand is being met by new and ever larger ships, but there is a lack of cruise terminals, especially in the Mediterranean. This is likely to lead to the development of more terminals as destinations strive to capitalise on market growth." (Ref: **CO_0023**)*

#### *1.2.5.2 Change of Lifestyle and Values*

**Driver description**

- *"Lifestyle concepts have been drawn upon for many years to explain and differentiate between social actions in various need areas – e.g. via target group concepts, which are common practice in the consumption and food sectors, as well as in the field of mobility and tourism." (Ref: **CO_5006**)*
- *"Mobility patterns are also being affected by changing values and attitudes." (Ref: **CO_1023**)*
- *"Non-work related mobility (leisure, culture, consumption, education) has increased, while home-working has developed and will continue to do so." (Ref: **CO_1023**)*
- *"It is difficult to make future estimates about tele-working. In 2050 it is likely that it will be difficult to distinguish "tele-workers" from "nonteleworkers", since most people will be "part-time tele-workers." (...) But they will still do some face-to-face work due to human relationship needs, which are fundamental in business." (Ref: **CO_5048**)*
- *"In light of economic globalisation and of the intensification of information flows, international experience is becoming an increasingly common phenomenon in the life of Europeans, affecting lifestyles, consumption patterns and basic values." (Ref: **CO_1023**)*
- *"The decreasing price of air fares has encouraged long-distance leisure mobility though rises in energy prices could significantly impact this sector in future." (Ref: **CO_1023**)*
- *"The spread of air travel has drastically changed the way in which Europeans conduct business, visit family and friends, and spend their holidays." (Ref: **CO_5031**)*
- *"Long holidays have largely been replaced by more frequent "mini-breaks" and shorter holidays." (Ref: **CO_1023**)*
- *"Highly-qualified young members of the working population, in particular, manifest a high degree of professional mobility that goes hand in hand with a high level of residential mobility and travel. The consequence of this is that social networks such as families and friendships are cultivated over long distances inside and outside Europe (Global Locals), so that coping with mobility by its very nature turns into a lifestyle in its own right (Durrschmitt, 2002; Petzold, in print; Reuschke, 2009)." (Ref: **CO_5006**)*
- *"In view of contemporary attitudes to time and speed, we can expect transport users to demand high levels of mobility and prioritise high-speed modes of transport." (Ref: **CO_2041**)*
- *"Many younger people are more excited about electronic equipment such as cellular telephones and computers than automobiles. The portion of 16 to 19 year olds licensed to drive declined from 71% in 1983 to 56% in 2007, in part due to increased vehicle costs and license requirements, but probably also due to waning interest." (Ref: **CO_5047**)*
- *"According to current surveys on traffic behaviour and global developments, a trend is emerging that could possibly replace the overall automotive concept adhered to by young adults (BMVBS/infas/DLR, 2009). In Germany, for instance, the proportion of 18 to 25- year-olds with a driving licence has decreased. This is an indication of changing mobility socialisations, above all in the case of young people growing up in conurbations with multioptional mobility systems (well-developed public transport system, car-sharing, NMT). Obtaining a driving licence as part of the initiation into adult society is being dispensed with, to be replaced by a multi-optional navigation capability within a mobile society." (Ref: **CO_5006**)*
- *"Consumer technology has shown a drastic change in the past few decades. (...) Home entertainment has also changed drastically; there is now a television set in virtually every home. More recently, video games, videocassette recorders, big-screen television sets, cable television, and a variety of home computers have been introduced into American homes. Concurrent with this, video rental outlets are mushrooming in suburban shopping centers. It seems as if ''home-based leisure'' (Maloney 1982) is replacing traditional out-of-home social recreation activities." (Ref: **CO_0196**)*
- *"Behavioural and technological strategies not only differ in the extent to which they may improve different sustainability aspects, but probably also in the extent to which they affect the quality of life of citizens. In general, people prefer technological solutions to behaviour changes, because the latter is perceived as more strongly reducing the freedom to move. (...) Behavioural changes*

*generally are associated with additional effort or decreased comfort. For example, reducing car use implies that we need to adjust our lifestyle, which may evoke (initial) resistance because it requires effort and reduces freedom, comfort and convenience." (Ref: **CO_0042**)*

- *"This discussion of the many changes that are pertinent to travel behaviour indicates that future effort must focus on understanding and predicting the direction and magnitude of behavioural changes." (Ref: **CO_0196**)*

## Interactions within the Social Domain

### *Migration flows*

- *"Alongside traditional migration and mobility, new forms of mobility are taking place. People are moving abroad for shorter periods, mainly to other Member States, to seek work, pursue their education or other life opportunities. These mobile people tend to be well-educated young adults, towards the higher end of the occupational scale. Increasingly, this form of mobility is based on personal preferences and life choices, and not only on economic opportunities." (Ref: **CO_0069**)*

### *Income structure and distribution*

- *"As people's incomes grow, their preference towards non‐essential travel (e.g. holidays), speed and comfort also increase, making aviation an attractive option (see Doganis, 1995)." (ref: **CO_5031**)*

### *Car ownership*

- *"Assuming that negative views of public transport prevail, the demand high levels of mobility and prioritise high-speed modes of transport can be expected to contribute to a continuing increase of the motorisation rate." (Ref: **CO_2041**)*
- *"There are already signs in some cities that the popularity of the car as a status symbol is declining, especially as congestion problems get worse and alternative status symbols (such as smart technology devices) emerge." (Ref: **CO_5018**)*
- *"It is difficult to measure consumer preferences, and more difficult to predict how they will change in the future, but there are many indicators that consumers' often-mentioned "love affair" with automobiles is losing its passion. This occurs, in part, simply because it would be difficult for automobiles to capture more affection, or a greater share of consumers' financial and time budgets, than occurred during the Twentieth Century." (Ref: **CO_5047**)*
- *"The impact of an emerging "sustainable consumption" culture on transport could be important. Car ownership could be affected most, with a move away from owning a car being seen as a status symbol and the only provider of "mobility freedom", particularly for the younger generation." (Ref: **CO_5048**)*

### *Urbanisation*

- *"Lifestyle perceptions of city or rural quality of life, leisure and tourism, also affect the trends of peri-urbanisation." (Ref: **CO_0097**)*
- *"In contrast to the apparent attractions of the suburbs, the many negative aspects of the inner city cores, including poor environment, social problems and safety issues, create powerful drivers of urban sprawl. City cores are perceived by many as more polluted, noisy and unsafe than the suburbs. The built-up environment is also considered unattractive because of poor urban planning, with areas lacking green open space and sports facilities." (Ref: **CO_0028**)*
- *"A survey sponsored by the National Association of Realtors and Smart Growth America found that consumers value a shorter commute time and having sidewalks and places to walk in their neighborhood. Among people planning to buy a home in the next three years, 87% place a high importance on a shorter commute as their top priority." (Ref: **CO_5047**)*
- *"(...) most households want to own an automobile and many want a large-lot suburban home. But demand for these seems to be declining somewhat, while demand for more multi-modal, urban lifestyles is likely to grow." (Ref: **CO_5047**)*
- *"Urban living is now "cool," and increasingly popular with the middle-class, including younger and retired people." (Ref: **CO_5047**)*

- *"Spatially, the new forms of work primarily affect densely populated areas. As a result of overlay effects – especially between flexible working and opening hours – the spatial impacts are greater on specific densely populated areas in urban centres and agglomerations than across the entire region. Over the long term, many of the new forms of work will actually be able to support these spatiotemporal changes thanks to the acceptance by commuters of longer distances between home and work locations." (Ref: **CO_0009**)*

*Planning*

- *"There is also a need to better understand people's behaviour in order to adjust the transport system to their true mobility needs – after all, policies implemented today will determine the design of cities for many decades." (Ref: **CO_5019**)*
- *"Not enough distinction is made between users on the basis of their different orientations, needs and demands. Instead they are treated as a homogeneous group. On the one hand, with the findings available it is possible to identify and address target groups for different services of sustainable transport. On the other hand, emission profiles can be calculated for these groups, thus identifying the groups who contribute to a greater or lesser degree to GHG emissions and who could therefore be targeted by incentives or restrictions. The approach of the TRANSvisions study points in the right direction in this respect (TRANSvisions, 2009)." (Ref: **CO_5006**)*
- *"Demand for speed is far from saturation, but speed has a social price and needs space. This immature behaviour will collide with or at least will be smoothed out by eco-mobility and relaxed attitudes, leading to new urban planning mix." (Ref: **CO_5005**)*
- *"A heightened appreciation of environmental values is likely to require the future development of public transport as well. In a fragmented community structure, however, all alternative for development of public transport systems are costly ventures." (Ref: **CO_0004**)*

*Tourist flows*

- *"Besides the need for appropriate transport options to serve the everyday travel demand of an increasing share of leisure consumers in our cities, the most evident consequence of the growing leisure society, and availability of free-time, is the fast growth of tourism." (Ref: **CO_5048**)*
- *"The increased use of aviation for leisure trips is witnessed in some countries by the popularity of 'city breaks' over the weekend, stag/hen parties in Eastern European capitals, and workers flying back to meet parents over holiday seasons." (Ref: **CO_5031**)*

*Education*

- *"Trips made for school purposes typically constitute a small fraction of total transport demand. (...) However, the timing of school journeys is a reason for concern. School traffic flows often coincide with peak traffic flows, which can contribute to morning peak-time road congestion." (Ref: **CO_5031**)*
- *"Concerning Education based travel effects on transport demand, trends across Europe indicate an increase in journeys to school by car caused for instance by concerns over children's safety and security, adults' travel behaviours and household income." (Ref: **CO_5031**)*
- *"(...) habits children develop in their youths may affect how they choose to travel later in their lives. For example those who are accustomed to the car are unlikely to change modes in their adult lives (Cairns et al., 2004b)." (Ref: **CO_5031**)*
- *"Likewise, children who are accustomed to cycling, walking or using public transport are more likely to continue to do so in the future." (Ref: **CO_5031**)*

*Health*

- *"The decreasing numbers of children walking or cycling can have a serious impact on their physical health and mental well-being. Furthermore there is a potential reduction in children's ability to socialize on the way to school whilst getting adequate daily exercise. It is widely known that falling levels of exercise can contribute to growing levels of obesity in children and young adults." (Ref: **CO_5031**)*

- *“Walking and cycling have great potential to contribute to more sustainable and healthy cities. Active mobility brings physical and mental health benefits that largely outweigh possible increased exposure to pollution or safety risks.” (Ref: **CO_5019**)*

## Interactions with the Economy Domain

### *GDP trends*

- *“Demand for speed is directly linked to GDP and individual welfare and is far from saturation (Thisse, 2009).” This is due to increasing value of time: we want to do more things (especially with our free time) in a day that still has 24 hours.” (Ref: **CO_5005**)*

### *Employment*

- *“In contemporary societies we can observe a trend towards the flexibilisation of labour. This is evidenced by the increase of part-time work as well as telework, the introduction of flexible working times in several economic sectors but also the increase of unemployment and the reduction of job stability. Life-long and full employment are no longer considered realistic goals among political elites and the social policy community. At the same time there is a steady increase of the employment moratorium period in young age due to longer education and training periods in conjunction with stagnating labour market demand.” (Ref: **CO_2041**)*
- *“Working hours have become more flexible, work locations are changed more frequently, the proportion of part-time employees is increasing and new technologies have led to the development of new forms of work such as telecommuting, video conferences and remote maintenance. These behavioural trends and their traffic impacts have been analysed in various studies, allowing for an assessment of their affects and general planning directives.” (Ref: **CO_0009**)*
- *“Part-time work is a widespread form of employment in Nordic countries and in the UK and Germany, whereas it is rare in the southern European and candidate countries.” (Ref: **CO_0083**)*

### *Regional differences in economics*

- *“(...) economic development is an important driver for value change, but that cultural (religious) heritage leaves a permanent imprint.” (Ref: **CO_0114**)*
- *“(...) cultural differences (while still present) are loosing their previous importance as a driving force for regional development, giving way to more market-oriented globally unified regional patterns.” (Ref: **CO_0222**)*

### *Energy availability and prices*

- *“People’s lifestyle choices, such as opting for virtual services instead of travel, could directly affect energy demand levels in cities too.” (Ref: **CO_5018**)*

## Interactions with the Environment Domain

### *GHG mitigation*

- *“Almost everything we produce and consume means GHG emissions today, because we do not use much renewable energy or live very sustainably. Much of what we use may arrive with superfluous packaging itself a problem to dispose of, a waste of energy and a source of emissions.” (Ref: **CO_0091**)*

### *Pollution levels and emissions standards*

- *“Various strategies have been proposed to arrive at a more sustainable transport system. In general, a distinction can be made between behavioural and technological changes. Behavioural changes are aimed to reduce the level of car use, e.g. by shifting to less polluting modes of transport, changing destination choices, combining trips, or travelling less. Such strategies may improve environmental quality, urban quality of life, and destination accessibility.” (Ref: **CO_0042**)*

### *Scarce resources of fossil fuels*

- *“There were more than 6.6 thousand million people in the world in early 2008, and the UN Population fund expects the total to reach about 9 thousand million before it starts to decline. Add to that a growing global appetite for consumer goods, and it becomes clear that unless we disconnect consumption and growing standards of living from the use of natural resources, we* *shall soon run short of many essential resources – minerals, like uranium, copper and gold, for example." (Ref:* ***CO_0091****)*

*Energy availability, production and consumption*

- *"Transportation patterns and technology choices also require a balanced approach that recognises both the human and technological dimensions of energy consumption. From vehicle choices to decisions about amounts and modes of travel, human behaviour significantly influences levels of energy demand in the transportation sector." (Ref:* ***CO_0154****)*

## Interactions with the Technology Domain

*Technology development in general and innovation diffusion*

- *"Other digital media such as those for telephony, photography, video and music are used by larger sections of the population. The motivation to work with digital media has sharply risen in recent years. In most European countries all parts of the population, from young to old, and from low to high educated want to participate." (Ref:* ***CO_2018****)*
- *"The phenomena of computer anxiety and computer hatred have diminished." (Ref:* ***CO_2018****)*
- *"User behaviour plays a determining role in the success or failure of new technologies. Users, apart from 'early adopters', are often unwilling to change their customary way of travelling and transporting goods, whereas the uptake of new technologies might require modifying deep-rooted habits." (Ref:* ***CO_0089****)*

*Information systems*

- *"Rapid advances are being made in telecommunications technology. New telecommunications capabilities now available offer the potential of replacing certain shopping and personal business trips. Through the use of home computers or television sets, consumers can shop electronically for an increasing variety of goods and services." (Ref:* ***CO_0196****)*

*Booking and payment systems*

- *"(...) the emergence of smartcard ticketing is symptomatic of a global trend toward cashless transactions. Driving this shift, major credit card companies such as Visa and MasterCard are embedding smart chips in cards that enable them to perform the functions of a public transport ticket as well as regular functions. This concept has also been extended to mobile phone technology, with the availability of applications for smartphones that enable the phone itself to perform ticketing and card payment functions." (Ref:* ***CO_0290****)*

*Pollution abatement and monitoring*

- *"As a result of these often marginal effects of new abatement technologies, the potential for behavioural change to promote further emissions reductions through reduced demand is becoming more important." (Ref:* ***CO_0276****)*

*Energy efficiency*

- *"Although energy efficiency improvements are expected to continue to reduce energy intensity in the future, the size and speed of such savings will depend on several behavioural factors including patterns of technology adoption, maintenance and use." (Ref:* ***CO_0154****)*
- *"(…) the 'social efficiency' of energy use (…) is the effectiveness with which a given amount of energy is used to satisfy human needs. We have appropriated the term 'social efficiency', because the more common term 'energy conservation' usually includes reductions through both technical efficiency gains as well as less use of energy-using devices." (Ref:* ***CO_0044****)*
- *"Consumer choices lie at the heart of the well-known gap between potential and actual levels of energy efficiency. These choices often reflect a significant disconnect between consumer attitudes and behaviours. To address this, policy makers need a better understanding of the dimensions of consumer behaviour and energy use." (Ref:* ***CO_0154****)*
- *"(…) there has been a consumer revolution in recent years, thanks in part to initiatives such as the EU labelling scheme to show us just how much energy our appliances consume. A recent survey indicated that as many as 85 % of consumers now consider energy consumption a more important criterion than price, when they purchase white goods." (Ref:* ***CO_0269****)*

- *"From vehicle choices to decisions about amounts and modes of travel, human behaviour significantly influences levels of energy demand in the transportation sector. Transportation policies that reflect people's behaviour can enable better vehicle choices, help induce modal shifts from less efficient to more efficient modes of travel, encourage constraint in the number of vehicle kilometres (km) travelled, and help reshape driving habits in ways that will reduce fuel consumption and carbon emissions." (Ref: **CO_0154**)*

## Impacts on Mobility and Transport

*The clear impact of changing lifestyles on overall travel demand is not so easy to assess…*

- *"Numerous elements in the travel environment change continuously. New consumer products appearing constantly on the market greatly reduce the time spent in homemaking; home entertainment equipment is enriching in-home leisure activities; institutional and technological changes are transforming the way urban residents work, and social attitudes and values are evolving. How these changes will transform life-style and affect travel demand is difficult to assess at this point." (Ref: **CO_0196**)*
- *"The potential of telecommuting in relieving traffic congestion, reducing energy consumption, mitigating air pollution, and saving infrastructure construction and maintenance costs remains to be determined. Unfortunately, assessments of the impact of telecommunications technology on life-style, residential location, and travel demand tend to be educated guesses." (Ref: **CO_0196**)*
- *"One critical difficulty is the lack of data that can support the effort to determine whether in-home activities may substitute for out-of-home activities, whether out-of-home activities will be suppressed, or whether new out-of-home activities will be induced as a result of new telecommunications technology." (Ref: **CO_0196**)*

*…though an increasing demand for air transport shall be expected*

- *"Social-demographic changes, such as the increased movement of people across Europe, also have a large effect on air travel. Furthermore, cultural factors such as image and status of flying, and environmental consciousness are likely to impact on demand." (Ref: **CO_5031**)*
- *"For leisure travel, as Tol (2006) suggests, most people would see a foreign holiday in a different light to a domestic one and hence the two would not be completely substitutable." (Ref: **CO_5031**)*

*"Virtual" mobility will develop…*

- *Teleworking and video conferencing has been hailed as a solution to mobility (...) since the 1980s; (...). This is another forecasting mistake that did not consider human behaviour and psychology. People still need to interact personally (face-to-face meetings and interaction foster confidence, a key point in business) and want to leave home to differentiate work from private life. (Ref: **CO_5005**)*
- *"Not all employees want to telework or have suitable home conditions." (Ref: **CO_5047**)*
- *"However, future generations may have a different set of mobility preferences. Today's children will have grown up with immersive networking technology, and are likely to be much more comfortable spending time in virtual spaces." (Ref: **CO_5018**)*

*…even though global time spent on mobility will probably remain unchanged*

- *"OECD carried out an analysis in 2002 based on travel surveys over a long span of time and in many different countries. The results showed that there is robust evidence that the daily amount of time spent on travelling has only slightly changed over time. (...) the average time budget is around 1.1 hour a day: importantly, this does not depend on income level or historic period." (Ref: **CO_5048**)*

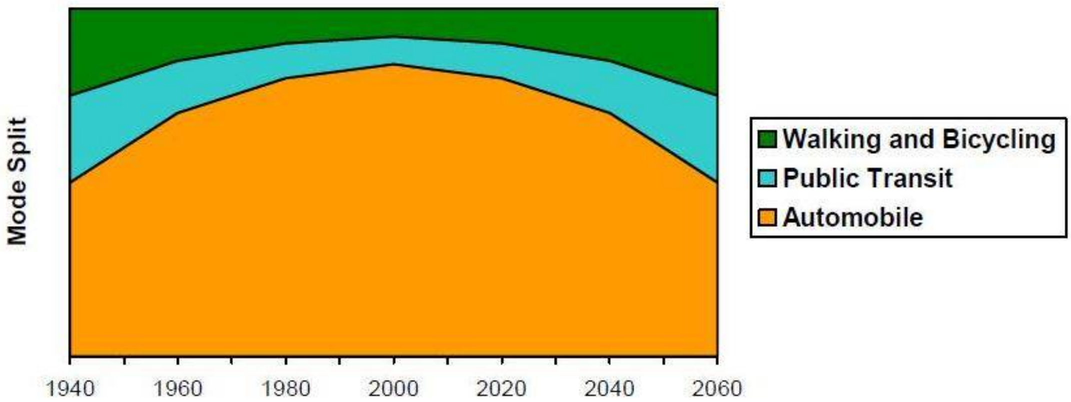
*As far as transport modes are concerned, there will probably be an increase in demand for the fast ones*

- *"Since some leisure service consumption takes place outside private homes, the need for appropriate transport possibilities, including public transport services, is increasing." (Ref: **CO_5048**)*
- *"Most people 'want to get there as fast as possible', regardless of the destination." (Ref: **CO_5005**)*

- *With regard to mobility preferences, European citizens prioritise high-speed and subsequently high-speed travel. This is evidenced, among others, by car manufacturing. Another indicator of preference for speed is the success of high-speed trains (HST). (Ref: **CO_5048**)*

#### *Increasing acceptability of alternative transport modes*

- *"During the Twentieth Century, walking, cycling and riding public transit travel were stigmatized, but in recent years alternative modes have become more socially acceptable. For example, bicycle commuting is increasingly accepted and even prestigious. Transit travel is also increasingly accepted as urban living becomes more popular and where service is upgraded." (Ref: **CO_5047**)*
- *"Car-sharing will occupy a growing market share in some urban areas, slowing the growth of car travel and possibly reducing urban vehicle stocks." (Ref: **CO_0284**)*
- *"Although automobiles are expected to be the dominant mode in the future, with the largest mode share and mileage, alternative modes growth rates are expected to be large, since they start with such small percentages." (Ref: **CO_5047**)*




Source: The Future Isnt What It Used To Be. Changing Trends And Their Implications For Transport Planning (Ref: **CO_5047**)

**Figure 1-27 Urbanisation impact on mode split**

- *"Society as a whole needs to change its approach to understanding transport issues. Being mobile does not necessarily mean having two cars for every household. Many urban young have grown up much less car dependent and much more reliant on public transport than their parents, seeing the car as something to hire or share when needed rather than owned and used habitually regardless of trip purpose." (Ref: **CO_0284**)*

#### *Emerging mobility patterns with new temporal distribution*

- *"A factor common to all new forms of work is increased flexibility. Individual transport offers greater advantages than public transport in this respect. With regard to choice of transport mode or future services, therefore, public and combined transport faces a major challenge in preventing the loss of market share to individual transport." (Ref: **CO_0009**)*
- *"The labour market situation and especially the flexibilisation of labour will affect mobility patterns by challenging the nine-to-five work and delivery day and the peak congestion hours associated with this. Even though this could alleviate the strain on transport networks in periods of economic stagnation, in periods of economic growth it could also lead to a deterioration of the situation." (Ref: **CO_2041**)*
- *"The SVI_2001_515 project showed that the influence of new forms of work on transport is substantial, not so much because of the total traffic volumes but rather in view of their spatiotemporal distribution." (Ref: **CO_0009**)*
- *"They mainly extend the morning and evening peak hours. However, they are more likely to extend the capacity limits rather than alleviate them in any absolute sense (taking into consideration a further general increase in transport volume). In general, there is more pressure on late-evening and (secondary) weekend traffic." (Ref: **CO_0009**)*

#### *1.2.5.3 Education*

**Driver description**

- *"Better education reduces risk of poverty, eases participation in the labour market and is key to economic growth" (Ref: **CO_0197**)*
- *"In the EU, the share of adults of working age with at most lower secondary education declined between 2000 and 2010, improving possibilities for personal and professional development." (Ref: **CO_0197**)*
- *"The prevalence of low educational attainment[15] in the EU differs between age groups. In 2000, 35.6 % of 25 to 64-year-olds had at most lower secondary education; ten years later their share declined to 27.3 %. The respective shares for people aged 65 and over were higher and amounted to 59.9 % in 2010. In both age groups the percentages have steadily fallen. The relative decline was greater for the 25 to 64-year-olds than for the over-65s." (Ref: **CO_0197**)*
- *"Reasons for this favourable trend include intensified training of adults and, above all, the presence of a cohort effect: younger people, especially younger women, tend to have better education, and as they grow older the prevalence of low educational attainment in a given age group declines." (Ref: **CO_0197**)*
- *"In all the IPROSEC countries, the proportion of young people aged 15–24 in education or training has increased over the past 20 years. In general, Nordic countries register the highest proportion of young people in education or training, whereas the figures are lower in the southern European countries. The percentage of women aged 15–24 in education or training exceeds that of men in all EU IPROSEC countries, except in Germany (...) .This was not the case in the 1960s and 1970s. In 2000, the proportion varied from 53.6% in Italy to 69.7% in Germany for men, and from 58.3 % in Italy to 70.4 % in Sweden for women. The gap between men and women is particularly large in Spain (+ 7.6) in Sweden (+5.4) and Italy (+4.7), in favour of women. Everywhere except Germany, women exceed the number of men in higher education. The largest difference is found in Estonia, Sweden and Poland." (Ref: **CO_0083**)*

**Interactions within the Social Domain**

***Migration flows***

- *"Within countries, education attainment continues to determine who moves and who does not—certainly from rural areas to cities. People with more education are more likely to migrate in their own country. Many temporary, seasonal migrants with little or no education also migrate. But education boosts the velocity of labour mobility, by opening employment opportunities farther afield and shortening the job search at migrants' destination." (Ref: **CO_5028**)*
- *"Education also increases the likelihood of people moving abroad. The international migration of skilled workers relative to that of unskilled workers has been rising since the 1970s for every developing world region." (Ref: **CO_5028**)*
- *"Student migration has become particularly important in some parts of the EU, with generally young adults migrating to take part in university courses and other educational opportunities. Although student migration may be seen as essentially temporary in nature, significant numbers remain within the destination country after the end of their studies either as labour migrants or following family formation with a person resident in the destination country." (Ref: **CO_0066**)*

***Income structure and distribution***

- *"Moving towards a knowledge intensive society in the global economy is associated with increasing economic growth, economic integration and major economic restructuring. In mature European economies there has been a shift from manufacturing, which provided relatively well paid and regular employment for people with medium levels of skills, to services, where employment is more polarised between highly paid professional and managerial work and more routine manual service work." (Ref: **CO_5026**)*

[15] The indicator defines the percentage of the population having reached UNESCO's International Standard Classification of Education (ISCED) level of 2 or less (lower secondary education at most). (Ref: **CO_0917**)

- *"Economic restructuring, innovation and a highly educated and well trained workforce are critical to the development of a competitive, smart, knowledge economy ("Europe 2020") but these economic, employment and educational changes are associated with wage polarisation, primarily due to the expansion of earnings at the top of the distribution relative to those lower down and the inability of labour (especially lower paid labour) to capture an adequate share of productivity gains as findings from INEQ, RESIST, LoWER3 and EQUALSOC show." (Ref: **CO_5026**)*

*Change of lifestyle and values*

- *"Education for both children and adults regarding the causes and effects of climate change may change behaviour to a certain extent, as witnessed in the increasing popularity of fair-trade and 'green' products, and carbon-offsetting schemes." (Ref: **CO_5031**)*

## Interactions with the Economy Domain

*Employment*

- *"Employment rates rise everywhere with the level of education (...). The employment rate for women aged 25–49 with higher education ranged from 73.8% in Spain to 86.6% in the UK, where men with higher levels of education also have a higher level of employment. Employment rates are more dispersed for women with a lower education level (compulsory schooling): for women aged 25–49, they ranged from 40.5% in Spain to 63.5 % in Sweden in 2000." (Ref: **CO_0083**)*
- *"The employment rate is greater for those with higher education levels. Since 2000, more than four-fifths of 25 to 64 year olds with a tertiary-level educational qualification have been employed compared with less than half of those with lower secondary education. The relative employment rates for the different education subgroups have evolved in parallel over time. People with lower education levels were the most vulnerable to job losses, which may be explained by loss of jobs in sectors largely requiring lower qualification, e.g. the construction sectors of Spain, UK and Ireland. In 2009, the employment of people with completed primary and lower secondary education fell by 4.0 %, for those with upper and post-secondary education it fell by 2.1 %, and for those with tertiary education it fell by 1.2 %. The decreases in employment rate continued in 2010." (Ref: **CO_0197**)*
- *"Unemployment can be caused by other drivers of social exclusion such as ill-health, low educational attainment and lack of skills." (Ref: **CO_0176**)*

*Availability of public and private resources and investments in the transport sector*

- *"Mobility behaviour can be influenced through information and promotion campaigns which are aimed at developing sustainable mobility behaviour among the citizens without any additional infrastructure investment." (Ref: **CO_0199**)*

## Interactions with the Environment Domain

*GHG mitigation*

- *"Scientific knowledge has also been significant in the development of local inventories and forecasts of GHG emissions." (Ref: **CO_0147**)*
- *"Information instruments (e.g. awareness campaigns) may positively affect environmental quality by promoting informed choices and possibly contributing to behavioural change, however, their impact on emissions has not been measured yet." (Ref: **CO_0146**)*
- *"To achieve 60-80% GHG reductions in the transportation sector, a major research effort will be needed to overcome these limitations and to provide sound information that will help reduce transportation GHG. Research is needed to inform multiple audiences, at multiple levels, and for a wide range of GHG reduction strategies." (Ref: **CO_0149**)*

## Interactions with the Technology Domain

*Technology development in general and innovation diffusion*

- *"Human resources are crucial both to the development and application of technology. Certainly, some inventions have been made by individuals with little education — but today the majority of inventions are made by those with substantial education in science or technology. The reduction of inventions to commercial application usually also requires skilled entrepreneurs and,* *depending on the particular field, skilled mechanics, lab technicians, or software writers." (Ref: **CO_2013**)*

- *"Apart from sporadic initiatives there are no signs of education to incorporate the real potentialof ICT." (Ref: **CO_2018**)*
- *"Consumer adoption of technology has been noted to occur in five stages—innovators, early adopters, early majority, late majority and laggards—which are generally differentiated on the basis of innovativeness, or "the degree to which an individual or other unit of adoption is relatively earlier in adopting new ideas than other members of a social system" (Rogers 1995). Influencing factors on this innovativeness may also include demographic characteristics (including age and education) and prior experience with technology (Munnukka 2007)." (Ref: **CO_0164**)*
- *"(...) there are significant divides between people with different levels of education, employment status, age and ethnic minority membership." (Ref: **CO_2018**)*
- *"Most research of digital media access, that often deals with the so-called digital divide shows that there is a strong correlation between access and personal or positional characteristics of people. Primarily education, age and societal position appear to be important. People that need ICT for their work or education have a much higher chance of having physical access." (Ref: **CO_2018**)*
- *"The biggest access problems are now a lack of digital skills and very unequal use, both in time and in type of applications. Four types of digital skills can be distinguished. First we have operational skills; the popular expression is 'button knowledge'. Then we have formal skills. Every medium has particular formal characteristics. Regarding the internet one has to learn to browse and to navigate using hyperlinks. The third type of skill is information skills: the ability to search, select and evaluate information in computers and on the Net. The last type of (so-called 'higher') digital skills is strategic skills: using computers and the Internet as a means to reach a particular personal or professional goal. Information and strategic skills appear to cause the biggest problems. Only a minority of Internet users master them sufficiently." (Ref: **CO_2018**)*
- *"Rising levels of education together with increased per capita incomes in many parts of the world mean that demand for new products is growing, leading to shorter product innovation cycles." (Ref: **CO_0274**)*
- *"Social media is used mostly by a young generation, at an age where they would move from public to private transport. Therefore, any tool which directly targets this (difficult to reach) market should be maximised in order to connect with this crucial group of future customers." (Ref: **CO_0290**)*

#### Information systems

- *"What kind of traveller is relatively prone to acquire information? The literature states that male, highly educated, high-income travellers (e.g. Petrella and Lappin, 2004) are more likely than others to use travel information, as well as professionals (Emmerink et al., 1996), as groups these appear to attach greater importance to making an accurate choice (Hato et al., 1999)(...) Regarding the awareness of ATIS services (Goulias et al., 2004), it was found that professionals in general, higher income and younger persons are more likely to be aware of all kinds of ATIS, as are car owners and owners of a bus pass." (Ref: **CO_5038**)*

### Impacts on Mobility and Transport

#### Education concerning sustainable mobility is increasing in importance and diffusion

- *"Education, information and awareness-raising campaigns will play an important role in influencing future consumer behaviour and facilitating sustainable mobility choices. Transport policies have a very direct impact on people's lives and tend to be highly controversial: citizens should be given better information on the reasoning behind policy decisions and on the available alternatives. A better understanding of the challenges ahead is a precondition for public acceptance of the solutions." (Ref: **CO_0015**)*
- *"There are other factors that may help shift consumer preferences toward more multimodal transportation systems. For example, experts and individuals are increasingly concerned about the health impacts of a sedentary lifestyle. Market surveys indicate that consumers increasingly value opportunities to walk and bicycle in their communities." (Ref: **CO_5047**)*

*…but lack of data and proper campaigns are still hindering public transport modes' acceptability*

- *"Transport users, customers of equipment and even operators may not have the ability of making truly informed decisions for lack of relevant, correct and well presented data. Wrong perception or uncertainty may also influence decisions, as, for example, in the case of the overestimation of waiting times for public transport." (Ref: **CO_0089**)*

*There is an impending need to invest in education for future generations*

- *"<Children need our utmost attention when it comes to traffic. We need to adequately prepare them for a responsible integration with traffic.> Jan Mücke" (Ref: **CO_5019**)*

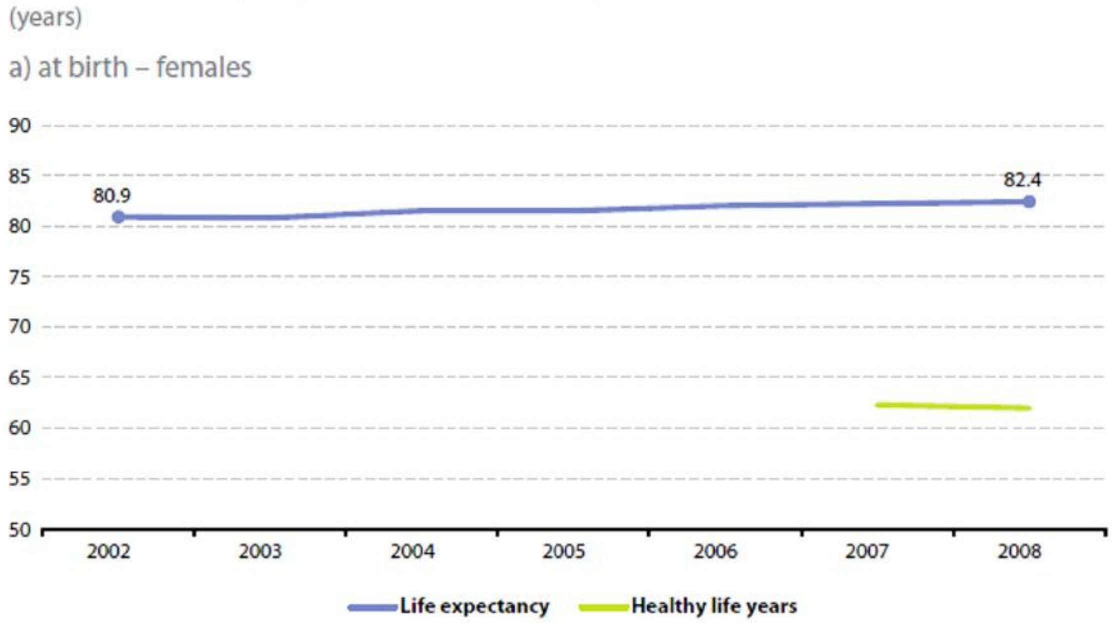
### 1.2.6 The Health Factor

- *"While the changes in the demographic structure of the population are relatively straightforward to analyse, based on the observed trends in fertility and mortality rates forecasting future evolution in the health status of a population is a considerably more challenging exercise especially given changes in morbidity and epidemiological variables are highly unpredictable." (Ref: **CO_2050**)*

#### *1.2.6.1 Health*

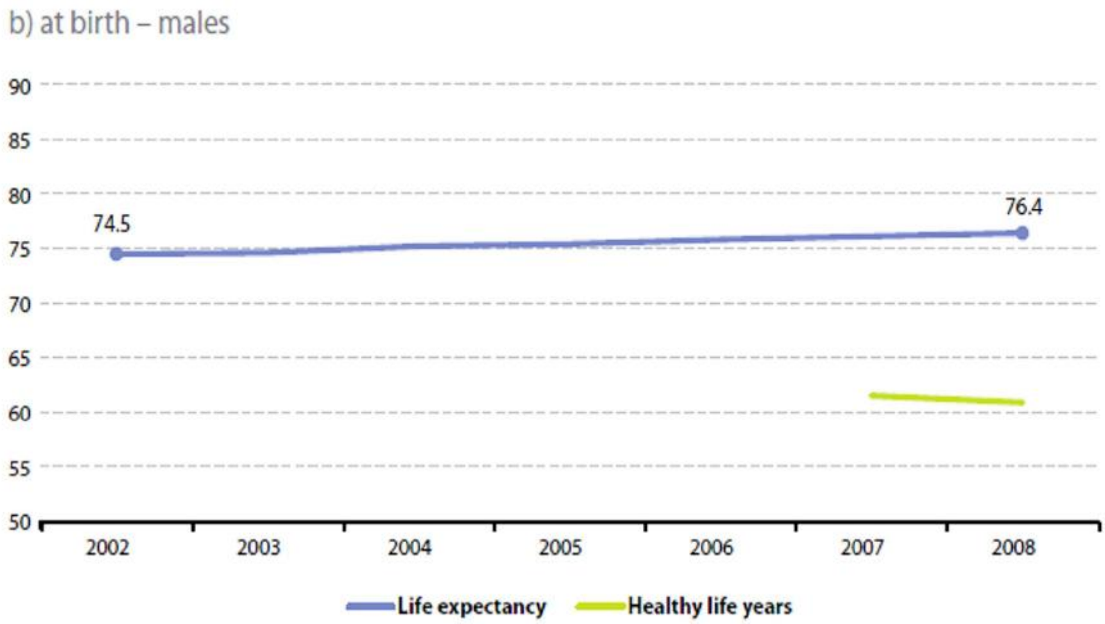
**Driver description**

- *"The society's state of health largely depends on health policy and the health system, especially health care resources, access to health care and financing. But health is also related to many other issues such as water supply and sanitation, road safety and safety of workplaces, income and education, air pollution, human settlements, etc." (Ref: **CO_0197**)*
- *"Improvements in life expectancy demonstrate that there has been progress in promoting a healthier and longer life for EU citizens. Life expectancy at birth for men and women grew by 4 and 3 months per year respectively between 2002 and 2008. It is also apparent that the life expectancy of men is catching up with that of women." (Ref: **CO_0197**)*
- *"However, this increase in life expectancy usually occurs at the detriment of people's health or "quality" of life. While the medical advancement is able to save human life from a growing number of diseases, it is not as apt at keeping people in good health, which thus very often means extending the time spent in chronic illness." (Ref: **CO_2050**)*
- *"While life expectancy constitutes a conventional and solid indicator to reflect general health and health care conditions in different countries, the indicator of healthy life years adds complementary information on the of quality of life." (Ref: **CO_0197**)*
- *"Healthy life years measures the number of years that a person is still expected to live in a healthy condition. It is compiled separately for males and females, (...) A healthy condition is defined by the absence of limitations in functioning/ disability." (Ref: **CO_0197**)*




Source: Sustainable development in the European Union (Ref: **CO_0197**)

**Figure 1-28 Healthy life years and life expectancy, EU-27, females**




Source: Sustainable development in the European Union (Ref: **CO_0197**)

**Figure 1-29 Healthy life years and life expectancy, EU-27, males**

- *"Road traffic has become the leading killer of young people worldwide. Almost 1.3 million people die each year on the world's roads, between 20 and 50 million are severely injured." (Ref: **CO_5019**)*

## Interactions within the Social Domain

### *Population ageing*

- *"The researchers are almost unanimous in stating that life expectancy is constantly increasing over time all over the world due to falling mortality rates in all age cohorts and constantly growing ability of medicine to save people's life. Both average life expectancy and maximum age are rising over time, increasing the share of elderly and the oldest old in total population." (Ref: **CO_2050**)*

### *Car ownership*

- *"International evidence suggests that health may continue to improve, but some causes of disability may at the same time become more prominent." (Ref: **CO_2050**)*

In an ageing population it can be expected that some causes of disability may become more prominent and thus reducing the ability to drive with a consequent impact on future car ownership rates.

### *Gender roles*

- *"Life expectancy at birth is six years higher for women than men, but the gap is closing." (Ref: **CO_0197**)*
- *"Deaths due to chronic diseases are almost twice as common in the EU for men than for women, but the gap has slowly narrowed between 2000 and 2008 (average annual declines: men 2.3 %, women 1.7 %)." (Ref: **CO_0197**)*

### *Tourist flows*

The same consideration expressed for car ownership applies for tourist flows: it is often mentioned in current literature that future elderly will be more active traveller than their predecessor. Nevertheless it can be considered possible only in case of healthy condition.

### Interactions with the Economy Domain

*GDP trends*

- *"Good health is the foundation of human welfare and productivity and is hence essential for sustainable development. Healthy people represent added value for the economy and the society since they are more productive and can contribute to cohesive ways of living together in the society. Sustainable development cannot be ensured in societies marked by widespread disease." (Ref: **CO_0197**)*
- *"Two recent economic studies (Muller and Mendelsohn, 2007; World Bank, 2007) estimated the total health costs of selected environmental risk factors in the US and China, respectively. These analyses suggest that health damage associated with air and water pollution represents a significant share of GDP." (Ref: **CO_5009**)*

*Employment*

- *"Growing life expectancy reflects improved living conditions in the EU in terms of economic welfare, social security and health care resources. Nevertheless, there are differences between Member States. Some of the Central and Eastern European Member States tend to have shorter life expectancies mostly due to poorer socio-economic conditions in these countries, especially higher unemployment rates." (Ref: **CO_0197**)*

*Regional differences in economics*

- *"The proportion of environment-related diseases in non-OECD countries is higher (24%) than in high income OECD countries (14%)[16]." (Ref: **CO_5009**)*

*Availability of public and private resources and investments in the transport sector*

- *"Improving environmental conditions upstream, in order to prevent downstream environment-related health outcomes, is often cost-efficient." (Ref: **CO_5009**)*

### Interactions with the Environment Domain

No particularly relevant interrelationships have been found.

### Interactions with the Technology Domain

*Technology development in general and innovation diffusion*

- *"Health-on-the-web encompasses the wide variety of formal and informal online health-related services and activities that have emerged in recent years. (...) Data from Eurostat shows that usage of the Internet by the general population for health related purposes has been growing steadily in Europe over the past number of years." (Ref: **CO_2018**)*

### Impacts on Mobility and Transport

The impact of health on mobility lies in the possibility of individuals to maintain their self-sufficiency in satisfying their mobility needs. In an ageing population an increase in life expectancy with generally good health condition, but also with reduced personal abilities, can be expected. This evidence could at first reduce elderly population's propensity towards the personal transport mode given the reduced ability to drive and in a second stage lead to the reduction of overall personal mobility due to physical diseases.

Private vehicles are increasingly equipped with safety equipments: preventing accidents but also limiting their negative impacts when they occur are most important targets of road-safety policy and one of the major challenges for vehicle manufacturers. The reduction of injured persons and of the entity of personal damages (i.e. permanent or temporary disability) can have considerably benefits on the overall health and social-care expenditures of a country.

[16] The definition of "environment" used in this WHO (World Health Organisation) survey was quite broad, and includes many risk factors not commonly referred to as "environmental", such as injuries (e.g. burns, poisoning, falls, etc.), physical inactivity, sexually transmitted diseases, etc.

## 1.3 THE ECONOMY DOMAIN

### 1.3.1 Economy Domain Key Factors and Drivers

Economic activities are underlying in all societies, and multiple connections exist with all the other domains considered in this project.

Within this section, the relationships of the economic field have been investigated, checking a wide scope of drivers, through both scientific literature and documents issued by the most important economic institutions.

Nevertheless, some of the links identified have been changing since the economic downturn that began in 2008, due to the collapse of US private financial system. Thereafter, consequences spread worldwide and the role governments have been playing until then has changed, as public resources have been diverted to balance negative effects. Moreover, forecasts about the evolution of the economic cycle are even more complicated today through the budget crises of countries belonging to the Eurozone.

To fill the gap of the information found in the older literature, the project team put a thorough effort looking for other and more recent documents properly depicting the current scenarios; in such a sense, effort has been devoted to presenting how the links among variables have been modified, even though they are hard to disentangle, as straightforward clues of an economic recovery are not yet identifiable.

Variations of the growth rate (namely in terms of GDP) have effects on many of the drivers introduced (e.g. employment, investments, trade, energy consumption, etc.); on the other hand, this variable is influenced in different manners. How the population is structured and its size, the level of education, the scientific advancements, public and private investments are examples of drivers that may either support or slow down an economy, behaving as endogenous factors.

The purpose of this section is to analyse the role the economy plays as dependent variable belonging to a long chain of interconnected relationships, both upstream and downstream.

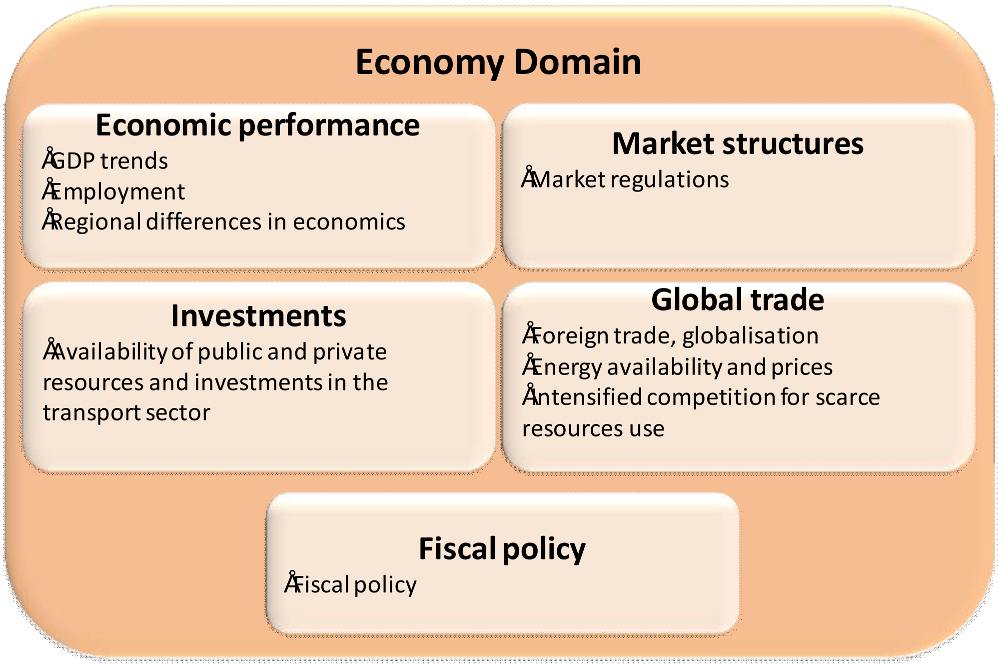


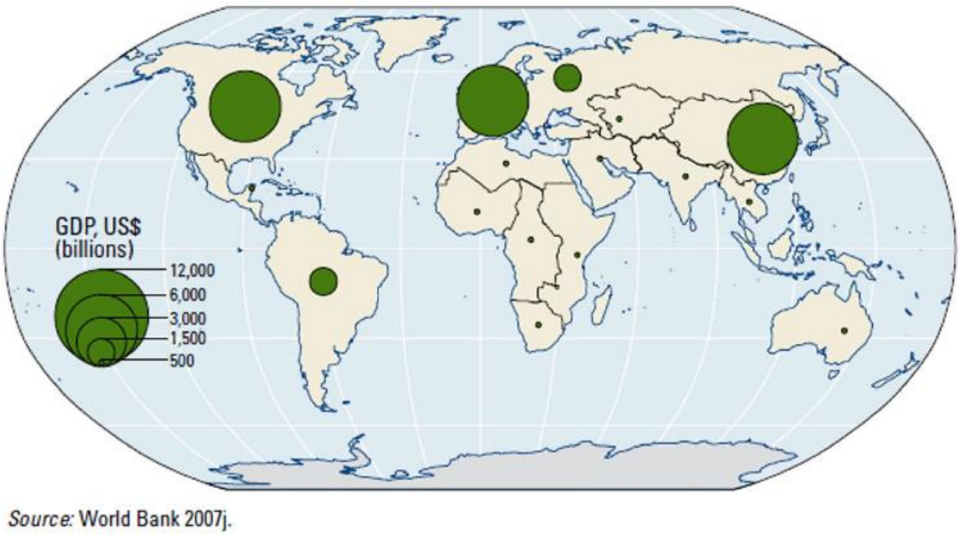

**Figure 1-30 Economy domain key factors and drivers**

### 1.3.2 The Economic Performance Factor

#### *1.3.2.1 GDP Trends*

**Driver description**

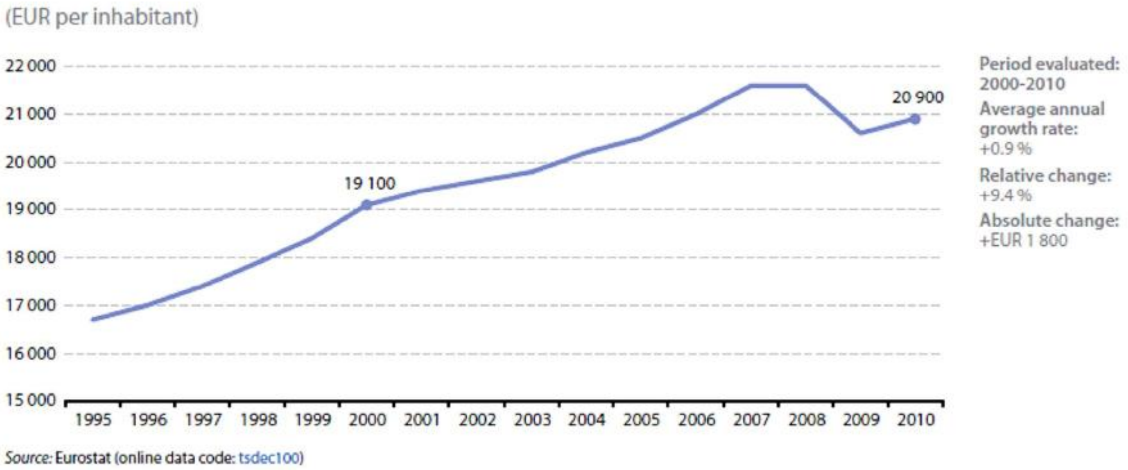
- *"The growth of GDP per capita is a measure of the dynamism of an economy and its capacity to create new jobs. It reflects the phases of the economic cycle." (Ref: **CO_0197**)*
- *"This indicator is a measure of economic activity, namely the value of an economy's total output of goods and services, less intermediate consumption, plus net taxes on products and imports, in a specified period. GDP can be broken down by output, expenditure or income components. The main expenditure aggregates that make up GDP are household final consumption, government final consumption, gross fixed capital formation, changes in inventories, and net exports, i.e. the difference between imports and exports of goods and services (including intra-EU trade)." (Ref: **CO_0197**)*
- *"The keys determinants of economic development are split into three groups:*
  - → *Economic governance: the degree of monetary stability, political rights and the level of democracy, the rule of law, the size of government (with large government restricting activity).*
  - → *Human capital: the level of education, health of the population and fertility rate.*
  - → *The starting level of income per capita." (Ref: **CO_2026**)*
- *"So, what drives economic growth? It is tempting to assume that growth is driven solely by investment and, therefore, ultimately by savings. But experience tells us that the quantity of investment will not determine economic growth in the long run. This is because production becomes increasingly capital intensive and adding even more capital often leads to less overall output. This will translate into low growth figures over time." (Ref: **CO_0178**)*
- *"For the past 50 years, by far the largest share of global economic activity has been concentrated in North America, Western Europe, and Northeast Asia (see picture below)." (Ref: **CO_5028**)*




Source: Reshaping Economic Geography (Ref: **CO_5028**)

**Figure 1-31 Global GDP is concentrated in a few world regions, 2006**

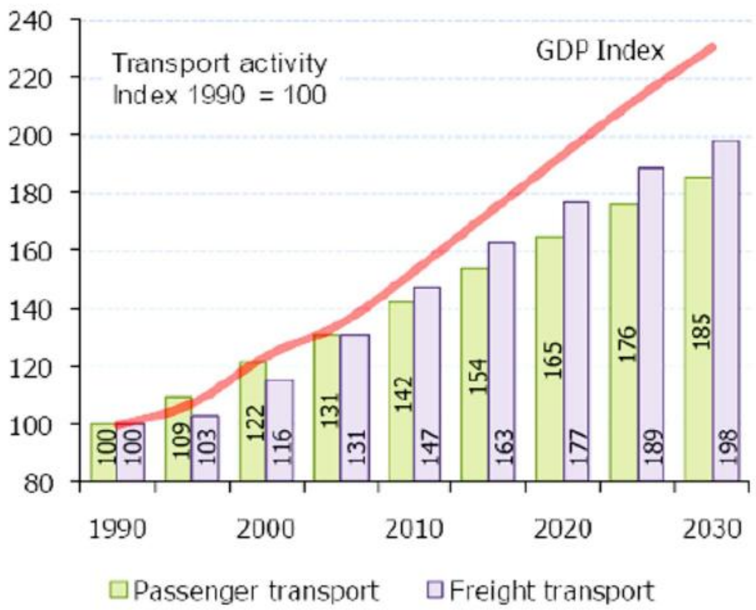
- *"[In Europe] After the economic peak of 2000, GDP per capita grew rather slowly during the economic downturn between 2000 and 2003. This was followed by a period of higher growth rates until 2007. However, with the onset of the crisis, GDP per capita grew by only 0.1 % in 2008 and fell by -4.6 % in 2009 down to a level similar to that of 2005. GDP per capita grew by 1.6 % in 2010, and short-term statistics show 2.2 % growth of GDP in the first quarter of 2011 as compared with the same quarter of the previous year, but only 1.7 % in the second quarter." (Ref: **CO_0197**)*




Source: Sustainable development in the European Union (Ref: **CO_0197**)

**Figure 1-32 Real GDP per capita, EU-27**

- *"Particularly affected by the crisis in terms of GDP per capita were Latvia (with the previous GDP per capita growth rate between 2000 and 2007 being 9.4 % on average), Estonia (8.8 %), Ireland (4.1 %), Lithuania (8.1 %) and Finland (3.2 %). However, some eastern European countries (in particular Poland, Bulgaria, Slovakia and Romania) were hit less severely, due in part to lower current account deficits and external debts at the start of the crisis, stricter banking policies, lower dependence on stock exchange performance and exports, more stable domestic demand and modest exchange rate depreciation (in Member States outside the Euro area). A moderate recovery began in 2010 for most EU countries, with the exception of Greece, Ireland, Latvia, Romania and Spain." (Ref: **CO_0197**)*
- *"We forecast that growth will remain weak, especially in Europe, and unemployment will remain high for some time." (Ref: **CO_0180**)*
- *"The euro area is still projected to go into a mild recession in 2012 as a result of the sovereign debt crisis and a general loss of confidence, the effects of bank deleveraging on the real economy, and the impact of fiscal consolidation in response to market pressures." (Ref: **CO_0180**)*
- *"Despite the recent economic crisis, it can be said that Europe is living in an age of unprecedented economic prosperity and material affluence." (Ref: **CO_0197**)*
- *"The (…) dithering by the European institutions to deal with the crisis (too little, too late) might lead to the default of a number of periphery states with unpredictable consequences on the global economy."* (*Ref:* ***CO_0300***)
- *"The European crisis appears as the nth 'this time is different' [Reinhart and Rogoff] episode of the financial liberalisation sequence cum fixed exchange rates, capital flows from the centre to the periphery, housing bubble, current account (CA) deficit and indebtedness, default."* (*Ref:* ***CO_0301***)
- *"The impact of economy on transport demand is a well-known phenomenon. GDP growth and trade relations are the key variables for predicting transport volume and assigning transport flows." (Ref: **CO_2041**)*




Source: Backcasting approach for sustainable mobility (Ref: **CO_1014**)

**Figure 1-33 Transport activity growth 1990-2030**

- *"Changes in the transport sector may induce changes in various other sectors, which in turn may affect sustainable development. For example, they may induce macro-economic changes (e.g., lower production values in transport, and higher production values in trade and industry), resulting in changes in GDP and employment levels." (Ref:* ***CO_0042****)*
- *"Uncontrolled economic growth is unsustainable on a finite planet. Governments should recognise the serious limitations of GDP as a measure of economic growth and complement it with measures of the five forms of capital, built (produced), natural, human, social and institutional/financial capital, i.e., a measure of wealth that integrates economic, social and environmental dimensions and is a better method for determining a country's productive potential." (Ref:* ***CO_0118****)*

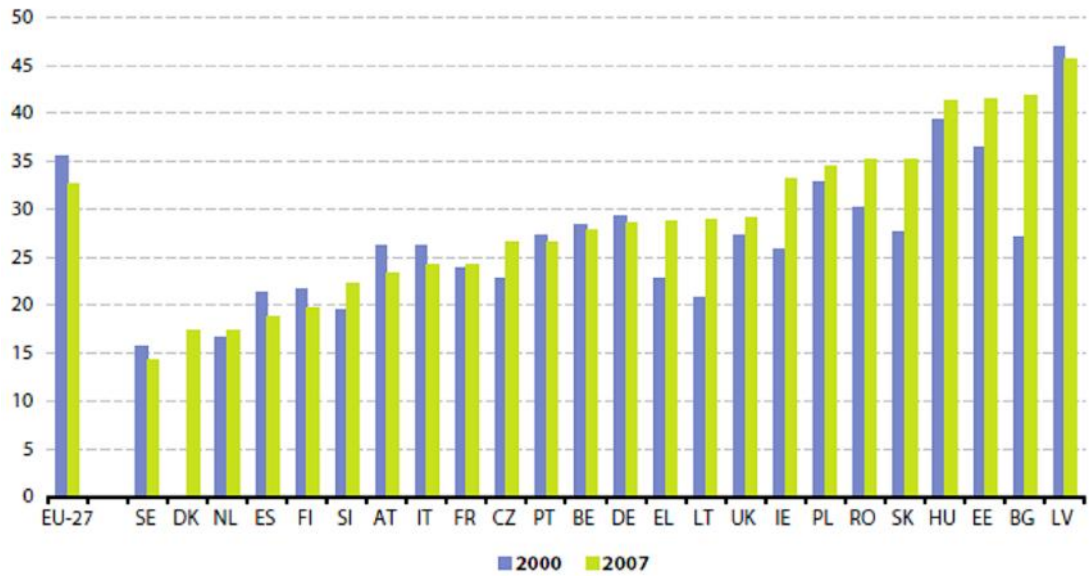
## Interactions within the Economy Domain

### *Employment*

Good economic performance is expected to influence positively the employment rate, as a GDP variation upturn stimulates the demand of production factors, namely capital and labour.

### *Regional differences in economics*

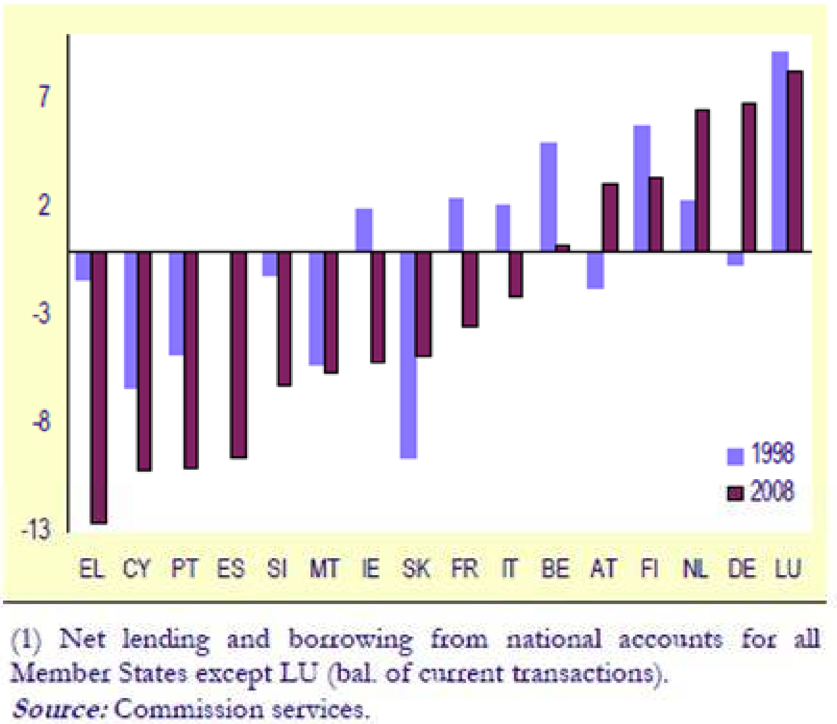
- *"Regional disparities in GDP in the EU fell from 35.5 % to 32.7 % during the period 2000 to 2007. Together with the reduction of regional disparities in employment it suggests a growing convergence of EU regions. Within-country dispersion of regional GDP remained high, in particular in eastern European Member States, where the rapid transition into market economies has led to an increasingly uneven distribution of wealth." (Ref:* ***CO_0197****)*
- *"In 2009, GDP per capita in the EU still varied widely between Member States. Among the countries with GDP per capita, in terms of purchasing power standards (PPS), higher than the EU average are Luxembourg (by 171 %), Ireland (by 27 %), Netherlands (by 31 %), Austria (by 24 %), Denmark (by 21 %) and Sweden (by 18 %). The countries with the lowest are Bulgaria (lower than the EU average by 56 %, Romania (by 54 %), Latvia (by 48 %) and Lithuania (by 45 %)." (Ref:* ***CO_0197****)*
- *"High dispersion rates of regional GDP not only indicate a high inequality in how populations of individual regions enjoy economic and social resources, but also that economically disadvantaged regions are more vulnerable to economic shocks." (Ref:* ***CO_0197****)*




Source: Sustainable development in the European Union (Ref: **CO_0197**)

**Figure 1-34 Dispersion of regional GDP per capita, by country**

- *"Over the period 1998 - 2007 (as a share of GDP) the worsening of the current account balance of the peripheral countries emerges pari passu with the improving surplus of the central countries."* (*Ref:* ***CO_0300***)




Source: Germany and the European and Global Crises (Ref: **CO_0300**)

**Figure 1-35 Current Account Positions, Euro-Area Member States (in % of GDP – 1999 to 2008)**

*Availability of public and private resources and investments in the transport sector*

- *"Balanced budget rules take the cynical view that all government debt is bad. This is also the view that governments are simply wasteful and do not contribute to the productivity of a nation. If one takes this view, then yes, a balanced budget rule makes sense. Such a view, however, is the expression of an economic fundamentalism that says that what governments do is bad, and what markets do is good." (Ref:* ***CO_0302****)*

*Fiscal policy*

- *"In the euro area, the fiscal withdrawal in 2012 is projected to amount to about 1½ percent of GDP, up from about 1 percent of GDP in 2011." (Ref: **CO_0180**)*

## Interactions with the Social Domain

*Migration flows*

- *"Net migration is determined by levels of economic development and migration policy." (Ref: **CO_2041**)*

*Income structure and distribution*

- *"GDP per capita, however, does not reflect the equality of distribution of that prosperity, so is not representative of many social issues. (...) GDP per capita cannot be used as a holistic measure of the well-being of individuals." (Ref: **CO_0197**)*
- *"Income per capita should grow in all the countries that we consider. But demographic patterns vary significantly across the world and have a major influence on growth prospects." (Ref: **CO_2026**)*
- *"Household income correlates strongly with GDP per capita and could be thought of as a proxy to the latter for the estimation of transport demand." (Ref: **CO 2041**)*

*Car ownership*

- *"Economic growth generates wealth, which individuals invest in cars, airline flights and travelling." (Ref: **CO_6006**)*
- *"Evidently, higher economic growth results in more vehicle ownership and increased traffic and freight movement, especially in eastern markets." (Ref: **CO_0159**)*
- *"Economic development has historically been strongly associated with an increase in the demand for transportation and particularly in the number of road vehicles (with at least 4 wheels, including cars, trucks, and buses). This relationship is also evident in the developing economies today." (Ref: **CO_2038**)*
- *"The increases in economic growth and population, mainly in non-OECD Europe and Russia, will be associated with an increase in vehicle ownership. In 2005, OECD Europe vehicle ownership stood at 424 cars/1,000 capita while that of Eastern Europe and Russia stood at 149 and 134 cars/1,000 capita, respectively. Through 2050, vehicle ownership for OECD Europe is expected to increase slightly, but will almost double for Russia and non-OECD Europe." (Ref: **CO_0159**)*

*Change of lifestyle and values*

- *"Economic development is behind social change. Economic development is the process in which the growing technical efficiency of provision for basic needs allows society to shift its time progressively towards production and consumption activities relating to more sophisticated needs. Cultural change, change in habits and beliefs and values, is an integral part of the process. The developing society does not just engage in new forms of production, but also in new sorts of consumption. Its members can do new things with their time, and different sorts of leisure emerge." (Ref: **CO_5048**)*

## Interactions with the Environment Domain

*Climate change impacts*

- *"There is a tension, however, between consumer demand generating freight and societal demands for environmental quality." (Ref: **CO_5009**)*
- *"Environmental outcomes are heavily influenced by the economy. The sheer scale of economic activity can lead to impacts on the environment that accumulate over time and can lead to large scale changes in the quality of the environment. Economic growth is thus an important determinant of the environmental outlook." (Ref: **CO_5009**)*

*GHG mitigation*

- *"The economic recession had a significant impact on the EU's total greenhouse gas (GHG) emission trends but a more limited effect on progress towards Kyoto targets. This is because emissions in the sectors covered by the EU Emissions Trading Scheme (ETS), which were most* *affected by the crisis, do not affect Kyoto compliance once ETS caps have been set." (Ref: **CO_0131**)*

- *"The economic crisis of 2008 has led to a prolonged downturn in economic activity and has had a significant impact on CO2 emission rates." (Ref: **CO_4016**)*
- *"Due to the economic crisis, emissions declined in 2008 (4 % below 2005 levels) and in 2009 (16 % below 2005 levels). In 2010 emissions started to rise again, but are still 13 % below 2005 levels." (Ref: **CO_0131**)*

#### *Pollution levels and emissions standards*

- *"(...) no evidence [has been found] that GDP growth will turn environmental degradation around after a certain point, as much of the literature has suggested. Instead, GDP's impact is mixed and conditional upon governance. Increases in GDP and progress of governance are associated with constant improvement of air and water quality. Specifically, water quality improvements are more dependent on governance, while GDP seems to have a greater impact on air quality." (Ref: **CO_0119**)*

#### *Energy availability, production and consumption*

- *"Energy intensity[17] is strongly linked to the economic cycle. Thus energy intensity decreased from 1996 to 2000, remained almost constant from 2000 to 2003 and fell again from 2003 to 2009. This is a result of GDP growth slowing faster than gross inland energy consumption during economic downturns. The overall decline in energy intensity by almost 12 % has been enough to meet the 1 % average yearly reduction target despite only minor improvement during the downturns." (Ref: **CO_0197**)*
- *"Rapid urbanisation and infrastructure development is expected to accompany economic growth, particularly among developing and transition economies. As such, industrial energy demand is highly sensitive to growth in these economies over the medium term." (Ref: **CO_2024**)*

#### *Scarce resources of raw materials*

- *"Social growth, with its focus on education, health, care and climate protection, puts less pressure on natural resources than the conventional market-driven growth model." (Ref: **CO_0235**)*
- *"(...) in the past, economic growth has accelerated greenhouse gas (CO2) emissions and caused the price of many raw materials to rise. (...) The looming competition for access to raw materials will – in the ideal case – lead to more competition among importers of raw materials for the markets of the exporting countries (so that they are able to pay for those raw materials) and to a race to improve resource efficiency, but it could also turn into conflicts for territorial and economic control of natural resources." (Ref: **CO_0235**)*

### Interactions with the Technology Domain

No particularly relevant interrelationships have been found.

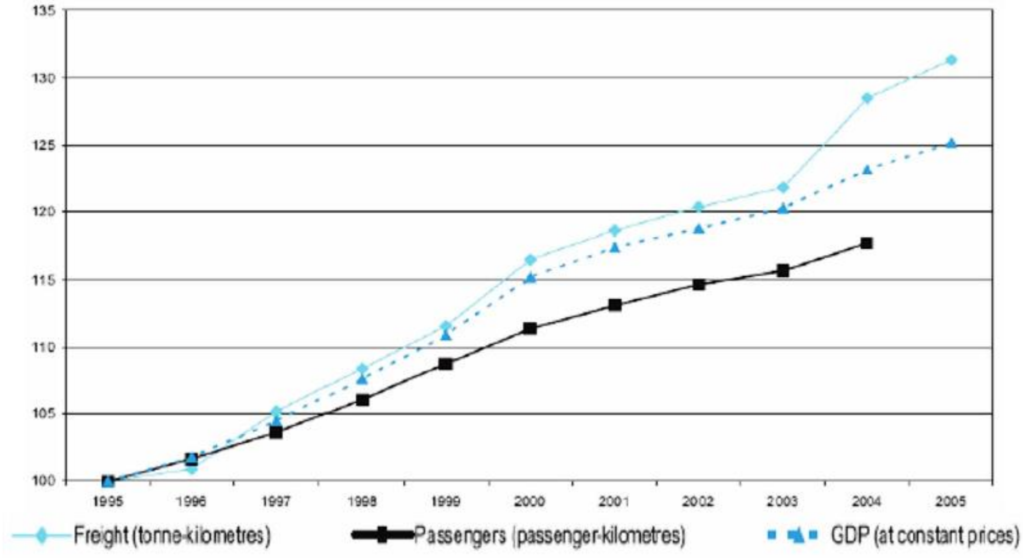
### Impacts on Mobility and Transport

#### *Decoupling transport and GDP growth*

- *"Economic growth creates a spiral of greater demand for mobility, and greater demand for goods and services. Providing more goods and services requires more transport, support and staff; increased wealth allows people to travel more and encourages more expensive modes of transport such as the car; and growth in property prices leads to longer commutes." (Ref: **CO_5018**)*
- *"The analysis of the relationship between transport and economic growth remains complex and difficult to specify because of the causal and feedback mechanisms that involves. Decoupling of economic and transport growth remains challenging subject of current and future analysis about how (and whether) economic growth could be compatible with ecological and social sustainability." (Ref: **CO_1014**)*

[17] Total energy intensity is the ratio between the gross inland consumption of energy and the gross domestic product (GDP). Energy consumption comprises the consumption of solid fuels, liquid fuels, gas, nuclear energy, renewable energies, and other fuels. (Ref: CO_0197)

- *"According to the analysis presented in the EC DGTREN Baseline scenario to 2030, in the period 1990 to 2005, the GDP elasticity of transportation activity in the EU was estimated at 0.90 for both passenger and freight transport. This is a remarkably high value indicating great dependence of economic and social activity on transportation." (Ref: **CO_0034**)*
- *"The transport sector plays a central role in the European economy and accounts for continuous growth in terms of tonne and passenger-kilometres. Whilst goods transport grew on average by 2.8% per year between 1995 and 2005 in the EU-25, thereby surpassing the average growth in GDP (at constant prices) of 2.3%, passenger transport increased at a slower rate of 1.8% (based on data covering the 1995-2004 period). Overall, as against a 25% increase in GDP between 1995 and 2005, goods transport grew by 31%. Passenger transport went up by 18% between 1995 and 2004, as against an increase in GDP of 23% over the same period (figure below)." (Ref: **CO_5008**)*




Source: Energy and environmental aspects of the transport policy (Ref: **CO_5008**)

**Figure 1-36 Evolution of freight and passenger transport compared with growth in GDP, 1995-2004/5 (1995=100)**

- *"Individual demand for transport will continue to increase in line with GDP in the EU15 due to higher wages and the fact that people spend more or less the same percentage of their disposable income on transport." (Ref: **CO_2041**)*
- *"(...) the stable relationship between growth in GDP and traffic volume implies that world-travel demand will increase approximately in proportion to the projected level of income, from 33 trillion passenger-km in 2000 to 105 trillion in 2050." (Ref: **CO_0059**)*
- *"Decoupling is a key concept defined as maintaining levels of economic growth, but with lower levels of transport intensity-breaking the historic link between GDP growth (desirable) and traffic growth (undesirable)." (Ref: **CO_4017**)*
- *"Therefore, the prime political strategy vis-à-vis the environmental goal, is to promote a decoupling of transport growth from GDP growth." (Ref: **CO_4017**)*
- *"Mobility cannot be restrained; even if one wanted to, economic growth implies a growth of transport. (...) Mobility is a major asset for competitiveness. One must break with the dogma of the decoupling of the growth rate of transport with the growth rate of GDP." (Ref: **CO_5048**)*

### *Increased demand for faster transport modes*

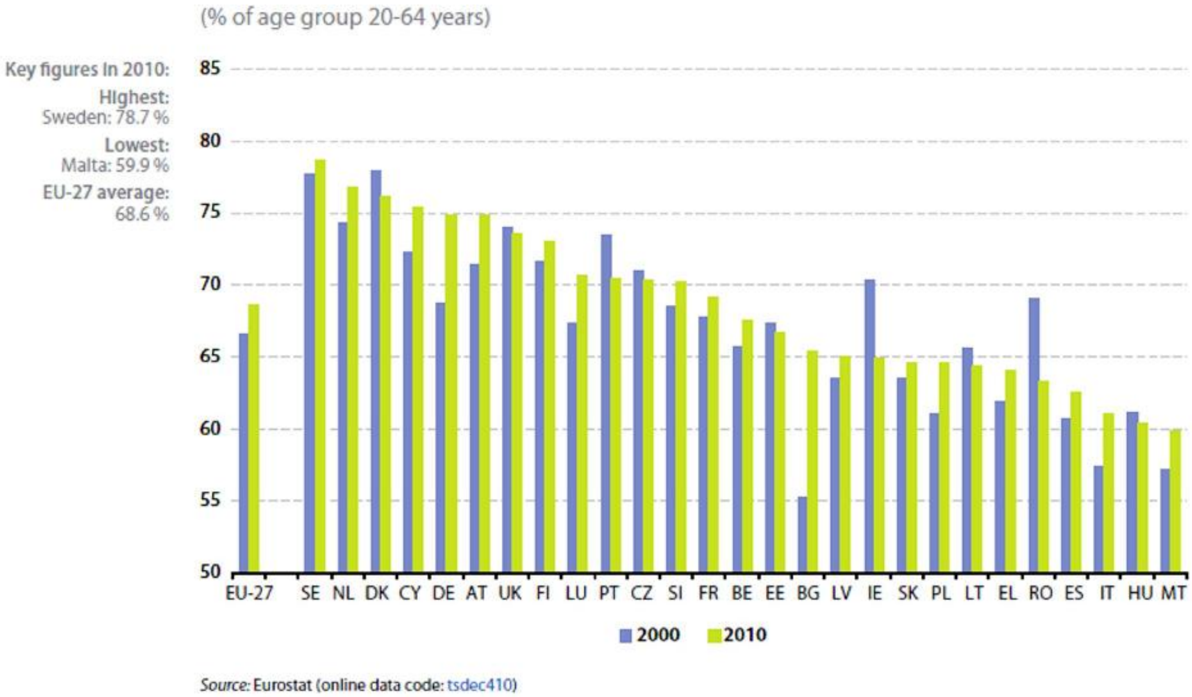
- *"Demand for speed is directly linked to GDP and individual welfare and is far from saturation (Thisse, 2009)." (Ref: **CO_5005**)*
- *"Increasing purchasing power, as a result of economic growth, allowed people to buy faster transport modes." (Ref: **CO_5048**)*

- *"The passenger demand for air-transport is assumed to be closely related to Economy developments represented in the method by GDP growth." (Ref: **CO_2042**)*
- *"While the travel-money budget translates rising per capita GDP into rising PKT per capita, the fixed travel time budget requires that the increasing travel demand be satisfied in the same amount of time. Since each transport mode operates within a known range of speeds, the increasing per-person travel demand can only be satisfied by shifting toward increasingly rapid transport. Future increases in per capita GDP will continue to cause a rise in PKT. At the same time, the fixed travel-time budget will continue to push travellers toward faster modes of transport. (...) At that high mobility level, most travel would be international. Prices would adjust, and so would income levels." (Ref: **CO_0059**)*

### 1.3.2.2 Employment

**Driver description**

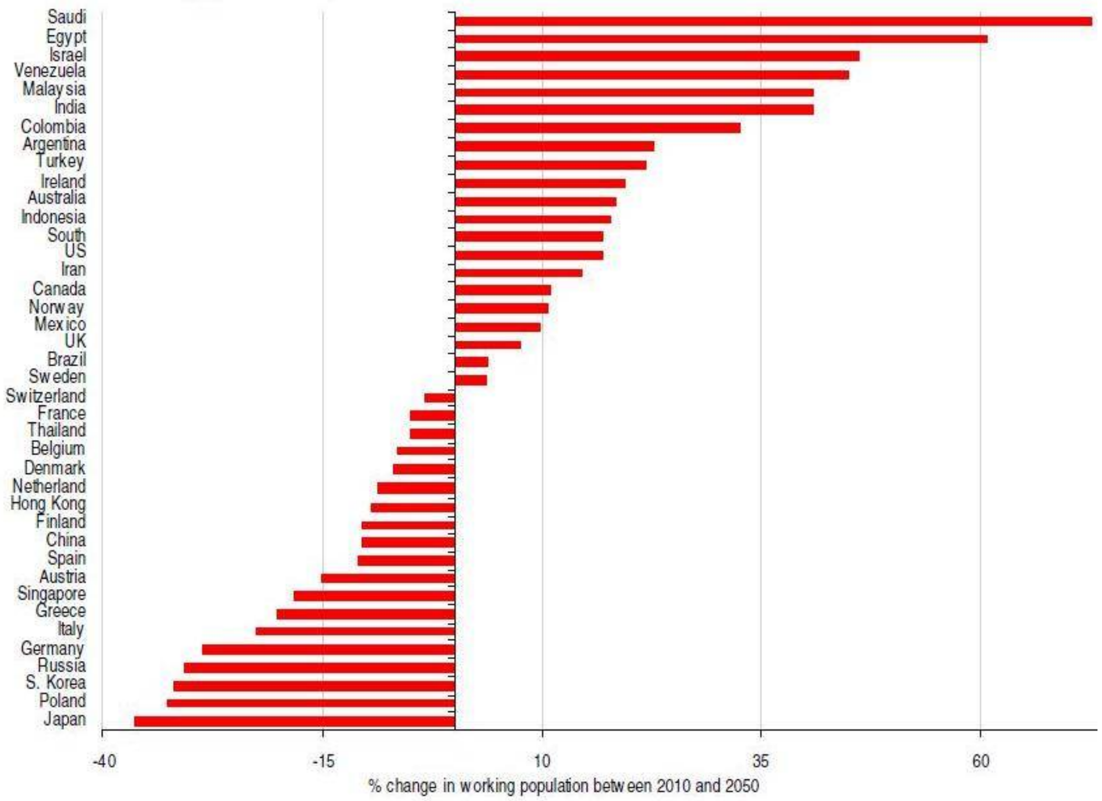
- *"Employment contributes to economic performance, quality of life and social inclusion, making it one of the cornerstones of socioeconomic development. Labour market participation widens people's range of freedoms and resources in striving to achieve life goals and aspirations." (Ref: **CO_0197**)*
- *"Between 2000 and 2008, employment among 20 to 64 year olds in the EU rose from 66.6 % to 70.4 % (...) The economic crisis had a pronounced effect when in 2009 the employment rate fell to 69.1 % – below the 2006 level. The employment rate has continued to fall since then, reaching 68.6 % in 2010." (Ref: **CO_0197**)*




Source: Sustainable development in the European Union (Ref: **CO_0197**)

**Figure 1-37 Total employment rate, by country**

- *"Unemployment by age and gender show the labour market situation is worst for young people aged 15 to 24. More than 20% of people in that group were unemployed throughout the second half of 2009 and 2010." (Ref: **CO_0197**)*
- *"The number of people being put to work will vary substantially across economies in the coming years. Perhaps the most striking way to see what's going on is to look at the total change over the whole 40-year period." (Ref: **CO_2026**)*
- *"Unemployment can be caused by other drivers of social exclusion such as ill-health, low educational attainment and lack of skills." (Ref: **CO_0176**)*




Source: The world in 2050. Quantifying the shift in the global economy (Ref: **CO_2026**)

**Figure 1-38 Change in working population between 2010 and 2050**

- *"In the EU27, the number of persons employed (using the LFS[18] definition) is projected to record an annual growth rate of only 0.3% over the period 2010 to 2020 (compared to 0.9% over the period 2000-2009), which is expected to reverse to a negative annual growth rate of a similar magnitude over the period 2020 to 2060. The outcome of these opposite trends is that employment will peak at 228.3 million in 2026 and go down to 208.7 millions in 2060. This implies a decline of about 10.5 million workers over the period 2010 to 2060. The negative prospects for population developments, including the rapid ageing of the population, will only be partly offset by the increase in (older workers) participation rates and migration inflows, leading to a reduction in the number of people employed during the period 2020 to 2060 (about 18.2 millions)." (Ref: **CO_0050**)*
- *"The employment rate of women is projected to rise from 62.1% in 2010 to 65.9% in 2020 and to 69.4% in 2060. The employment rate for workers aged 55-64 years is expected to increase by even more, from 46.3% in 2010 to 56.1% in 2020 and to 62.7% in 2060, reflecting the expected impact of recent pension reforms in many Member States, aimed at increasing the retirement age. For the euro area, the increase in the employment rate of older workers (55-64) is higher than in the EU27, rising by 18.1 p.p. compared with 16.4 p.p. in the EU27." (Ref: **CO_0050**)*
- *"There is a limit to how far the employment rate can be improved in the long term in developed countries, so long term growth is driven primarily by productivity. ("Productivity isn't everything, but in the long run it is almost everything." Paul Krugman). Over the longer term, growth will be determined primarily by the factors which determine productivity, and secondly those which improve labour participation. The drivers of productivity growth are factors which either improve the quality of outputs, or the efficiency with which inputs (such as capital, labour and materials) are transformed into outputs. The contribution of some of these factors to output growth can be captured by appropriate input measures, with everything else (eg unmeasured inputs and technological progress) allocated to a residual called Total Factor Productivity (TFP)." (Ref: **CO_0179**)*

[18] Labour Force Survey

## Interactions within the Economy Domain

### *GDP trends*

- *"Employment contributes to economic performance, quality of life and social inclusion, making it one of the cornerstones of socioeconomic development. Labour market participation widens people's range of freedoms and resources in striving to achieve life goals and aspirations." (Ref: **CO_0197**)*
- *"The simultaneous curbing of investment and consumption leads to low growth and endemic unemployment. This trend has been thwarted in the Anglo-Saxon countries by the development of household debt, and by asset bubbles that create fictional wealth, allowing for a growth of consumption without wages, but ending up with crashes." (Ref: **CO_0242**)*

### *Regional differences in economics*

- *"Regional disparities in employment rate fell from 13.0% in 2000 to 11.8% in 2009. Improvement has been achieved by the progressively more stable position of women in regional economies." (Ref: **CO_0197**)*
- *"Differences between EU Member States are large. The Netherlands, Sweden, Denmark, Cyprus, Germany and Austria are all close to or even above the 75% target, while Malta, Hungary, Italy, Romania, Spain, Greece, Lithuania, Poland, Slovakia and Ireland are all below 65%." (Ref: **CO_0197**)*
- *"(...) unemployment is spatially very concentrated and there are still areas with a considerable 'jobs gap'." (Ref: **CO_0176**)*

## Interactions with the Social Domain

### *Migration flows*

- *"Labour immigration may be permitted or encouraged by destination countries as a way to fill gaps in the national labour market. This labour migration may take a variety of forms, possibly being aimed at recruiting migrant workers from particular origin countries or workers with particular skills." (Ref: **CO_0066**)*

### *Income structure and distribution*

- *"When 'excessive' Keynesian macro-stabilities, government regulations (such as more effective financial regulation, tougher competition laws, strong capital controls and greater accounting transparencies), labour-securities and social safety nets laid the grounds for both an increased degree of 'compulsion' for capital, […] what capital urgently needed was […] a return to precarious jobs, with (among other anxieties) the constant threats of the transfer of jobs to China, India or Mexico, higher levels of unemployment, highly-constrained unions, increasingly porous safety-nets, insufficient and insecure pensions and so on – and, of course, high levels of persecutory personal debt could also be of great help."* (*Ref:* ***CO_0303***)
- *"There has been an increase in pay differentials with more low pay and the risk of low pay affecting certain groups more – women, young people, older males, long-term sick and disabled, and ethnic minorities. The low paid are also more likely to experience unemployment. Unemployment has knock on effects in other dimensions of social exclusion including homelessness, health, crime, and drug and alcohol problems." (Ref: **CO_0176**)*

### *Urbanisation*

- *"In more remote areas, there is migration from rural to urban areas by those in search of jobs. In more central areas larger and more specialised labour markets are enabled by peri-urban development and road based mobility. Employment and occupation patterns also affect the trends of peri-urbanisation. For example, the spread of teleworking in the service industries can encourage out-migration to peri-urban or rural areas." (Ref: **CO_0097**)*

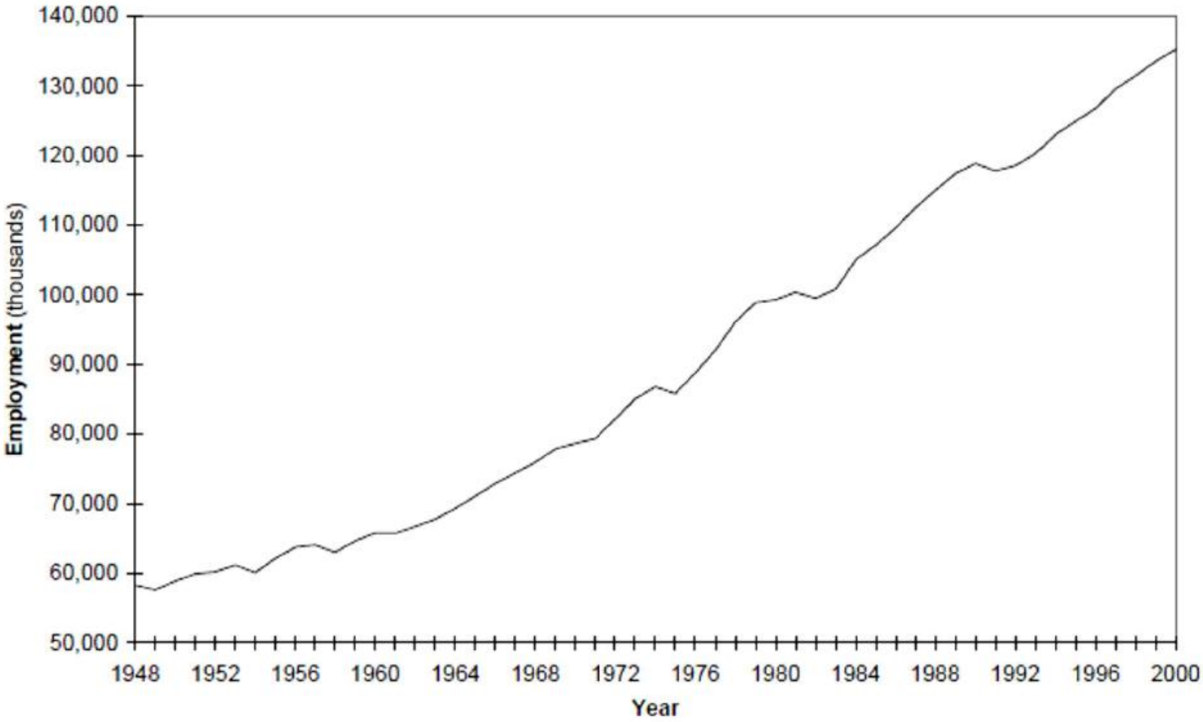
## Interactions with the Environment Domain

- *"(...) there is no evidence that environment policy is a job-killer overall but instead it seems to have a neutral or even mildly positive impact on the overall number of jobs. This is especially true if environmental policy is well designed and hence is cost-efficient. Some environmental policies may be particularly favourable from the point-of-view of employment policies: for example, policies to promote environmental innovation or environmental tax reform. Broadly though, the* *biggest impact of environmental policy is likely to be on the composition of the labour market rather than its size." (Ref:* ***CO_0170****)*

## Interactions with the Technology Domain

### *Technology development in general and innovation diffusion*

- *"Positive technology shocks lead to a decline in employment, and tend to generate a negative comovement between that variable and productivity." (Ref:* ***CO_0188****)*
- *"(...) high unemployment rate of engineers has encouraged the formation of new technology based companies." (Ref:* ***CO_0190****)*
- *"Data on total employment in the United States show robust and nearly uninterrupted growth between 1948 and 2000. During this period of rising productivity, mechanization, and computerization, total employment more than doubled from less than 60 million to more than 135 million, and there has been no obvious slackening of the pace in the past two decades, during which computers became much more common in the workplace." (Ref:* ***CO_0193****)*




Source: *Economic Report of the President* (1989, 2000), Washington, DC: Government Printing Office.
Source: SRI International (Ref: **CO_0193**)

**Figure 1-39 Total employment 1948-2000 USA**

- *"Employee entrepreneurship is widely heralded as an important driver of innovation, firm formation and growth." (Ref:* ***CO_0192****)*

## Impacts on Mobility and Transport

### *Network accessibility and labour participation*

- *"The results show that high initial levels of congestion dampen subsequent employment growth" and "... congestion has a broad negative impact on economic growth." (Ref:* ***CO_0103****)*
- *"(...) access to public transit is a significant factor in determining average rates of labour participation within (...) cities." (Ref:* ***CO_0104****)*
- *"(...) the positive correlation between access to public transit and labor participation may not be coincidental." (Ref:* ***CO_0104****)*

### *Employment in the transport sector*

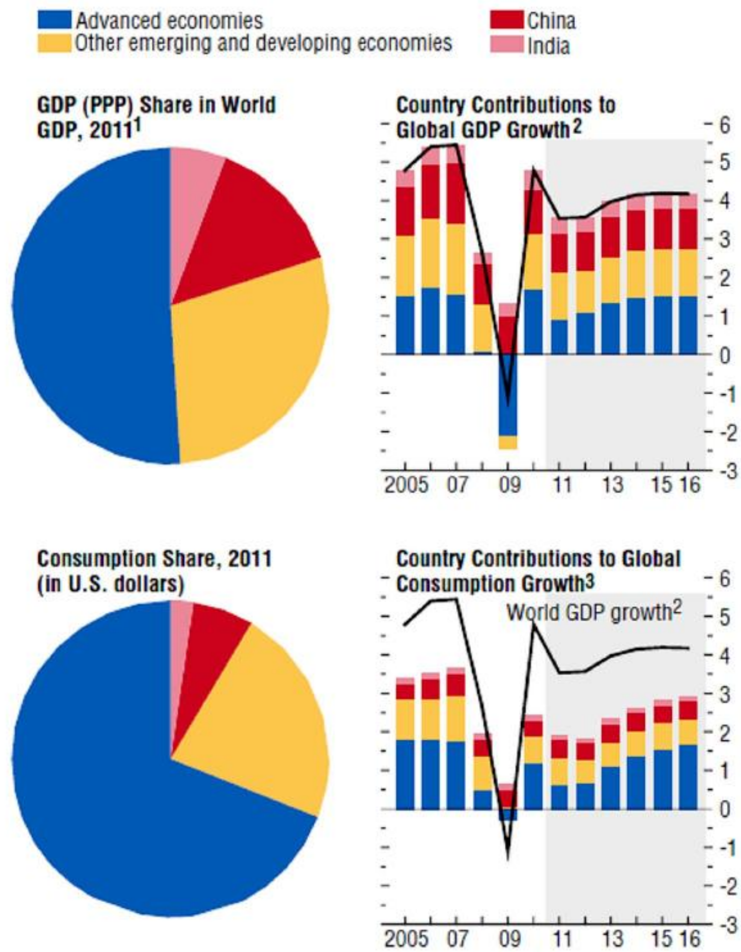
- *"Up to one in ten workers in developed countries works in transport." (Ref:* ***CO_5019****)*

- *"Globally, the transport sector is hiring in unprecedented numbers, despite the crisis. Prospects remain good for job growth in the sector." (Ref: **CO_5019**)*

### *1.3.2.3 Regional Differences in Economics*

**Driver description**

- *"Key factors influencing a global shift of economic power from the advanced economies to the emerging economies are, first of all, the rates of productivity and income growth in emerging economies, which are outpacing those in advanced economies. Other important drivers are similar to those underlying continued economic growth: population growth, continuing technological innovation and diffusion of technologies, favourable economic policies and integration at regional and global level (Maddison, 2001)." (Ref: **CO_0274**)*
- *"Regional inequalities in income per head arise from many different sources – differences in labour force participation, differences in employment rates, differences in the composition of skills and occupations and differences in productivity."(Ref: **CO_0116**)*
- *"The second factor driving regional variation in the productivity index is the educational qualifications of the local workforce." (Ref: **CO_0116**)*
- *"(...) an inverted U-shaped curve in the relationship between the national per capita income level and the extent of regional inequalities (holds) independently of the time period and regional administrative units considered." (Ref: **CO_0217**)*
- *"World output will treble, as growth accelerates on the back of the emerging economies. On average, annual world growth is projected to be accelerate towards 3% compared with growth of just over 2% in the 2000s. Emerging-world growth will contribute twice as much as the developed world to global growth over this period." (Ref: **CO_2026**)*
- *"Emerging and developing economies account for about half of global output and two thirds of global growth in purchasing-power-parity (PPP) terms, much of which is accounted for by China and India." (Ref: **CO_0180**)*




Source: International Monetary Fund, 2011 (Ref: **CO_0180**)

**Figure 1-40 World Economic Outlook**

- *"Economic and social disparities among regions weaken the EU's dynamism." (Ref: **CO_0197**)*

**TABLE 2.7: OVERVIEW OF NATIONAL FACTORS OF COMPETITIVENESS**

| Infrastructure & accessibility | Human resources | Productive environment |
|---|---|---|
| • *Basic Infrastructure*<br>- road<br>- rail<br>- air<br><br>• *Technological Infrastructure*<br>- ict<br>- telecoms<br>- internet | • *Labour force characteristics*<br>- productivity and flexibility<br>• *Management skills*<br>- internationalised<br>- levels of professionalism<br>- levels of efficiency<br>• *High skilled workforce*<br>- scientists and engineers<br>- symbolic analysts<br>• *High participation rates in post school education*<br>- tertiary education<br>- vocational training<br>• *Educational infrastructure* | • *Entrepreneurial Culture*<br>- low barriers to entry<br>- risk taking culture<br>• *Internationalization*<br>- exports/global sales<br>- investment<br>- business culture<br>• *Technology*<br>- application<br>- management<br>• *Innovation*<br>- patents<br>- R&D levels<br>- research institutes and universities<br>- linkages between companies and research<br>• *Capital availability*<br>• *Nature of competition*<br>• *Sectoral balance* |

Source: Study on the factors of regional competitiveness (Ref: **CO_0117**)

**Figure 1-41 Overview of national factors of competitiveness**

- *"(...) the global risk context in 2011 is defined by a 21st century paradox: as the world grows together, it is also growing apart. Globalization has generated sustained economic growth for a generation. It has shrunk and reshaped the world, making it far more interconnected and interdependent. But the benefits of globalization seem unevenly spread – a minority is seen to have harvested a disproportionate amount of the fruits. Although growth of the new champions is rebalancing economic power between countries, there is evidence that economic disparity within countries is growing. Issues of economic disparity and equity at both the national and the international levels are becoming increasingly important. Politically, there are signs of resurgent nationalism and populism as well as social fragmentation. There is also a growing divergence of opinion between countries on how to promote sustainable, inclusive growth. To meet these challenges, improved global governance is essential. But this is another 21st century paradox: the conditions that make improved global governance so crucial – divergent interests, conflicting incentives and differing norms and values – are also the ones that make its realization so difficult, complex and messy. As a result, we see failures such as the Doha Development Round of the World Trade Organization (WTO) and the lack of international agreement at the Copenhagen Conference on climate change. The G20 is seen as the most hopeful development in global governance but its efficiency in this regard has not been proven." (Ref: **CO_1035**)*

## Interactions within the Economy Domain

### *GDP trends*

- *"[Productivity]... is generally seen as the most important driver behind GDP per capita and subsequent explanation of differences between regions." (Ref: **CO_0117**)*
- *"(...) institutional quality is a determinant of regional differences in entrepreneurship and economic growth." (Ref: **CO_0115**)*
- *"(...) great heterogeneity in economic growth among rural regions and the distance from a populated centre could be a significant factor explaining these differences." (Ref: **CO_0216**)*

### *Employment*

- *"Remote rural regions appear economically more fragile: lower employment rates (Canada and Mexico) and economic output (Europe)." (Ref: **CO_0216**)*

### *Intensified competition for scarce resources use*

- *"Owning essential natural resources may further improve emerging economies' competitiveness. Their growing demand for resources stimulates domestic exploration and exploitation, possibly increasing the countries' share in the total global stock." (Ref: **CO_0274**)*

## Interactions with the Social Domain

### *Migration flows*

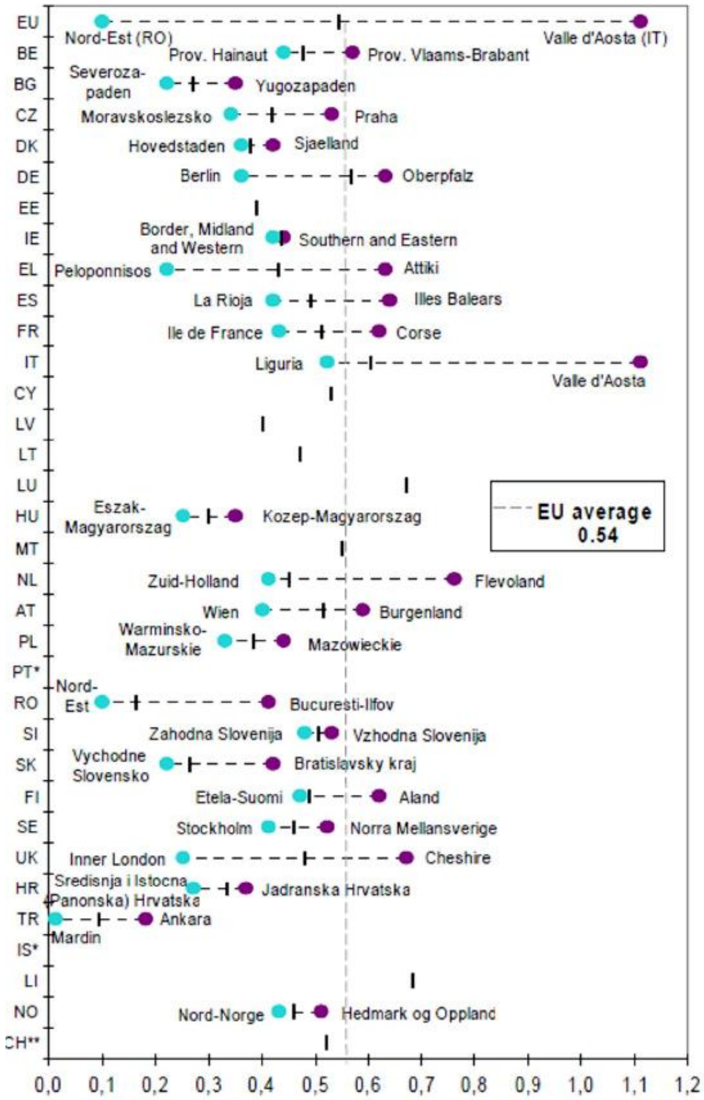
- *"The global economic crisis has affected all regions of the world. (...) The depth and extent of the crisis varies across regions, with some regions better insulated from the global downturn than others. The differential impact of the crisis in the different regions means that the impact on migrant workers will vary between regions." (Ref: **CO_0158**)*
- *"(...) demographic differences, combined with growing economic disparities, are increasing the pressure for migration, which is expected to become a more important factor in demographic change over the next 50 years." (Ref: **CO_0274**)*

### *Income structure and distribution*

- *"There is also a high level of inequality in Europe that primarily takes the form of major regional income differentials between countries, although inequality within most member states has increased in recent years. Recent regional catch-up, which had reduced between-country inequality and which the debt crisis has abruptly terminated, must be revived within the framework of a European growth strategy." (Ref: **CO_0235**)*

### *Car ownership*

- *"In the age of rising middle classes in emerging economies, demand for the car may explode – as we are already seeing in markets such as China." (Ref: **CO_5018**)*
- *"There are significant disparities in the ownership of passenger cars within the regions of the different European countries (...). The ratio registered in the various regions is often linked to economical issues." (Ref: **CO_0173**)*
- *"Dargay, Gately and Sommer find that geographic factors affect vehicle ownership saturation levels, and that most of the OECD countries are now approaching saturation levels." (Ref: **CO_5047**)*

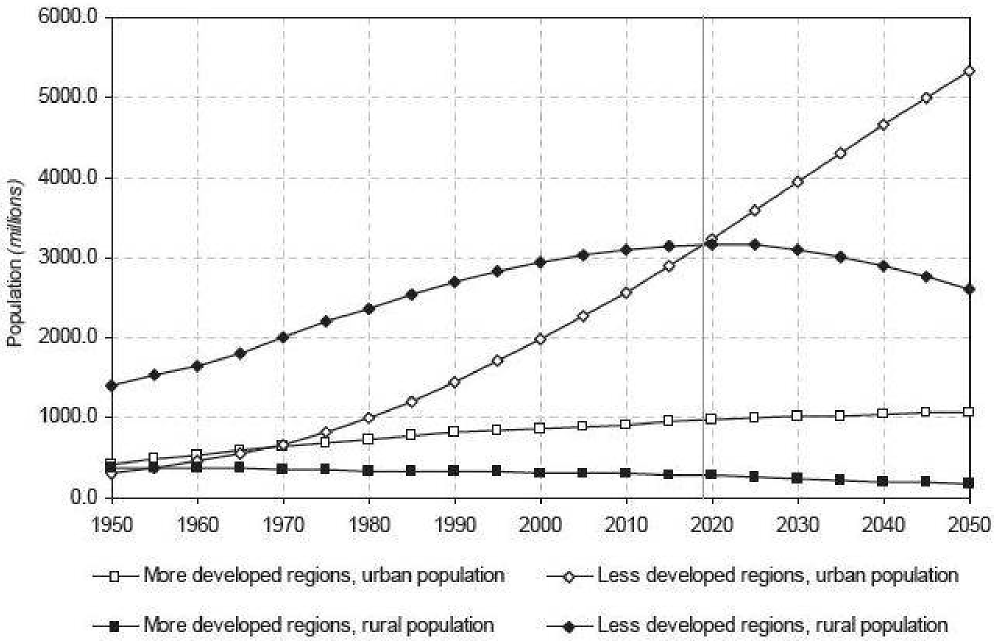



Source: Eurostat 2010 (Ref: **CO_0173**)

**Figure 1-42 Regional disparities (at NUTS2 level) in the number of passenger cars per inhabitant, 2007**

*Urbanisation*

- *“Urbanisation and economic growth in developing regions are strongly correlated.” (Ref: **CO_5042**)*
- *“The urban population of the more developed regions is projected to increase modestly, from 0.9 billion in 2007 to 1.1 billion in 2050 (Figure below).” (Ref: **CO_1015**)*
- *“The world rural population is expected to reach a maximum of 3.5 billion in 2018 or 2019 and to decline slowly thereafter, to reach 2.8 billion in 2050. These global trends are driven mostly by the dynamics of rural population growth in the less developed regions, which house today 90 per cent of the world rural population. Whereas the rural population of the more developed regions has been declining steadily during the second half of the twentieth century and will continue to do so for the foreseeable future, the rural population of the less developed regions more than doubled since 1950 and will likely continue to grow until 2021 before a long-term decline sets in (Figure below).” (Ref: **CO_1015**)*




Source: World Urbanization Prospects- The 2007 Revision (Ref: **CO_1015**)

**Figure 1-43 Total urban and rural populations by development group_1950-2050**

- *"While in the more developed regions, the proportion urban was already nearly 53 per cent in 1950, in the less developed regions the 50 per cent level will likely be reached around 2019." (Ref: **CO_1015**)*
- *"More developed regions are expected to see their level of urbanization rise from 74 per cent to 86 per cent over the same period. In the less developed regions, the proportion urban will likely increase from 44 per cent in 2007 to 67 per cent in 2050." (Ref: **CO_1015**)*
- *"The Chinese Ministry of Construction anticipates that by 2020 an additional 180 million people will reside in China's cities. Residential building floor area has already been dramatically increasing since 2000; according to projections about 13 billion m2 more residential floor space will be constructed in the next two decades, which is equivalent to the total floor area of all the existing residential buildings in the EU-15 countries." (Ref: **CO_5009**)*
- *"Over the coming decades, the level of urbanization is expected to increase in all major areas of the developing world, with Africa and Asia urbanizing more rapidly than the rest. Nevertheless, by mid-century, Africa and Asia are expected still to have lower levels of urbanization than the more developed regions or Latin America and the Caribbean." (Ref: **CO_1015**)*
- *"Indeed, tendency for jobs to increase faster in the suburbs and on the urban fringes than in the centres and inner districts of metropolitan areas is characteristic of all developed countries." (Ref: **CO_0034**)*
- *"(...) if developing countries follow the same path of urban sprawl in the coming decades as more developed countries, the scale of urban expansion could be much greater and the magnitude of its impacts on the environment and human society even more pronounced." (Ref: **CO_5009**)*

#### Education

- *"(...) inequalities should first rise then decline depending on the total amount of knowledge available in the economy which is directly linked to the level of economic development." (Ref: **CO_0217**)*
- *"The idea that concentrations of highly skilled human capital should be associated with faster rates of real GDP per capita growth (itself very closely related to productivity growth) is not new. It is represented (...) as the ratio of university students to total employees." (Ref: **CO_0223**)*

## Interactions with the Environment domain

### *GHG mitigation*

- *"In most cases in developing regions, paths for socio-economic and technological development imply increases in GHG emissions, not reductions in emissions, including both emissions from the cities themselves and emissions from systems that meet urban needs, such as electric power plants located elsewhere." (Ref: **CO_0147**)*
- *"For (local and national) governments in countries with minimal per capita GHG emissions, it is very difficult to justify to their electorates expenditures on climate change mitigation if they are already unable to provide their populations with basic infrastructure and services." (Ref: **CO_0147**)*
- *"Within OECD economies, CO2 emissions from transport have fallen by nearly 4% from 2007 to 2008 and all transport sub-sectors have seen emissions fall as a result of the crisis except for international aviation. Within non-OECD economies, transport-related CO2 emissions have continued to register strong growth from 2007- 2008 with the exception of the rail sector." (Ref: **CO_4016**)*
- *"Regionally, carbon sequestration schemes are more common in developing country cities, often associated with gaining CDM credits or development programmes. However, actions promoting urban tree-planting and restoration, preservation or conservation of carbon sinks may be taken in cities in developed countries for reasons of environmental protection or the preservation of urban green spaces without associating them specifically with climate change mitigation objectives." (Ref: **CO_0147**)*

### *Emissions trading schemes*

- *"Emission trading of CO2 and particularly the use of flexible mechanisms may export co-benefits of greenhouse gas mitigation — lower air pollution — to other regions of Europe or the world. Therefore, if decisions to buy CO2 emission credits abroad are motivated only by minimising the costs of climate change policies, this could result in a less cost-efficient overall solution." (Ref: **CO_0147**)*

### *Pollution levels and emission standards*

- *"Differences in economic structure have an important role in explaining the variance in emission-intensity between regions. Even if one corrects for differences in economic structure, differences in emission intensity remain. This leads (...) to believe that a difference in environmental efficiency of industries (...) also plays an important role." (Ref: **CO_0174**)*

## Interactions with the Technology Domain

### *Technology development in general and innovation diffusion*

- *"A basic reference point for the creation of transport innovation is the situation in the most economically advanced countries. For the developing nations, the large-scale replacement of traditional transport means (city rickshaws, pack or cart animals) with motor transport, commonly used in Europe, North America and Japan, does not mean innovation, but classical adaptation and modernisation. An innovative challenge is a vision of what new can be done which is different from the solutions currently considered to be most advanced in the world." (Ref: **CO_5065**)*
- *"However, more and more often emerging economies are starting to challenge developed economies in the core areas of their competitive advantage, namely high-technology developments. Competitive pressures will increase as many emerging economies step up their general research and innovation capacities." (Ref: **CO_0274**)*
- *"Increasingly, EU-27 multinationals are competing with technology based companies from emerging economies in high-end technology markets. Growth rates in patent filings in some Asian economies are beyond the level of several western OECD economies." (Ref: **CO_0274**)*
- *"There is a common need for greater knowledge sharing and RD&D collaboration among countries to accelerate technology advancement along the curve from demonstration to commercialisation. There is also a need to target some emerging and developing economies with specialised approaches to ensure capacity building and appropriate enabling environments." (Ref: **CO_0154**)*

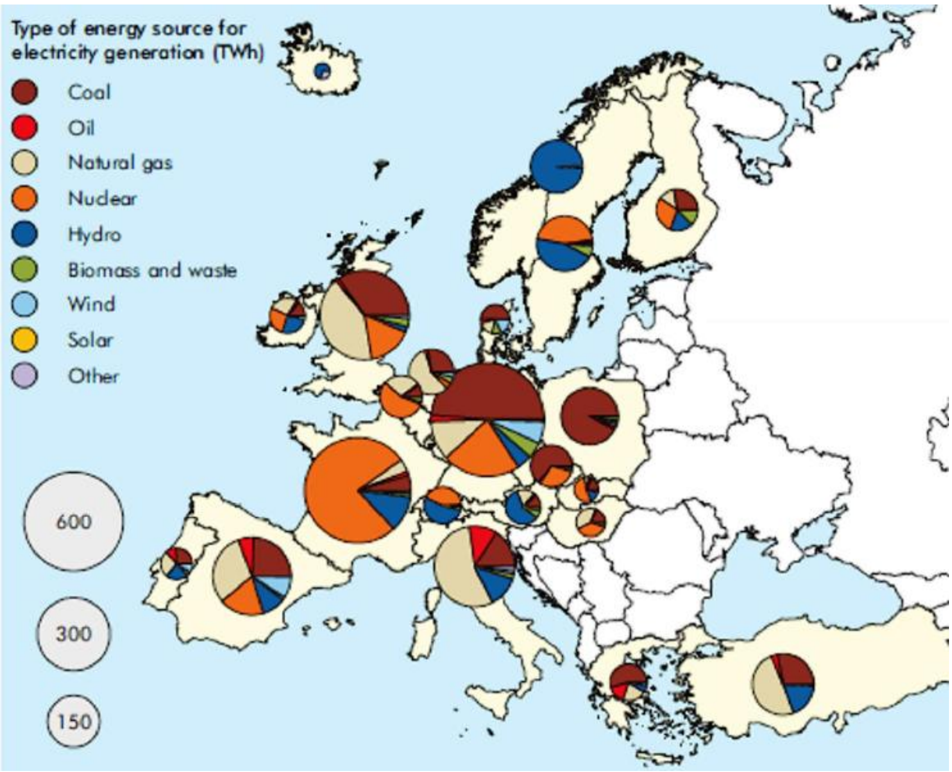
- *"Agglomeration economies, concentrations of research and development (R&D) activity and highly skilled human capital, and systems of urban governance play a significant role in driving spatial economic growth differences, but no role when it comes to population growth." (Ref: **CO_0223**)*
- *"(...) four basic factors (...) affect the innovative performance of firms. (...) Three of them concern mechanisms through which knowledge and routines are transferred from one organisation to the other, resulting in knowledge diffusion, interacting learning and innovation. (...) The fourth factor concerns organisational capabilities of firms, meaning the capacity of firms to deal effectively with a lack of required resources, such as knowledge, skills and capital." (Ref: **CO_0172**)*
- *"A revolution (...) may have started in developing nations such as India and China (...). Products from these regions are dramatically cheaper than those of Western competitors. The whole system of how businesses operate is being rethought – from supply chain management to recruitment – and the emerging economies are turning into hotbeds of innovation." (Ref: **CO_0284**)*
- *"According to Eurostat in 2009 60% of the EU 27 population between 16 and 74 years regularly used the Internet. However, there are large differences between European countries ranging from 31% regular internet use in Romania to 86% in the Netherlands and Sweden." (Ref: **CO_2018**)*

#### Traffic management systems

- *"Traffic volume in developing countries is usually lower, and infrastructure less evolved when compared to developed countries. Consequently, congestion levels are not necessarily lower and resultant pollution, specifically in urban areas, is a significant concern. Developing countries are usually in a phase of infrastructure deployment. The cost of technology is limited when compared to the cost of civil engineering work. This situation presents an important opportunity for building state-of-the-art infrastructure and implementing all necessary equipment." (Ref: **CO_0281**)*

#### Renewable energy production

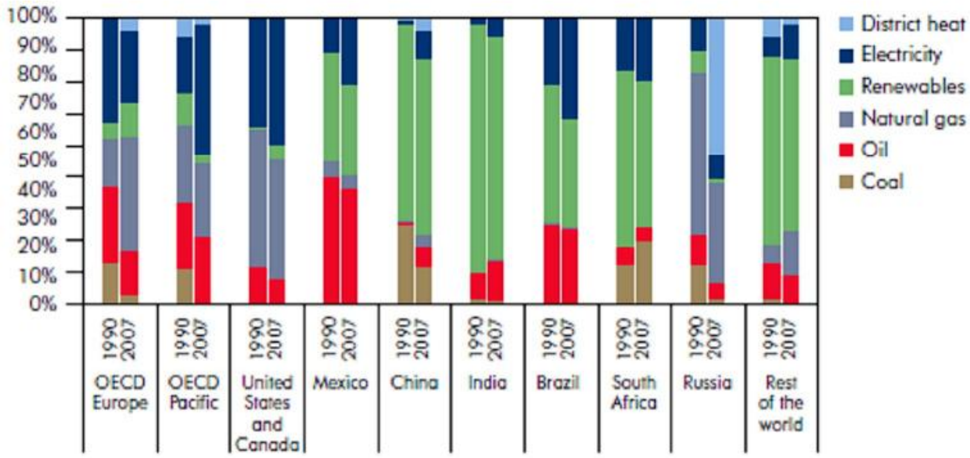
- *"The generation mix varies widely between countries in OECD Europe." (Ref: **CO_0153**)*




Source: Energy Technology Perspectives 2010 (Ref: **CO_0153**)

**Figure 1-44 Electricity generation mix, OECD Europe, 2007**

- *"Global energy use in the household sector increased by 28% between 1990 and 2007 to 1941 Mtoe. As is the case in the other major end-use sectors, energy consumption in households* *since 1990 has grown more in non-OECD countries (34%) than in OECD countries (17%). Natural gas is the fuel used most in OECD countries, providing 265 Mtoe (38%) of household energy requirements in 2007. Electricity use has been rising rapidly in OECD countries, largely because of the increased penetration of many different appliances. Electricity consumption increased from 169 Mtoe in 1990 to 248 Mtoe in 2007. In non-OECD countries, renewables, particularly traditional biomass, remain the largest source of energy, with consumption of 706 Mtoe in 2007. Electricity use is by far the fastest growing energy commodity, its use increasing by 175% since 1990 to reach 11% of total energy consumption. In Russia, district heating remains important in the household sector with heat consumption of 53 Mtoe in 2007, or 47% of total household energy consumption." (Ref: **CO_0153**)*




Source: Energy Technology Perspectives 2010 (Ref: **CO_0153**)

**Figure 1-45 Household energy use by energy commodity**

- *"In energy, renewables accounted for 61% of new electricity generating capacity in the EU in 2009. But Europe's lead is challenged. The 2010 Renewable Energy Attractiveness Index now cites US10 and China as the best investment opportunity for renewable energy. The US is aiming to double its renewable energy generation by 2012. In 2009, China topped the global league table for wind power installation. Chinese and Indian wind turbine manufacturers now appear in the top ten. China and Taiwan now produce most of the world's PV panels." (Ref: **CO_0201**)*

## Impacts on Mobility and Transport

### Transport modes amongst regions and income

- *"The wealthiest regions are most mobile and thus have the highest share of high-speed modes, but even in these regions travelers will spend most of their travel time in automobiles. In North America the HST share of mobility will rise fourfold to 71% by 2050, but only 17% of the average person's travel time budget (11 min) will be spent moving at high speeds; a little time goes a long way in aircraft. A five-fold increase in per-capita mobility will make more common what is extreme traveler behavior today, such as living in Bombay or Boston and commuting daily to Delhi or Washington. Because extreme mobility depends on access to high speed modes, pockets of low density living will persist where it is time-intensive to travel to nodes (airports and maglev train stations) in the high-speed transportation system ± as likely in the outskirts of London as the Sahara." (Ref: **CO_0001**)*

### Transport infrastructure and regions development

- *"The belief that transport infrastructure projects have significant impacts on the development of regional economies has often been used to justify allocating resources to transport infrastructure investment. However, the clear meaning of these impacts or how they could be evaluated has yet to be established." (Ref: **CO_0113**)*

### Transport and regions accessibility

- *"In many cases, the objective of transport infrastructure investment is to improve the accessibility of a given region by reducing travel time or increasing the potential to travel. Accessibility can be* *measured as the quantity of economic or social activities that can be reached using the transport system." (Ref: **CO_0113**)*

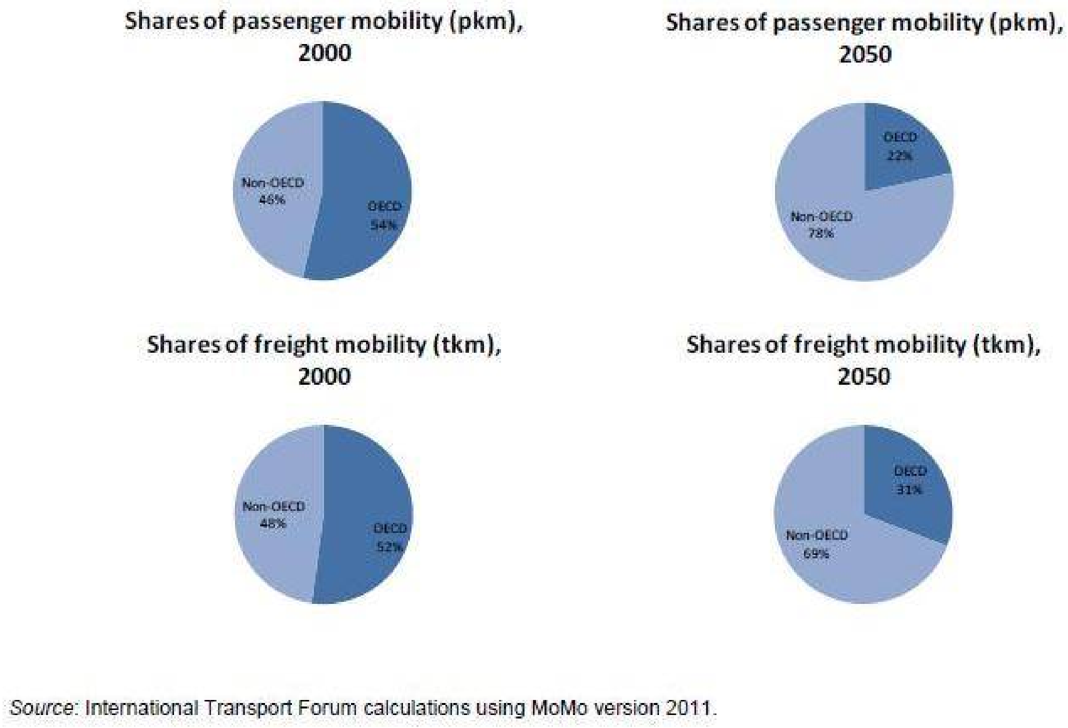
- *"Inter-regional accessibility is focused on competition between the regions in Europe. The attractiveness and growth potential of cities in the single European market depend on good communication. One reason for this is that increasing international competition entails a greater need for personal contacts in product development and marketing activity. Thus, transportation should not be an obstacle to contacts between major cities or regions. Good air communication is important for remote cities in Europe, while high-speed trains may play a more significant role in central areas." (Ref: **CO_0113**)*

*New transport and mobility patterns*

- *"The tendency to homogeneity (GDP per capita equity, regional GDP equity) is to prioritize many-to- many transport fluxes (intercity, and interregional), with increased mobility for everybody. The tendency to heterogeneity (a few are rich and many are poor; regional disparity) leads to the prioritization of a few nodes over all the others. Few people are able to travel, and there is the development of exclusive transport services, with more segregated networks. Gregariousness together with increased mobility fluxes may bring transport segregation according to travel purpose (tourist trains versus business trains, charter flights versus private jets), while individualism may increase car use." (Ref: **CO_5048**)*

*Increasing demand for transport in non OECD countries*

- *"While mobility growth in the OECD can be expected to be slow and gradual, and even negative in some countries, it could be very fast outside of the OECD." (Ref: **CO_4024**)*




Source: Transport Outlook 2011. Meeting the Needs of 9 Billion People (Ref: **CO_4024**)

**Figure 1-46 Distribution of passenger and surface freight mobility in 2000 and 2050: share of OECD and non-OECD countries**

- *"It is clear that urbanisation will significantly increase the strain on transport systems, notably on the public transport systems in the large cities of the developing world, since most of the growth in population over the next few decades will be in urban areas in these countries" (Ref: **CO_5042**)*
- *"In China, as in other emerging economies, higher living standards have greatly increased demand for transportation." (Ref: **CO_0284**)*

*Increasing demand for air travel in non OECD countries*

- *"Many countries may experience higher levels of per-capita air travel at lower levels of per-capita income than has historically been the case in OECD countries. By 2030 the combined domestic markets in China and India are projected to surpass the current US domestic market which, in 2010, was the largest in the world." (Ref: **CO_0160**)*

*Increasing demand for more cheaper cars in BRICS*

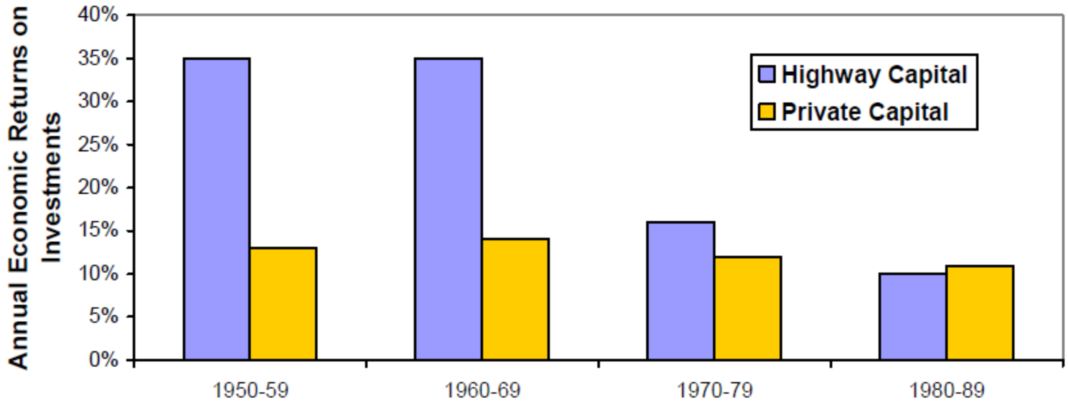
- *"New Asian automakers will increase the pressure on the highly saturated car markets in Germany and Europe. Many signs indicate that "lowest cost cars", in particular, will meet with rising demand in industrial nations, too. To the same degree that western societies become socially polarised, a "mobility divide" opens: While some remain able to afford mobility in comfort, others only manage to finance a mobility minimum. The success of the Dacia Logan has already given an impression of the potential offered by "discount cars" such as the Indian Tata Nano. Its European market entry has been envisioned for 2012. The low-cost market already belongs to the most important growth markets globally – European automakers will be forced to enter it, too." (Ref: **CO_0005**)*
- *"This applies for the fact alone that the European and US-American car markets will continuously lose in importance compared to the emerging markets. The BRIC-nations Brazil, Russia, India, and China have eagerly been envisaged as an escape from the market saturation trap. Some of the major automakers have been active in these markets for twenty years – Volkswagen in China – or thirty years – Fiat in Brazil – already. The current significance of these markets becomes obvious when one considers that in 2008, the number of cars sold in the BRIC nations equalled those sold in the USA. Framework conditions and consumer needs, however, differ widely between the four nations, necessitating a regional adaptation of strategies – in China and Russia, for instance, consumers prefer large – by western understanding "showy" – cars, whereas modern compact cars are well received in Brazil, as the Economist notes. Chances are that in the medium term, China will boast the world's largest car population. It goes without saying that reproducing western mobility lifestyles in the emerging markets will place great burdens on climate and environment. Against this background, the issue of sustainable mobility becomes much more pressing." (Ref: **CO_0005**)*

### 1.3.3 The Investment Factor

#### *1.3.3.1 Availability of Public and Private Resources and Investments in the Transport Sector*

**Driver description**

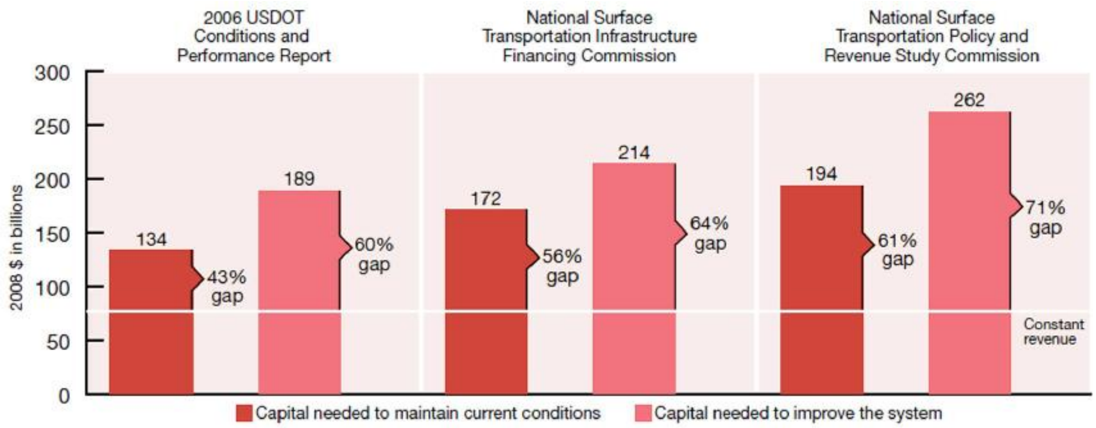
- *"There are ultimately two primary sources of financing – the user and the taxpayer. The choice of which source(s) to employ is, for the most part, independent of the model used to provide infrastructure. However, it has profound implications for the functioning of that model, including on the availability of financing and the use of the infrastructure. Making this choice is a key sovereign task that must be undertaken prior to the design of the model to be employed for providing the infrastructure." (Ref: **CO_0205**)*
- *"Whatever the models chosen for providing and financing infrastructure, government will retain key responsibilities, particularly with regard to establishing the policy frameworks under which financing occurs, and regulating this activity. However, the nature of government's role will be fundamentally transformed by the use of alternative financing, and government must develop appropriate structures to manage this." (Ref: **CO_0205**)*
- *"The extent and quality of transport infrastructure is of profound importance for the functioning of society and the economy." (Ref: **CO_0205**)*
- *"Investment in transportation infrastructure construction and transportation services has long been a favored policy option to aid economic recovery and accelerate employment growth." (Ref: **CO_0207**)*
- *"Infrastructure creates opportunities for mobility for people and goods. But infrastructure also has the ability to serve as a driver for transport development." (Ref: **CO_5048**)*
- *"The cost of EU infrastructure that would be required to match the demand for transport is estimated at over € 1.5 trillion for 2010-2030. However, in the coming years and decades there will be an increasing difficulty in finding the means for investing in transport infrastructure:*
  - → *an ageing society implies that larger amount of resources will be absorbed by social security expenditure;*
  - → *the 2008-9 economic crisis has severely hit public budgets and private lending. It will leave a legacy of long consolidation processes;*
  - → *the introduction of vehicles powered by alternative fuels and the greater use of public transport will reduce revenues from excise duties on gasoline and diesel." (Ref: **CO_0089**)*
- *"These developments will intensify the declining trend in transport infrastructure financing from government budget, which, before the financial crisis, was to some extent compensated by an increase in private sector financing." (Ref: **CO_0089**)*
- *"It is clear that investments in infrastructure – such as motorways, railways, terminals, ports, bridges and airports – and the physical conditions for mobility have a large impact on businesses in the transport sector, as well as on the behaviour of individuals." (Ref: **CO_6006**)*
- *"(...) improving transport connectivity can further concentrate economic activity. Roads and rails run both ways—better transport connectivity not only provides market access to firms in lagging areas, but also allows firms in leading areas to reach markets." (Ref: **CO_5028**)*
- *"The incremental economic benefit of roadway expansion is declining in developed countries. Figure below shows how highway investment economic returns exceeded those of private capital investments during the 1950s and 60s, but returns declined below private investments by the 1980s, and these trends are likely to continue, since the most cost-effective roadway investments have already been made." (Ref: **CO_5047**)*




Source: The Future Isnt What It Used To Be. Changing Trends And Their Implications For Transport Planning. (Ref: **CO_5047**)

**Figure 1-47 Annual highway rate of return**

- *"In Europe, the motorway construction era has ended with most resources now being placed in upgrading and extending the Trans European Rail Network (TERN). It is expected that this new age of the train will allow travel between the main cities of Europe at speeds averaging > 200 km per h (maximum speed of 300 km per h)." (Ref: **CO_4017**)*
- *"One aspect of the recent crisis has been a lack/shortage of availability of funds for businesses, since the banks have cut down heavily on lending. This clearly has direct impacts on the transport system, such as on the building of infrastructure which is not financed by national governments and on the viability of companies providing transport services." (Ref: **CO_5048**)*
- *"(...) public-sector funding provides a major part of the overall financing volume for transport infrastructure investments, at an average of 52.9 per cent in developing countries (...)" (Ref: **CO_0210**)*
- *"(...) government budgets are tighter than they've ever been: Infrastructure maintenance and improvement funding gaps as high as 70 percent are not uncommon, according to the American Association of State Highway and Transportation Officials." (Ref: **CO_0209**)*




Source: Investing in transportation: doing more with less (Ref: **CO_0209**)

**Figure 1-48 Average annual capital needs and gap estimates, all levels of government, 2008–2035**

- *"Infrastructure investment across all modes must not be neglected; innovative funding arrangements will need to be further developed." (Ref: **CO_0284**)*
- *"The automobile industry is now mature and overcapitalized. World vehicle production capacity significantly exceeds demand. As a result, vehicle manufacturing profits are low and likely to decline in the future. Although the automobile industry was once a leader in providing good wages, benefits and local taxes, this is no longer true. Many other industries now pay*

*comparable or better wages, and manufacturers demand various financial incentives from governments (tax rebates, infrastructure expenditures and training programs) in exchange for locating industrial facilities in a jurisdiction, capturing much of the economic benefits. As a result, there is declining justification for public policies that favour the automobile industry.“ (Ref: **CO_5047**)*

- *"In the medium and long term, investment in the transport sector could be shifted substantially from MIT[19] investment to public transport and NMT[20] investment. Then the growing PT expenditure could be afforded by countries and local authorities." (Ref: **CO_5006**)*
- *"The new popularity of public transport, in particular projects involving segregated infrastructure, will not drive down public spending, quite the contrary." (Ref: **CO_0034**)*
- *"We need significant investment in battery and fuel technology to take alternative energy-powered vehicles to scale over the next few decades." (Ref: **CO_5018**)*

### Interactions within the Economy Domain

*GDP trends*

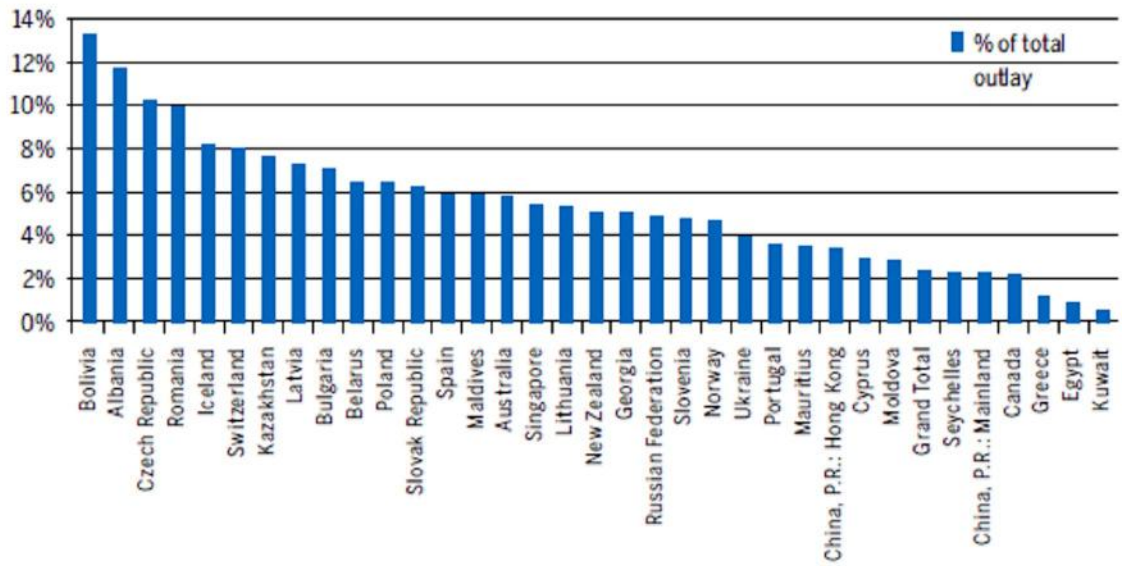
- *"Public investment in transport typically accounts for 2.0 to 2.5 per cent of GDP and may rise as high as 4 per cent or more in countries modernizing or building new transport infrastructure." (Ref: **CO_0204**)*
- *"Total public spending on transport and water infrastructure has fallen steadily since the 1960s and now stands at 2.4% of GDP. Europe, by contrast, invests 5% of GDP in its infrastructure, while China is racing into the future at 9%. America's spending as a share of GDP has not come close to European levels for over 50 years." (Ref: **CO_0213**)*


Source: The Economist (Ref: **CO_0213**)

**Figure 1-49 American public spending on transport and water infrastructure as % of GDP**

- *"Following a period of relative (economic) decline, more large cities have decided to boost investment in UPT[21] in light of projected needs to 2025/30, both in the industrialised world and in emerging countries such as Brazil, China and India." (Ref: **CO_5042**)*

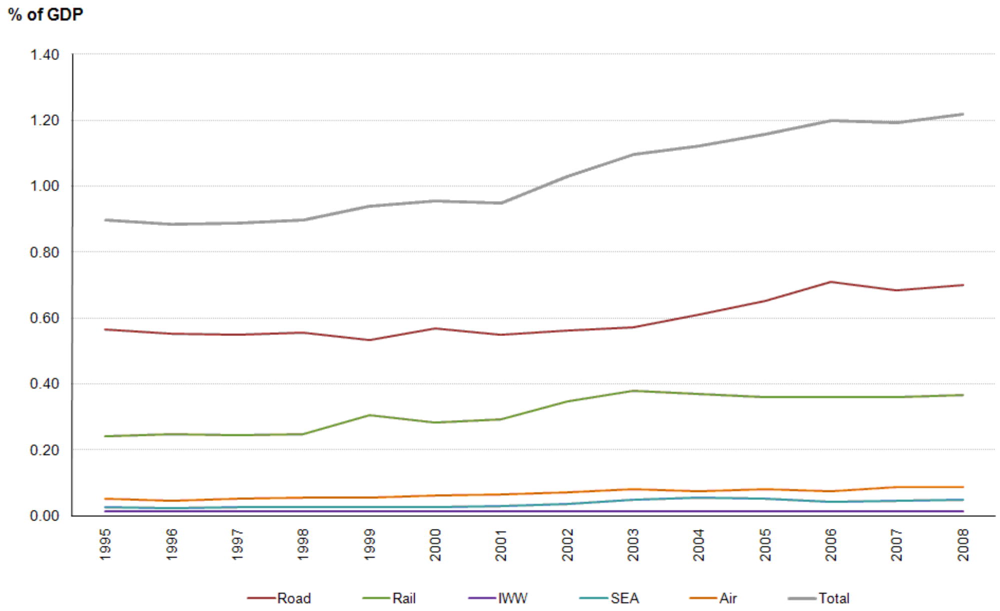
[19] Motorised Individual Transport
[20] Non-Motorised Transport (pedestrian and bicycle traffic)
[21] Urban Public Transport




Source: A paradigm shift towards sustainable low-carbon transport (Ref: **CO_0211**)

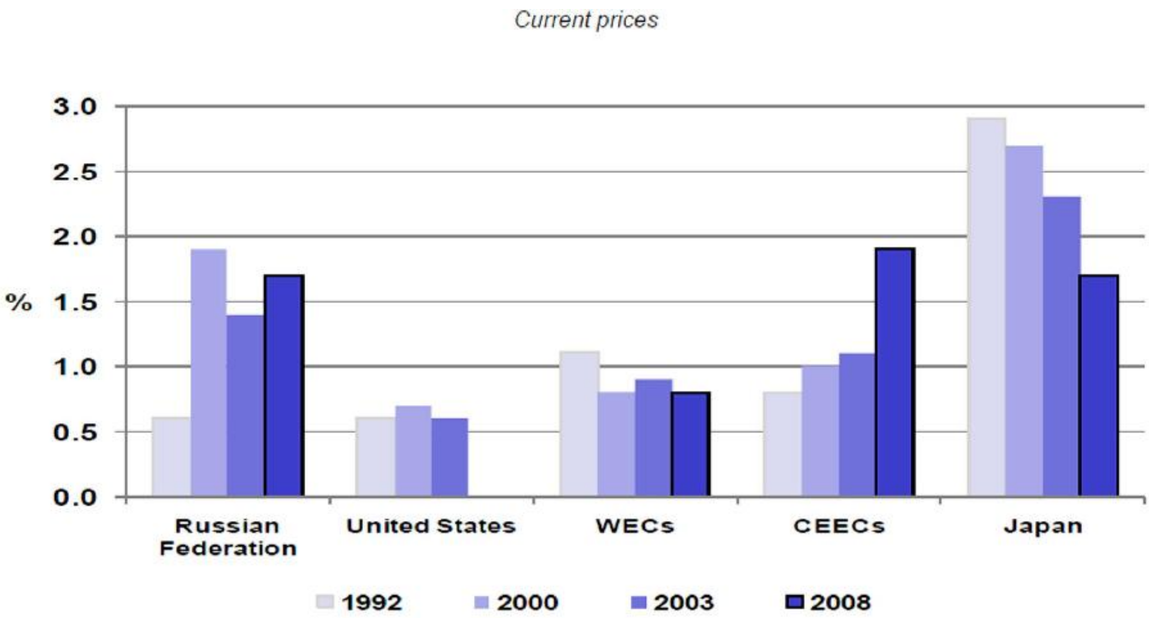
**Figure 1-50 Percentage of transport in national budgets for selected countries in 2005**

- *"Road infrastructure is perceived to be a "driver of economic growth." (Ref: **CO_0211**)*
- *"Investment in inland transport infrastructure (road, rail, inland waterways) as a percentage of Gross Domestic Product (GDP) has declined steadily in Western Europe since the 1970s. Our first reports from the 1980s noted this decline from an average 1.5% in 1975 to 1.2% in 1980 and further to 1.0% in 1982, after which it levelled off. Our most recent data show that investment in inland transport infrastructure as a percentage of GDP declined again in the 1990s in Western European countries (WECs), to around 0.8% in 2000, where it has remained. However, there are marked differences between countries, especially for recent years, varying from 0.5% in Denmark to 1.1% in Spain in 2009." (Ref: **CO_0109**)*
- *"For the 20 Member States included in the EEA32 analysis, the annual investment in transport infrastructure in absolute terms has risen steadily from around €67 bn in 1995 to more than €120 bn in 2008. This equates to a rise from around 0.9% of GDP to approximately 1.2% of GDP in the same period (a third increase). Road infrastructure has accounted for by far the largest expenditure in every year, though its share is smaller than a decade ago (from 62% to 58% in the decade to 2008). The share of investment in rail has increased slightly (28-30%) in the last 10 years, as have the shares of investment in sea (3-4%) and air (6-7%) infrastructure. However, looking over the last 5 years this trend reverses: the share of road infrastructure has increased between 2003 and 2008 (52%-58%), whilst the share of investment in all other modes has dropped. Inland waterways continue to attract the lowest share of infrastructure investment; its share has shrunk by nearly a third over 10 years to just over 1% in 2008." (Ref: **CO_0111**)*




Source: European Environment Agency 2010 (Ref: **CO_0112**)

**Figure 1-51 Investment in transport infrastructure by mode as % of GDP**




*Source*: ITF Investment in Transport Infrastructure. *Note*: CEECs and WECs in Euros, current prices and exchange rates. Japan 2008 refers to 2007.

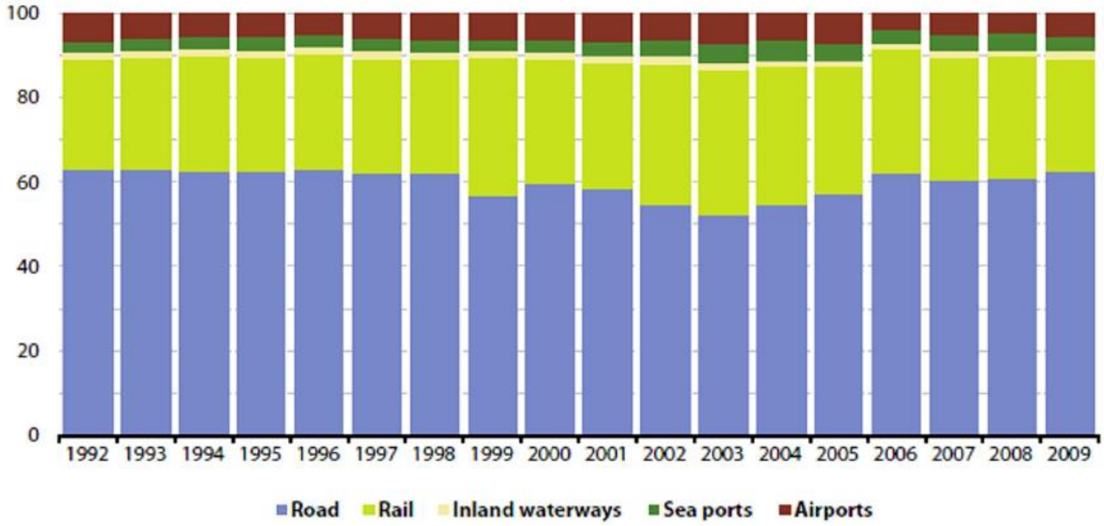
Source: International Transport Forum (Ref: **CO_0110**)

**Figure 1-52 Investment in inland transport infrastructure as % of GDP**

- *"(...) it is unsatisfactory to deal with the ratio of the public debt to GDP by considering the growth rate of the economy as independent of the composition of public spending. A larger share of public spending devoted to "productive expenditures" can positively affect the growth rate and, hence, the ratio of public debt to GDP." (Ref: **CO_0236**)*
- *"(...) the concern for a continuously growing ratio of the public debt to GDP does not derive from the unlikely possibility of a default of the state, but rather from the fact that a growing debt ratio indicates that the government is not using resources in an "efficient" manner. The government is spending resources in such a way that the GDP does not grow sufficiently to keep the debt ratio stable." (Ref: **CO_0236**)*
- *"The economic and financial crisis has laid bare the weaknesses of the dominant growth model in no uncertain terms. Manifestly, this growth, which was largely abandoned to market forces,*

*was not sustainable. (...) A simple return to pre-crisis business as usual scarcely seems convincing. If more balanced and social growth is to be achieved we have to bid farewell to the idea of »efficient« financial markets." (Ref: **CO_0235**)*

- *"(...) the rate of economic growth itself is not independent from public spending: in the short run, the existence of stable public expenditures restrain the size of recessions (through "automatic stabilizers"); in the long run, public investment and expenditures (education, health, research, infrastructures (...)) stimulate growth." (Ref: **CO_0242**)*
- *"Economic wealth provides for improvements in infrastructure, which increases the mobility of people and economic growth. Therefore, it is clear that economic growth has a very direct effect on the demand for transport and logistics services." (Ref: **CO_6006**)*
- *"A substantial cut in investments between 2007 and 2008 led to lower financing for all transport modes. Although the distribution of investment between the different transport infrastructures did not change significantly between 2007 and 2009, some modes did experience changes over the period 2000 to 2009. The share of road infrastructure investments fell from 60 % in 2000 to 52 % in 2003, but has since returned to 62 %. Investments in rail infrastructure have been in decline since 2003." (Ref: **CO_0197**)*




Source: Sustainable development in the European Union (Ref: **CO_0197**)

**Figure 1-53 Investment in transport infrastructure by mode, EU**

#### Employment

- *"It is often difficult to determine whether highway construction and maintenance jobs should be considered newly created jobs, relocated jobs, long-term jobs or short-term jobs." (Ref: **CO_0113**)*
- *"(In Unites States) an estimated 30,000 jobs are supported per billion dollars of spending. (...) The national rate can vary from of 24,000 to 41,000 jobs per billion dollars of spending, depending on the spending mix. The lower figure holds for spending on capital investments (vehicles and facilities), while the higher figure holds for spending on transit system operations." (Ref: **CO_0207**)*

#### Regional differences in economics

- *"Recent externality based growth models suggest that differences in public spending policies are able to explain, at least in part, the observed differences in growth rates across countries. This view has revived interest among economists in re-evaluating the relationship between the levels and the compositions of public spending and growth performances of countries." (Ref: **CO_0214**)*
- *"In a cross-country study, Easterly and Rebelo (1993) find that public investment in T&C sector is consistently positively correlated with growth with a very high coefficient (between 0.59 and 0.66)." (Ref: **CO_0214**)*
- *"Passenger transport is equally important for the region's economies. During the rapid catch-up phase of economic growth, the investments of countries of the region have focused on providing*

*international connectivity at the land-sea interface, exacerbating subnational disparities. More recently, their focus has typically included providing access for rural areas and small towns." (Ref: **CO_0204**)*

- *"The impressive growth of shipping in Asia is in large part due to the formation of regional production networks (RPN), whereby countries specialize in the production of particular components which are shipped from one country to another until final product assembly, a process that is often referred to as "regionalization"." (Ref: **CO_0204**)*

#### Foreign trade, globalisation

- *"Transport development has been a major factor driving the internationalization of production. (...) Large investments have been made in seaports to achieve the significant productivity gains from containers and changes in shipping technology." (Ref: **CO_0204**)*
- *"Falling transport costs in the 100 years or so before World War II brought closer economic integration within and between countries. Then, as in the twentieth century, the fall was caused by large infrastructure investments and breakthroughs in transport technology." (Ref: **CO_5028**)*
- *"Freight costs have about halved since the mid-1970s, driven by investments in transport infrastructure, better capacity use, and technological progress." (Ref: **CO_5028**)*

### Interactions with the Social Domain

#### Income structure and distribution

- *"Calderón and Servén (2004) examined the relationship between the breadth and quality of infrastructure and income inequality using a sample of 121 countries including 26 EU countries (UK was not included) and spanning the years 1960-2000. The study found that the Gini coefficient was negatively correlated with transport (-0.48 for roads, and – 0.57 for roads and rail). This suggests that public investments in transport and particularly rail are strongly associated with income equality. There are various reasons why infrastructure development may disproportionately benefit the poor. There is evidence that better transportation infrastructure helps poorer individuals to gain access to additional productive opportunities (Estache, 2003). It can also decrease production and transaction costs (Gannon and Liu, 1997) and raise the value of the assets (homes, agricultural land) of the poor (Jacoby, 2000). From the UK there is evidence suggesting that commuting to work distances are increasing. People are less likely to relocate, to find a job, rather they will increase their job search area to find a job and stay put. This suggests that households are increasing their spending on travel to work. Investments in transport, particularly public transport, is therefore likely to have an increasing equalising effect." (Ref: **CO_5054**)*
- *"However, the TEN-T related investment may also benefit, and potentially disproportionately benefit, higher income groups making use of the high speed rail infrastructure." (Ref: **CO_5054**)*
- *"Transport investments in roads (...) are likely to be somewhat less effective in reducing inequality because the benefits tend to accrue to those owning cars and because effects on property values are likely to benefit more middle and higher income groups than those on low incomes.(...) Bearing in mind the above and the evidence of Calderón and Servén (2004) it is reasonable to suggest that basic roads infrastructure is likely to be pro poor through improving the access of lower income groups living in, for example, rural areas. However, roads infrastructure in urban areas that is characteristically expensive is less likely to be pro poor." (Ref: **CO_5054**)*
- *"Airports is likely to bring more benefits to middle and higher income groups than low income groups because higher income groups travel more. (...) However, airports and related developments are major sources of employment and local economic activity and potential a source of construction, maintenance and service sector employment of benefit to lower income groups. They may also be associated with significant regional economic multiplier effects." (Ref: **CO_5054**)*

#### Urbanisation

- *"It is particularly important to gain greater understanding of the impact new transport infrastructure has on land. Investment in new motorways, for example, can accelerate urban sprawl by facilitating the growth of edge-of-town shopping centres and residential zones." (Ref: **CO_0260**)*

- *"(...) transport infrastructure also fuels urban sprawl when land use and urban planning policies are not optimised so as to avoid induced impacts, breaking down old distinctions between urban and rural land, and leading to a vast extension of urban uses in former rural areas." (Ref: **CO_5030**)*
- *"New transport investment, in particular motorway construction, can be a powerful stimulant for new development and sprawl, including shopping centres and residential areas." (Ref: **CO_0028**)*
- *"(...) newly constructed infrastructure, in return, spurs further urban sprawl – investments made in new motorways or road connections attract new development along the improved transport lines." (Ref: **CO_0034**)*
- *"Similarly, the construction of public transport links such as light railways and tramways tends to increase housing densities around access points." (Ref: **CO_0260**)*

#### Change of lifestyle and values

- *"Where regions suffer from economic or social problems, transport infrastructure projects could either result in further exclusion of such communities or could contribute to addressing the problem of social exclusion by improving accessibility and mobility." (Ref: **CO_0113**)*
- *"Sharing risk and liability with public-private partnerships will play a role, as will road pricing. The public perception that such pricing schemes are just an additional tax needs to be tackle." (Ref: **CO_0284**)*

### Interactions with the Environment Domain

#### Climate change impacts

- *"The 10-year increase in the share of investment directed towards rail and sea infrastructure could be seen as a positive shift towards more environmentally friendly modes of transport. However, in the case of sea infrastructure it could equally be argued that the investment has enabled an overall increase in freight movement, rather than shifting freight away from less environmentally friendly modes. Additionally, the more recent trend for road transport to take an increasing proportion of infrastructure investment could be seen as regressive from an environmental perspective." (Ref: **CO_0111**)*

#### GHG mitigation

- *"Between 2000 and 2009 the share of investments in the infrastructure of transport modes with lower environmental impacts (rail, maritime and inland waterways) decreased slightly. Road infrastructure investments remain dominant in the EU." (Ref: **CO_0197**)*
- *"Investment in public transportation and vehicle efficiency improvements generates exceptional economic returns. Several scenarios show that a green, low carbon, transport sector can reduce greenhouse gas emissions by 70 per cent without major additional investment." (Ref: **CO_0210**)*

#### Noise levels and emissions standards

- *"Transportation investment can reduce noise pollution – New automobiles are far quieter than their predecessors thanks to advances in engine technology. Erecting "green" roadway sound barriers can muffle the sound of passing vehicles." (Ref: **CO_0206**)*
- *"Noise barriers reduce noise levels by five to 10 decibels, cutting the loudness of traffic noise by as much as 50 percent." (Ref: **CO_0206**)*

#### Pollution levels and emissions standards

- *"Public funding at all levels (international – including Official Development Assistance (ODA) and climate related funds – national and local) is mobilised to support green transport." (Ref: **CO_0210**)*
- *"Private finance is leveraged, through the appropriate design of markets and the creation of consistent, longterm incentives to invest in green transport and through the application of public-private sector models to invest in and operate green transport systems (such as Bus Rapid Transit (BRT) systems)." (Ref: **CO_0210**)*
- *"Transportation investment can improve air quality and energy efficiency – Investments in clean vehicle technology, clean fuel technology, and congestion relief projects can reduce emissions*

*and contribute to energy efficiency. Investments in ridesharing programs, transit, pedestrian, and bicycle facilities can reduce vehicle miles traveled." (Ref: **CO_0206**)*

## Interactions with the Technology Domain

### *Technology development and innovation diffusion*

- *"The private sector is the major driver of innovation and the diffusion of technologies around the world. But governments can help to promote international collaboration to overcome barriers to technology development. Technology co-operation enables the sharing of risks, rewards and progress of technology development and enables co-ordination of priorities." (Ref: **CO_2024**)*
- *"The private sector plays the major role in R&D and technology diffusion, but closer collaboration between government and industry will further stimulate the development of a broad portfolio of low carbon technologies and reduce costs." (Ref: **CO_2024**)*
- *"Technology development tends to be driven most by corporate R&D and the public, especially those with few resources, struggle to access much of it." (Ref: **CO_5018**)*
- *"(...) there are also important uncertainties regarding the availability of R&D funding because of public and corporate budget constraints, public policy development and the availability of a sufficiently skilled labour force, which could be affected by barriers to international migration." (Ref: **CO_0274**)*
- *"More investment in low-carbon energy technology RD&D is needed at all stages of technology development. This should include direct government funding, grants and private-sector investment." (Ref: **CO_0154**)*
- *"The whole transport systems of countries or large urban areas can be made more efficient by capital spending and by innovations removing their chronic weaknesses. This goal, however, cannot be achieved by innovation alone, if it is not accompanied by the necessary investment in order to replace traditional elements of the system. Innovation becomes a must if traditional heavy spending on the existing transport systems produces no results." (Ref: **CO_5065**)*
- *"Increased public investments in infrastructure will be concentrated on the large-scale 'debottlenecking' (local expansion of road area) and upgrading (more, and stronger, bridges, tunnels, viaducts) of the congested economic regions and interconnecting corridors. The initial focus will be on those regions and corridors where the existing quality of infrastructure will allow for the most cost-effective development. After the next decade, investment will shift towards the development and introduction of advanced technology, such as intelligent systems for traffic management (e.g. cooperative systems)." (Ref: **CO_0077**)*

### *Traffic management systems*

- *"Investment in viable alternatives to congested road corridors can support intelligent solutions involving co-modal logistic chains, which optimise the use of transport infrastructure within and across different modes. This includes transalpine tunnels, rail corridors and intermodal nodes for rail, sea and air transport." (Ref: **CO_0255**)*

### *Information systems*

- *"Lack of funding to improve the current physical infrastructure puts a premium on intelligent solutions that can raise the potential of existing transportation systems." (Ref: **CO_0284**)*

### *Pollution abatement and monitoring*

- *"Tremendous strides in engine technology mean that the average car today produces 60 to 80 percent less pollution than the average car did in the 1960s." (Ref: **CO_0206**)*

### *Renewable energy production*

- *"Different renewable energy sources are at various stages of technological and commercial development. Under favourable conditions, wind, hydro, biomass and solar-thermal sources of energy are economically viable. Others like photovoltaic energy (which uses silicon panels to generate electricity from sunlight) require increased demand to improve economies of scale." (Ref: **CO_0270**)*
- *"In 2008 and 2009, the governments of many countries committed additional funds for renewable energy through economic recovery and stimulus packages. These short-term measures need*

*also to be coupled with more longterm oriented policy action to tackle non-economic barriers to the wider deployment of renewables." (Ref: **CO_0153**)*

- *"State support has undoubtedly kick-started the photovoltaic market across the EU. But with state budgets under severe strain there is no guarantee the same level of support will be available in the future." (Ref: **CO_0267**)*
- *"By 2020 we expect that there will be no incentives and that PV installations will be profitable without them." (Ref: **CO_0267**)*

#### *Energy efficiency*

- *"Since running eco-driving courses is relatively inexpensive, and the lifetime fuel savings per person can be very high, the cost-effectiveness of eco-driving is generally considered to be excellent." (Ref: **CO_0154**)*

### Impacts on Mobility and Transport

#### *Investment opportunities and transport modes*

- *"Infrastructure creates opportunities for mobility for people and goods. But infrastructure also has the ability to serve as a driver for transport development." (Ref: **CO_5048**)*
- *"Particularly in congested cases it is doubtful whether an expansion of infrastructure capacity will improve the mobility in the long term. Analyses have shown that expansion of infrastructure capacity in uncongested cases has a limited effect on mobility, whereas expansion of road infrastructure capacity in congested cases leads to a fast development of mobility, and a possible change of land use encouraging urban sprawl along the expanded infrastructure. Whilst, a part of the new demand is latent demand suppressed due to high costs of congestion, another part may be real new demand." (Ref: **CO_5048**)*
- *"An often promoted policy is to invest in public transport. According to the analysis presented here this will only have a substantial effect if the door-to-door speed of public transport at least equals that of the car. And this seems only feasible in large cities where car driving slows down to an average of 10 or 20 km/h and on longer distances between city centers, where public transport can reach a speed of 100 km/h. On other medium distances the car is unbeatable. Policy makers should avoid illusions about the effectiveness of promoting public transport as an instrument to reduce car mobility." (Ref: **CO_2046**)*

#### *Financial management schemes*

- *"The construction and maintenance of transport infrastructure will put enormous financial pressure on public entities. A possible reaction to this may be increased privatisation of transport infrastructure and services. In addition, we may see more financing models based on the "user-pays" principle." (Ref: **CO_0079**)*

### 1.3.4 The Market Structure Factor

#### *1.3.4.1 Market regulations*

**Driver description**

The influence and the role of market structures on future transport development is analysed through the relative importance of rules and regulation on (more or less) market liberalisation. The interactions with the various socio-economic domains and finally on mobility and transport are developed according to socio-economic scenarios ranging from lower level of regulation (i.e. liberalised markets) to stricter rules and regulation (regulated markets).

The sources of the scenarios are drawn basically from the following studies:

- TRANSvisions, Report on Transport Scenarios with a 20 and 40 Year Horizon, (DG TREN, 2009)
- CPB ìFour Scenarios for Europeò study (CPB, 2003).

The two studies have developed the following scenarios, for which the table below summarises the respective types of market regulation envisaged.

| Scenario | Market regulation | Characteristics |
|---|---|---|
| Hyper-mobility or Induced mobility scenario/Global Economy | Low | Strong market liberalisation |
| Decoupled mobility scenario /Strong Europe | Medium | Market regulation and international co-operation |
| Reduced mobility scenario/Regional Communities | High | National and regional market fragmentation |

**Interactions within the Economy Domain**

***GDP trends***

- *Hyper-mobility or Induced mobility scenario (strong market liberalization). "International integration and market-oriented domestic policies stimulate labour productivity which grows by 2.1% per year up to 2020 and by 2.0 thereafter. GDP grows rapidly due to significant employment growth. After 2020, growth falls somewhat since GDP growth levels off." ( Ref: **CO_5048**)*
- *Decoupled mobility scenario (strong co-operation and market regulation). "Annual GDP growth, equal to the sum of productivity and employment growth, thus falls from 3.0% between 2005 and 2020 to 2.7% between 2005 and 2030, and to 2.4% between 2005 and 2050." (Ref: **CO_5048**)*
- *Reduced mobility scenario (European market fragmented in a number of trade blocks). "GDP hardly grows after 2020, with a growth rate near to zero (0.4%) substantially smaller than the 2.2% that Europe experienced in the recent past." (Ref: **CO_5048**)*
- *"GDP growth in Regional Communities is less than a quarter of that in Global Economy: 0.6% versus 2.4%." (Ref: **CO_1010**)*
- *Hyper-mobility or Induced mobility scenario (strong market liberalization). "European countries find a new balance between private and public responsibility. Institutions are increasingly based on private initiatives and market-based solutions. Economic integration becomes broader, however, as countries find it in their mutual interest. The European Union finds relatively easy to enlarge further eastwards." (Ref: **CO_5048**)*
- *Decoupled mobility scenario (strong co-operation and market regulation). "The EU opens its borders further eastwards. Turkey becomes an EU member and, although Ukraine and Russia do not become full members, they become more integrated with Europe." (Ref: **CO_5048**)*
- *Reduced mobility scenario (European market fragmented in a number of trade blocks). "Poor member states from the Central and Eastern European countries are unable to absorb funds because they cannot comply with the complex and demanding administrative procedures set by the EU. Moreover, a large part of the cohesion budget is transferred to richer member states that are unwilling to give up their share." (Ref: **CO_5048**)*

- *"Economic integration boost trade in Global Economy and Strong Europe. World exports increase by 5½% and 4½%." (Ref: **CO_1010**)*
- *"Governments must ensure their policies do not actively work against achieving cleaner, more seamless transport by 2030. (...) Poorly aligned fiscal and regulatory instruments create uncertainty in the private sector regarding investments in greener and seamless transport." (Ref: **CO_0284**)*

*Foreign trade, globalisation*

- *"The growing integration of national economies into the world's trading system over the post-war period was driven not only by trade liberalisation but also by falling transportation and communication costs, rising income levels, higher productivity growth rates in tradable compared with non-tradable, and more recently by an ICT-enabled acceleration in the international division of labour linked with the development of increasingly global production systems. All these developments have led to a sharp increase in overall trade flows, underpinned by an expansion in both intra-industry flows and in a range of internationally tradable services" (Ref: **CO_5048**)*
- *Hyper-mobility or Induced mobility scenario (strong market liberalization). "Until 2020, world trade shows an increase of about 6% per year. After 2020, growth falls somewhat since GDP growth levels off. In 2000, almost 54% of all exports by EU countries have destinations within the European countries. Slightly more than 18% is shipped to non-OECD countries (mainly to Asia) while the remaining 28% flows more or less equally to the United States, the rest of the OECD and the Eastern part of Europe (the Central and Eastern European countries, Russia and Turkey).The direction of trade changes drastically in the future scenario. Asia will become a much more important trading partner for Europe during the coming decades, also due to the consistent growth of Asian economies (and primarily China and India). In 2040, about 60% of all European exports have a destination outside Europe, compared with less than 50% in 2000." (Ref: **CO_5048**)*
- *Hyper-mobility or Induced mobility scenario (strong market liberalization). "The share of services in the economy grows, and the EU maintains its comparative advantage in chemicals and minerals and business services, while the current comparative advantage in agriculture and food – somewhat artificially due to the Common Agriculture Policy – disappears. In contrast, the export pattern of EU becomes more specialised in trade and transport services." (Ref: **CO_5048**)*
- *Decoupled mobility scenario (strong co-operation and market regulation). "The integration of goods and services markets leads to large trade volumes and changing trade patterns. World exports increase by 4.8% per year until 2020, and by 4.1% thereafter. The larger in the period before 2020 is due to higher GDP growth and trade-liberalisation policies during that period." (Ref: **CO_5048**)*
- *Reduced mobility scenario (European market fragmented in a number of trade blocks). "A general reduction of international trade must be stressed. Many mature European industries are protected from outside competition through trade barriers. This holds in particular for agriculture, which is protected by the Common Agricultural Policy, but also for network industries. The scenario assumes also regional trade liberalisation between the Americas from 2015. In this situation, there will be only small changes in the trade patterns. The share of exports to non-OECD regions increases from 18% in 2000 to nearly 23% in 2040. This comes at the expense of trade with the rest of the OECD. The share of intra-EU trade remains stable because of the elimination of non-tariff barriers between the EU15 countries (the core EU group)." (Ref: **CO_5048**)*
- *Strong Europe and Global Economy scenarios "Market liberalisation and global trade liberalisation are successfully pursued and leads to a reduction in tariffs and non-tariff barriers in 2005 and 2015." (Ref: **CO_1010**)*

*Intensified competition for scarce resources*

Market regulation and related strategies are tools designed to stimulate efficiency where competition is not possible, or not suitable to achieve social aims. Regulatory strategies might be particularly useful when resources are scarce, since competition usually leads to a reduction of costs and therefore to demand of resources.

*Fiscal policy*

- *Hyper-mobility or Induced mobility scenario (strong market liberalization). "Reforms in the labour market, income taxation and social security encourage labour force participation. This applies particularly to elderly workers. Their incentives to participate increase because of reforms in early retirement provisions, tougher eligibility criteria in social security and an increase in retirement age. As ageing tends otherwise to reduce the supply of capital savings fall after 2020 by around 4% points. This is less than in the other scenarios, however because governments increase national savings by prudent government budgetary policies an early reforms in pensions towards individualised defined-contribution schemes." (Ref: **CO_5048**)*
- *Decoupled mobility scenario (strong co-operation and market regulation). "Savings decline, especially after 2020. This is because the growing retired population dissaves and policies to increase savings cannot fully compensate for this. Indeed, in some European countries, national savings are stimulated by redirecting pension systems toward more funding and/or by sustained surpluses on the government budget." (Ref: **CO_5048**)*
- *Reduced mobility scenario (European market fragmented in a number of trade blocks). "Increasing expenditure on old-age benefits and publicly provided health care pushes European public sectors to their boundaries. Inefficient and large public sectors render sustainable public finance problematic." (Ref: **CO_5048**)*

## Interactions with the Social Domain

*Migration flows*

- *Hyper-mobility or Induced mobility scenario (strong market liberalization). "The EU follows a selective immigration policy by allowing each year a fixed number of immigrants, which ensures that immigrants are high-skilled and they easily enter the European labour market." (Ref: **CO_5048**)*
- *Hyper-mobility or Induced mobility scenario (strong market liberalization). "Personal services (e.g. home elderly care) continue to be increasingly provided in the richer EU countries by low-skilled immigrants from less well-off European countries or poorer countries outside Europe." (Ref: **CO_5048**)*
- *Hyper-mobility or Induced mobility scenario (strong market liberalization). "Immigration is facilitated by the reformed, flexible European labour markets, which can easily absorb new workers" (Ref: **CO_5048**)*
- *Decoupled mobility scenario (strong co-operation and market regulation). "Labour mobility is encouraged by the removal of institutional barriers to migration. (Immigration policy is coordinated by the European Union. With a focus on international cooperation and solidarity with other regions, European immigration rules become less strict and immigration flows increase. The reformed, more flexible labour markets are able to integrate the majority of immigrants in European societies" (Ref: **CO_5048**)*
- *Reduced mobility scenario (European market fragmented in a number of trade blocks). "Migration is restricted within the European Union. Only a limited number of immigrants from the Central and Eastern European countries move towards the core of Europe." (Ref: **CO_5048**)*
- *Reduced mobility scenario (European market fragmented in a number of trade blocks). "The labour force participation rate falls from 46.7% of the population in 2000 to 40.2% in 2040 and beyond. Apart from ageing, this is the result of the adverse incentive effects of fairly generous social security systems and labour-market regulations" (Ref: **CO_5048**)*

*Urbanisation*

- *Hyper-mobility or Induced mobility scenario (strong market liberalization). "While a significant number of, mainly younger, people thrive on the buzz of living in the urban hubs, tele-presencing and ever more powerful miniature communication devices are increasingly allowing the more affluent to move to the outskirts of towns or to rural areas, accelerating the trend toward urban sprawl" (Ref: **CO_5048**)*
- *Decoupled mobility scenario (strong co-operation and market regulation). "Population, housing density and employment in big cities are rising faster than before. Cities are more compact, widening the range of local opportunities and activities that are accessible without using the car." (Ref: **CO_5048**)*

- *Reduced mobility scenario (European market fragmented in a number of trade blocks). "Large cities start to decline." (Ref: **CO_5048**)*

*Planning*

- *"The introduction of a correct pricing system will help in better factoring transport costs into location decisions; even so, however, there is a risk that transport costs are not properly taken into account by planners and that the availability of cheap transport solutions is taken for granted." (Ref: **CO_0015**)*

*Change of lifestyle and values*

- *Hyper-mobility or Induced mobility scenario (strong market liberalization). "Government regulations to ensure uniformity in supply (e.g. in pensions, housing and so on), are relaxed so as to meet more diversity in lifestyles. Governments remain responsible for the production of pure public goods (basic education, defence, police, justice), but also use the regulatory powers to ensure effective competition on markets" (Ref: **CO_5048**)*
- *Hyper-mobility or Induced mobility scenario (strong market liberalization). "As it concerns the prevailing people lifestyle, in the Hyper-mobility highly connected world, life and work are intense, and the boundary between them is blurred. Some thrive on the buzz of activity that results, but early burn-out is common and stress is a way of life for the vast majority of the EU population" (Ref: **CO_5048**)*
- *Hyper-mobility or Induced mobility scenario (strong market liberalization). "Toward the year 2050, intelligent positioning systems, encryption technology, real-time telepresencing and a shift towards a low-carbon economy have boosted the economy and accelerated consumerism that shows few signs of abating." (Ref: **CO_5048**)*
- *Reduced mobility scenario (European market fragmented in a number of trade blocks). " Self-help communities have started to emerge everywhere, in the urban and rural environment, to react to the staggering economy and the increasing inflation, which makes individualistic consumerist attitudes unaffordable for an increasing share of people. Local food production and services have increased." (Ref: **CO_5048**)*

### Interactions with the Environment Domain

*Climate change impacts*

- *Hyper-mobility or Induced mobility scenario (strong market liberalization). "Europe's waste footprint is still far large than Europe is." (Ref: **CO_5048**)*
- *Decoupled mobility scenario (strong co-operation and market regulation). "A global climate change mitigation policy aiming at reducing the GHG emissions by about 57% in 2050 compared to 2005 levels (corresponding to a atmospheric concentration of about 450 ppm of $CO2$-eq) caused a reduction of about 0,1% of the indicated annual GDP growth." (Ref: **CO_5048**)*
- *Reduced mobility scenario (European market fragmented in a number of trade blocks). "Carbon emissions have contracted, mostly, simply because far less energy is used than in the later 20th century." (Ref: **CO_5048**)*

*GHG mitigation*

- *"Various incentive and pricing schemes can be designed to reduce GHG travel. Road pricing for city centres or highway congestion can moderate traffic and reduce GHG intensive travel. Parking policies, such as park and ride near transit facilities and parking cash-out programmes by employers, encourage higher occupancy travel modes. Incentives by workplaces to promote telecommuting and carpooling can also help mitigate peak time congestion travel. Vehicle pricing in conjunction with improved transit service programmes, such as bus rapid transit, attracts travellers to higher occupancy and thus lower GHG modes." (Ref: **CO_0148**)*
- *"The political dilemma is to put in place the right economic incentives and regulatory measures that encourage efficient, cost effective transport services for all users. In the environmental debate, the price signal is very important but is not the sole element available to policymakers. Reducing regulations that make it difficult to either implement or simply test new schemes is essential." (Ref: **CO_0284**)*

*Energy availability, production and consumption*

- *Hyper-mobility or Induced mobility scenario (strong market liberalization). "The vision for the whole Europe is that, by 2050, non-fossil energy sources (excluding nuclear) will account for more than 35% of the total energy supply, with biomass, wind and solar energy taking leading roles." (Ref: **CO_5048**)*
- *Hyper-mobility or Induced mobility scenario (strong market liberalization). "About half of the EU member States will support the use of nuclear energy. Coal with CO2 capture will be applied on a large scale for the production of both electricity and hydrogen. The hydrogen will be used in the transport sector." (Ref: **CO_5048**)*
- *Reduced mobility scenario (European market fragmented in a number of trade blocks). "Small self powered communities have emerged, especially in the countryside, using wind, water and solar power." (Ref: **CO_5048**)*

*Scarce resources of raw materials*

- *Hyper-mobility or Induced mobility scenario (strong market liberalization). "Ever increasing consumption of goods and high-impact services means that society's waste footprint is growing inexorably and unsustainably." (Ref: **CO_5048**)*
- *Decoupled mobility scenario (strong co-operation and market regulation). "The concept of "zero-waste" society has been fully implemented in 2050, as even the notion of "waste" almost disappeared from the vocabulary. Instead, everything either gets recycled as a raw material for another production processes or returned." (Ref: **CO_5048**)*
- *"Resource pricing has a large role to play in managing demand for food, water and energy. Prices are kept artificially low by government subsidies or other regulation in many countries, thereby increasing demand. However, even if they were allowed to rise through market mechanisms, prices would not account for many of the negative externalities created by water, food and energy consumption. Both the cost of local impacts (such as the long-run social and environmental costs of resource exploitation) and global impacts (such as contribution to climate change through carbon emissions) should ideally be included in resource pricing. Without accurate pricing to reflect the full cost of resource use, it is likely that unsustainable decisions regarding resource use will continue." (Ref: **CO_0024**)*

**Interactions with the Technology Domain**

*Technology development in general and innovation diffusion*

- *Hyper-mobility or Induced mobility scenario (strong market liberalization). "The negotiations in the WTO lead to a successful liberalisation of global trade, including intellectual property and services." (Ref: **CO_5048**)*
- *Hyper-mobility or Induced mobility scenario (strong market liberalization). "A rapid institutional reform in these countries and a catching up of technology take place. Indeed, a surge of foreign direct investment flows into the Eastern regions of Europe." (Ref: **CO_5048**)*
- *Hyper-mobility or Induced mobility scenario (strong market liberalization). "As it concerns the development of specific IT and transport technologies, the foundations of hyper-mobility were laid down starting from 2009 with the development of a range of intelligent miniature devices able to connect consumers directly, and continuously, to national area wireless networks." (Ref: **CO_5048**)*
- *Reduced mobility scenario (European market fragmented in a number of trade blocks). "The lack of international competition in combination with extensive public intervention hurts economic efficiency and hinders development and diffusion of new technologies." (Ref: **CO_5048**)*
- *"The Global Economy scenario reflects an efficient functioning of markets, both nationally and internationally, which brings static efficiency gains but also dynamic technology gains. In Regional Communities lack of international competition in combination with extensive public intervention hurts economic efficiency and hinders development and diffusion of new technologies." (Ref: **CO_1010**)*

*Advanced Driving Devices*

- *Hyper-mobility or Induced mobility scenario (strong market liberalization). "In the field of drivers assistance, governments and local authorities worked with car manufacturers to integrate disparate vehicle management systems (on-board driver assistance, automated driving) designed to even out traffic flows and reduce congestion Information systems." (Ref: **CO_5048**)*

*Traffic management systems*

- *Hyper-mobility or Induced mobility scenario (strong market liberalization). "The development of GPS technologies, driver assistance supported by the interoperable Galileo and GPS systems helped to curb the number of road accidents." (Ref: **CO_5048**)*
- *"The competitively of railways for international passenger and freight traffic is still hampered to a large extent by lack of interoperability, i.e. different signalling and electrification systems in different countries, and for some countries, different track gauges. Thus, a second major plank of EU policy is to increase the interoperability of networks and control systems to improve efficiency. This involves directives and research into harmonising infrastructure, signalling, telecommunications and data transmission, as well as operational procedures." (Ref: **CO_0254**)*

*Renewable energy production*

- *Hyper-mobility or Induced mobility scenario (strong market liberalization). "In 2050 the "hydrogen economy" has become a reality. The combination of increased nuclear capacity and the development of renewables had reduced dependence on carbon-based fuels, which however remain the larger share of energy sources." (Ref: **CO_5048**)*

*Energy efficiency*

- *Hyper-mobility or Induced mobility scenario (strong market liberalization). "As it concerns the future development of vehicle technologies, in the hyper-mobility scenario, starting from a relatively modest level, a steadily increasing proportion of motive power has been supplied electrically. A growing proportion of engines has been equipped with electric starter/generator systems (hybrid vehicles), thereby improving emissions and fuel consumption." (Ref: **CO_5048**)*

### Impacts on Mobility and Transport

*Rail transport regulation*

- *"One of the key EU policies affecting rail traffic management has been opening of the rail market, involving the separation of rail infrastructure and train operations at national level and allowing new operators to provide passenger and freight services. This opening of networks has largely been achieved for rail freight services, whereas open access passenger services only exist in certain Member States so far, although public service contract awards to private train operators for passenger network operation are more common. This market opening has increased demands on rail network management, with the need to allocate and manage train slots to different operators, while at the same time ensuring maximum safety and reliability of passenger and freight services." (Ref: **CO_0254**)*

*Impacts of transport demand (long distance)*

- *"Decoupled mobility scenario (strong co-operation and market regulation). "In the transport sector, a significant decrease of transport demand can be observed and both for international and national transport as well as for passenger and freight transport, with technology substituting for mobility (through e-commerce and e-work)." (Ref: **CO_5048**)*

*Impacts of transport demand (short distance)*

- *"There is an increase in the demand for short-distance local mobility, both for work and for leisure. This is, however, primarily met through non-motorised transport. Non-motorised transport as well as shared modes of transport are explicitly supported through policy, i.e. tax-breaks, company transport plans, as well as RTD and ICT. Social inclusion as well as punctuality and reliability rather than speed are high on the transport policy agenda." (Ref: **CO_5048**)*

*Impacts on frequency and average distance*

- *Reduced mobility scenario (European market fragmented in a number of trade blocks). "Transport is slow: energy efficiency matters far more than speed. Economic production and development as well as transport are re-organised according to ecological principles supporting* *strong sustainability – in general and with regard to transport – and new forms of social organisation with less work, more leisure, strong voluntary sector and "togetherness" in consumption (e.g. co-housing, car-sharing, etc.) emerge." (Ref: **CO_5048**)*

*Impacts on transport intensity*

- *"The more the globalisation process deepens, and the more intensive the effects of globalisation, the more transport-intensive the given economy will become. The growth of freight transport intensity certainly increases the 'environmental bad', i.e. the load on the environment; consequently, we have to detach the negative effects resulting from increase of transport performances." (Ref: **CO_5055**)*

*Impacts on the use of private means of transport*

- *As people aspire to sustainable living, purchasing patterns would reflect ecological sensitivity, consumerism would abate and travel patterns would shift toward mass transport (Ref: **CO_1010**)*

*Impacts on air transport*

- *"Opening of the markets saw the rise of low-cost, low-service operators. The future may see something different – hybrid companies that operate services for all parts of the market.(...) Low cost airlines have arisen even without complete liberalisation and have quickly transformed into hybrids with the addition of long haul operations. Such changes have a profound effect on airports, as hubs require very different facilities from other airports. Changing airline business models will dictate future airport development." (Ref: **CO_0284**)*

*Development of infrastructures and technologies*

- *"It is evident that without strong government regulation, putting public interest and common good before individual concerns, transport markets will tend to develop along the lines of business as usual and little progress will be made in developing infrastructure and technologies to reduce the negative impacts of transport." (Ref: **CO_0159**)*

### 1.3.5 The Global Trade Factor

#### *1.3.5.1 Foreign Trade and Globalisation*

**Driver description**

- *"The post-1990 globalisation phase is characterised by three key interrelated phenomena which differentiate it from previous phases stretching back to the 1850's: firstly, an unprecedented deepening in trade and capital market integration; secondly, a cost-induced and ICT-enabled acceleration in the worldwide relocation of production processes, with an associated boost to trade in intermediate goods and services; and finally, regarding the developing world, higher trade and capital flows coupled with strong human capital endowments are driving a steady process of global income and technological convergence." (Ref: **CO_1002**)*
- *"(...) the growing integration of national economies into the world's trading system over the post-war period was driven not only by trade liberalisation but also by falling transportation and communication costs, rising income levels, higher productivity growth rates in tradeables compared with non-tradeables, and more recently by an ICT-enabled acceleration in the international division of labour linked with the development of increasingly global production systems. All these developments have led to a sharp increase in overall trade flows, underpinned by an expansion in both intraindustry flows and in a range of internationally tradeable services." (Ref: **CO_5048**)*
- *"Globalisation is leading to new ways of organising production and distribution, relying heavily on efficient supply chains and thus the organisation of the logistic process (...) This has been facilitated by the decline of international transport costs because carrying capacities have expanded and transport operators could take advantage of larger economies of scale." (Ref: **CO_5048**)*
- *"Transport costs and scale economies interact to produce the trade flows observed in the past half-century. The main insight from research is that the relationships between transport costs, production locations, and trade patterns are nonlinear. Falling transport costs first led to countries trading more with countries that were distant but dissimilar. When they fell further, they led to more trade with neighboring countries. Similarly, when transport costs fell from moderate levels, production concentrated in and around large markets." (Ref: **CO_5028**)*
- *"World trade is another important aspect of economic growth, and world trade can also be seen as an indicator for globalisation." (Ref: **CO_5048**)*
- *"The world economy continues to be the most important driver of growth. Trade has grown faster than emissions in practically all production sectors of the world economy. The role of foreign trade will grow and its share will increase, and this trend – after the temporary world economic recession – is likely to continue. Since the mid 1990s, the expansion has been driven by the reintegration of the countries of the former socialist bloc and the integration of developing countries into world trade. The key sector has been trade in services, which is likely to continue." (Ref: **CO_5055**)*
- *"While it is accepted that there will be winners and losers, this study shows clearly that when all the effects are properly accounted for, that the transition costs are in fact relatively small (less than 0.1 off the growth rate of EU living standards over the period 1991-2003), with offsetting effects on consumers and producers:*
  - → *On the consumption side, the downward pressure on consumer prices from cheaper imports has contributed to a doubling in the growth rate of real consumption wages over the 1990's in the EU (and in the US). This globalisation-linked increase in the consumer surplus has also been bolstered by the gains accruing from a significant increase in product varieties.*
  - → *On the production side, while the EU is holding its own in export markets both in terms of volumes and prices, domestically globalisation is being reflected in higher import penetration rates, increased net FDI outflows and a faster pace of external outsourcing of goods and services, all of which are potentially negative in the short run." (Ref: **CO_1002**)*
- *"The openness of the world economy is increasing and despite slowing world trade growth, world trade continues to be the driver of economic growth. The unfavourable side of globalisation and integration processes is that in most countries the growth of freight transport services exceeds*

*GDP growth, while most transport surpluses - contrary to the objectives of Marco Polo I - have not been diverted to rail or inland waterways but chiefly to the road." (Ref: **CO_5055**)*

- *"Nowadays, 1% GDP growth is commonly associated with world trade growth of 2.5-3.0%,and the level of transport services parallels this. The proportion of road transport within this growing transport sector is increasing as well. One reason for this is that land transport has more favourable commercial speed (the total distance taken between the place of despatch and the destination). In Europe, this is approximately 300 km/day for rail transport and 1000 km/day for road transport. While transport policies of developed countries, including the European Union, aim to achieve a transport performance level for themselves that is decreasing, or increases less compared to the level of their economic growth, world trade trends result in the opposite: a unit of GDP growth is coupled with a much higher level of transport performance." (Ref: **CO_5055**)*
- *"In the intermodal competition, the time factor is the greatest issue for goods transport by rail: the rail's trading rate is barely one third of the road's. Reduction of the time factor is mainly impeded by the following factors: the rate of the so-called operation times is very high in relation to useful running, the EU's railway network – for historical reasons – is fragmented (there are so many countries and at least as many rail infrastructure companies), different standards exist (e.g. in electric traction), and technical standards vary between member countries. With combined (mainly containerised) transport, the operation of the shuttle service freight trains can be classed as a necessary but inadequate solution. Inside the European Union, goods transport by rail could be made genuinely competitive in the longer term provided that a technically uniform, border-free railway network with equal capacities existed." (Ref: **CO_5055**)*
- *"This necessitates the redefining of the role of rail transport, the application of proven solutions on a larger scale (e.g. freight trains engaged in shuttle service), the search for new technological procedures and construction of a technically uniform EU railway network. Of course, long-distance road transport cannot be eliminated, but the effort should be to make road transport involved in the implementation of local tasks. It would be expedient to give preference to alternative solutions in the case of average and long distances." (Ref: **CO_5055**)*
- *"It is characteristic for our globalising world that the time needed in order to overcome distances is decreasing, from an economic perspective, national borders are falling, the cycles of production are shortening, stocks are shrinking and time is becoming the neediest source of power. All this means that fast transport of people and valuable goods is becoming more and more important; as a consequence, air transport has become the driving force not only of the transport sectors but also of globalisation. The significance of the air transport market and the extent of air transportation are steadily increasing the negative effects of flying as well" (Ref: **CO_5055**)*
- *"Economic opportunities and improvements in living standards have generated the more intensive usage of faster and more convenient transport modes which are also less energy efficient. In the developed countries, car mobility stands at around 75%, but even in the developing countries it has reached 40%."(Ref: **CO_5055**)*
- *"More passengers transported by planes of higher capacity – with passenger traffic unchanged – leads to a relative decrease in the number of the planes. The technical development trend on busier routes is the appearance of higher-capacity and therefore heavier airplanes. Inside the European Union, the construction of high-speed rail networks also has the potential to decrease the growth rate of air transport. In the other countries of the world, over a 20-year perspective, although the growth rate cannot be constrained, the extent of environmental pollution can be moderated by the increased use of alternative fuels" (Ref: **CO_5055**)*

### Interactions within the Economy Domain

#### *GDP trends*

- *"The overall consequence of global trade patterns on transport is seen in the close relationship between GDP and (freight) transport growth." (Ref: **CO_5048**)*
- *"(...) in the period 1990 to 2005, the GDP elasticity of transportation activity in the EU was estimated at 0.90 for both passenger and freight transport. This is a remarkably high value indicating great dependence of economic and social activity on transportation. A closer look at the period 2000 to 2005 shows that the GDP elasticity of passenger transport in EU remained constant at a level just below one (...)." (Ref: **CO_5048**)*

- *"The projections for the EC DGTREN Trends to 2030 assume values of the GDP elasticity of transportation activity that remain stable over time as far as passenger transport is concerned (...). For passenger transport in EU, the GDP elasticity is equal to 0.65 on average for the period 2005 to 2030." (Ref: **CO_5048**)*
- *"When one also includes the dynamic effects of globalisation (i.e. general equilibrium effects which would be expected to kick into action once shifts in worldwide relocation patterns start to impact on the respective economic structures of countries) the EU gains in the long run from global relocation. These GDP per capita gains reflect the higher productivity growth rates which emerge over time due to a more efficient global division of labour. The size of the EU's share of these worldwide efficiency gains will depend on the speed with which the necessary sectoral reallocation of resources takes place in the EU and, in particular, on the success of governments in facilitating this adjustment process." (Ref: **CO_1002**)*
- *"To overcome these problems, Member States will need to implement a productivity agenda focussed on the following five key areas, namely action on the level of regulation; the structure of financial markets; product and service market integration; adapting to ageing populations; and progressive moving towards an innovation, as opposed to an imitation, based economic model focussed on both the production and diffusion of knowledge. Without such an agenda, EU GDP per capita growth rates will continue to decline relative to those of other developed countries and the EU will fail to elicit a share of the gains to be generated from the catching-up processes of the emerging economies." (Ref: **CO_1002**)*
- *"For surface freight transport activity (tkm), the low scenario assumes a gradual decline of the freight intensity of GDP in all regions, while the high scenarios assumes that freight intensity stays at the 2005 level in all regions through 2050. A declining freight intensity of GDP could be the consequence of "dematerialisation" of growth, i.e. a proportionally faster increase in those components of GDP that are not particularly freight-intensive, including many services and IT applications. A constant or increasing freight-intensity might be the consequence of continued globalisation, characterised by geographical fragmentation of supply chains. Moreover, countries at lower levels of economic development may be embarking upon a relatively freight-intensive growth path, so that in those regions the assumption of declining intensity is less straightforward than for regions where GDP is already very high. On the global level, we expect high and roughly constant growth rates that lead to a tripling or quadrupling of global passenger transport volumes by 2050 compared to 2000, while surface freight activity grows by a factor of 2.6 to 3.5 over the same period." (Ref: **CO_4024**)*
- *"Openness to international trade and investment is also important to promote economic growth." (Ref: **CO_0178**)*
- *"To the extent that economic growth is driven by productivity gains, a higher export share in GDP should then correspond to a better growth performance." (Ref: **CO_0178**)*
- *"The economic indicators mostly used in transport and other analyses are the annual growth of GDP (at constant prices) – in general and per economic sector – and trade (imports and exports per country)." (Ref: **CO_2041**)*
- *"Globalisation: The internationalisation of markets for information, capital, goods and services and labour has fostered growth since around 1990. The transformation of former communist economies – especially China – and the increasing involvement of developing and emerging countries in the global economy have enabled an international division of labour and gains from specialisation, thus boosting productivity. In global terms, this has led to greater prosperity. On the other hand, this exclusively market- and competition-oriented globalisation has forced all the countries concerned to undergo major upheavals in order to adapt to the new circumstances." (Ref: **CO_0235**)*
- *"It is perfectly possible that some degree of gradual trade liberalization may have been beneficial, and even necessary, for certain developing countries in the 1980s – India and China come to mind. But what has happened during the past quarter of the century has been a rapid, unplanned and blanket trade liberalization. Just to remind the reader, during the 'dab old days' of protectionist import substitution industrialization (ISI), developing countries used to grow, on average, at double rate that they are doing today under free trade." (Ref: **CO_0241**)*

*Employment*

- *"(...) globalisation has however a strong and accelerating influence on the process of the creation and destruction of jobs and therefore on the territorial distribution of employment opportunities." (Ref: **CO_1023**)*
- *"The relocation of businesses outside Europe is the most sensitive aspect of globalisation. In future, not only manufacturing activities but also service activities such as software production and programming, telephone marketing, law and tax consultancy, accounting, and financial information analysis etc., will be affected." (Ref: **CO_1023**)*
- *"While the process itself is not new, the present phase of this secular globalisation process has witnessed a significant acceleration over the last 1-2 decades, with the integration of China, India and the former USSR countries into the world economy. This acceleration in integration has resulted in a 50% increase in the world's non-agricultural labour force, with a large proportion of these additional 700 million workers comparing well in human capital terms with the low skilled workers of the "developed" world. This labour supply boost has also coincided with a period rich in technological progress, most notably in the ICT area, with positive effects from the sharp reduction in communication costs being reflected in the growing tradeability of many traditionally sheltered service sectors." (Ref: **CO_1002**)*
- *"Since the classic efficiency gains from deeper trade and capital market integration depend heavily on the restructuring of the respective economies (specialisation requires restructuring), labour market flexibility is an essential prerequisite for a mutually beneficial integration process. In the case of the EU, there needs to be a shift of the displaced resources from the low-skilled / labour intensive sectors which are strongly affected by globalisation into those higher skilled activities where the EU continues to hold its comparative advantage." (Ref: **CO_1002**)*
- *"Considered under the aspect of labour markets, globalisation has however a strong and accelerating influence on the process of the creation and destruction of jobs and therefore on the territorial distribution of employment opportunities. This is why this aspect of the globalisation process is perceived more tangibly by the general public than others." (Ref: **CO_1023**)*

*Regional differences in economics*

- *"Accelerating globalisation is certainly the most important external factor with significant territorial impacts." (Ref: **CO_1023**)*
- *"Looking to the future from a trend perspective, it is likely that more and more regions will be negatively affected by the globalisation process, both urbanised and more rural ones, while the benefits of globalisation will largely remain concentrated in a limited number of regions with advanced metropolitan functions and a few others with specific characteristics. The globalisation process is therefore likely to sharpen territorial imbalances within Europe." (Ref: **CO_1023**)*
- *"In the context of progressing globalisation, it can be expected that trade flows with Latin America and a number of emerging Asian countries will intensify, while trade with Africa is not expected to grow significantly." (Ref: **CO_1023**)*
- *"Another indication of continuing globalisation and the growing role of emerging countries in the world economy is the increase in their exports as a proportion of national GDP." (Ref: **CO_0274**)*
- *"Fast-growing countries may even gain more in economic influence than their growth rates suggest when their middle class consumers grow in numbers and start to spend discretionary income on modern, short-cycle consumer goods, becoming attractive export markets for advanced economies (Accenture, 2008)." (Ref: **CO_0274**)*

### Interactions with the Social Domain

*Migration flows*

- *"Both immigration and tourism have increased significantly in recent decades. (...) A common perception is that most migrants are moving from poor countries to rich countries, but in reality half of the migrations take place within the developing countries. One cause of this growth is the globalization process that enhanced mobility and improved accessibility to different places (Poot et al. 2008)." (Ref: **CO_0092**)*

*Car ownership*

- *"Specifically, there will be limited growth in OECD economies and very strong growth outside of the OECD, notably in the emerging economies. The strong demand increase in the high end scenario is driven to a large extent by continued fast growth of passenger mobility in emerging economies (...). This is most usefully interpreted as an indication of "where demand would like to go", in the sense that it is assumed that the car ownership and usage patterns in emerging economies emulate those of European economies in the past. Whether this is a realistic assumption is uncertain, and whether such aspirations could materialise even if they existed is not straightforward either. For example, fast urbanisation might slow down the growth rate of private vehicle ownership and slow growth in the use of vehicles even more. Rising energy prices and less accommodating policies than have been observed in Europe in the past may also put a check on growth in car use. Nevertheless, the high growth scenario is not impossible and even in lower growth cases the increase in non-OECD mobility is strong." (Ref: **CO_4024**)*

*Urbanisation*

- *"Conventional economic development often takes peri-urban land as the location for large scale industry, science and business parks, roads and other urban infrastructure." (Ref: **CO_0097**)*
- *"Throughout Europe in the 1990s, changes in land cover were mainly characterised by increases in urban and other artificial land development and forest area, at the expense of agricultural and natural areas. Anticipated growth of the urban population by 5 % in the coming decade, will further fuel these trends. Globalisation, transport networks, socio-demographic changes, societal aspirations for the 'urban culture' and uncoordinated land-planning mechanisms at various levels are the main sources of the environmental unsustainability of our cities." (Ref: **CO_1031**)*
- *"Global economic growth is one of the most powerful drivers of urban sprawl. Globalisation of the economy is today fundamentally interrelated with the development of information and communication technologies (ICT). Both phenomena are beginning to have profound impacts on the spatial distribution of population and employment. Overall, it is likely that ICT will drive urban development towards an even more sprawled future." (Ref: **CO_0028**)*
- *"Global competition is also driving efforts to secure economies of scale in the distribution and consumption of goods that have driven changes in the retail sector over the past decades. In the 1950s, most shops were small and located in the middle of residential areas, and the majority of the population did their shopping on foot. Today, major out-of-town shopping centres are the dominant form of retail provision, which together with the surrounding parking areas occupy vast areas of land only accessible by car." (Ref: **CO_0028**)*

## Interactions with the Environment Domain

*Climate change impacts*

- *"In general, increased economic openness (mainly trade and investment liberalisation) seems to have had, at worst, a benign effect on emissions of localised pollutants. It has, for example, been found that (for the statistically average country), a 10% increase in trade intensity leads to approximately a 4% to 9% reduction in sulphur dioxide (SO2) concentrations. Other studies have found that openness appears to have a beneficial impact on SO2 and nitrous dioxide (NO2), but no statistically significant impact on particle matter (PM) emissions. Still another study found that trade intensity increases land releases of pollutants, but either reduces or has no statistically significant effect on air, water and underground releases." (Ref: **CO_1033**)*
- *"It is not clear how the relative price changes that result from openness will affect the environmental composition of economic activity: some countries will produce more environmentally intensive goods, others will produce fewer. On the other hand, liberalisation will raise incomes, perhaps increasing the willingness to pay for environmental improvements: these potential income effects could outweigh the negative scale effects associated with increased economic activity. When combined with the positive effects associated with technology transfer, the net effect on local pollutants could be positive." (Ref: **CO_1033**)*
- *"However, the evidence concerning carbon dioxide (CO2) and other greenhouse gas emissions is less encouraging, with the net effect of trade liberalisation likely to be negative. One study, using a cross-section of 63 countries (and correcting for trade intensity and income) concluded that a 1% increase in trade leads to a 0.58% increase in CO2 emissions for the average country.*

*Other studies also find openness raises CO2 emissions, but the detrimental impact disappears when corrections are made for income levels, etc." (Ref: **CO_1033**)*

- *"The climate change issue will clearly lie at the heart of efforts to deal with the environmental impacts of transport that result from globalisation. No other environmental issue has so many potential implications for transport sector policy today. Although the specific estimates vary, transport-based CO2 emissions are projected to grow significantly in the coming years. Light duty vehicles on roads will continue to be the largest contributors to this problem, but air-based emissions will grow more rapidly. Some shift toward less carbon-intensive technologies is foreseen, but no significant shift to truly low-carbon technologies is anticipated in most of the current estimates. In other words, incremental, rather than drastic, technological change is foreseen." (Ref: **CO_1033**)*

### Interactions with the Technology Domain

No particularly relevant interrelationships have been found.

### Impacts on Mobility and Transport

#### *Transport intensity*

- *"It has been argued that transport, both passenger and freight, should be decoupled from economic development. This would mean that mobility and trade should be carried out in a less transport intensive way. Given that mobility as well as trade are some of the fundamentals for development of our society, this debate is complex and controversial. Current discussion is therefore focused on how mobility and trade can be maintained, whilst reducing the adverse effects of transportation: in short, how can economic growth be decoupled from the negative impacts of transport." (Ref: **CO_5048**)*
- *"In the long term (20-40 years), in order to reduce the negative effects, the transport intensity of the economy should be influenced, not only detached (with solutions within the transport sector), but reduced (with non-transport solutions). The demand for transport arises outside the transport sector itself - as with most of the basic issues to be solved with decoupling. The demand for transport services, transport infrastructure, vehicle stock and logistics systems depends largely on the structure of industry, agriculture and settlements, on school and health care systems, on tax and tariff policies, on trade, and on integration and globalisation effects." (Ref: **CO_5055**)*
- *"It is most likely that the processes which started in the last quarter of the 20th century will continue in the 2nd millennium as well. As far as our subject is concerned, the most important of these processes are as follows:*
  1. *As a consequence of globalised production, purchase and distribution will also be globalised, creating huge supply chains realised in international networks of logistical service centres and transfer stations.*
  2. *Instead of locally concentrated production, production and servicing networks will be created; here, in order to decrease the transfer times, to minimise stocks, improve performance capacities and reduce expenditures, internal and external logistics will be integrated, and the automated products and goods detection will come in play.*
  3. *Logistic informatics is taking on an ever-increasing role in the operation and development of logistical systems (e. g. wide-range application of codes, sensors, telecom techniques, expert systems, databases, data research and optimising methods).*
  4. *The European transport routes are being modified and the volume of transported goods is increasing considerably. The proportion of intermodal and combined increase, transport solutions with the lowest environmental load will take on a prominent role, and regional airports will become more important.*
  5. *When developing the transport routes, the west-east flow of goods must be taken into special consideration. Consequently, the development of west-east and west south- east logistical routes and network elements should take priority."*

  *Unfortunately, at present, the facts tell a very different story. After the enlargement of the European Union, the economic growth predicted for the newly acceded countries and the improving relations between the regions further strengthened the position of road transport and road freight. The planned economy previously in place in the recently acceded member states gave preference to the rail transport mode, but the transformation of economic structures has resulted in strong growth in the road freight sector." (Ref: **CO_5055**)*

- *"It is a task of decades to explore the non-transport solutions, to elaborate programmes, and to harmonise them with transport development (development of infrastructure, vehicle stock, division of labour and technology). Expediently, location of industry and the regional division and management of agriculture should also be based on the one hand on comparative advantages, on the other hand to execute under the circumstances of the 'regulated market' from global aspect. During the location process, the European Union (comparing several variants) would support the most favourable one, of course on the basis of subsidiarity. However, the 'regulated' policy of industrial location and agriculture, which also influences transport, belongs to a 'sphere' beyond transport and this can be realised only by close cooperation among the EU member states." (Ref: **CO_5055**)*
- *"Key aspect is that transport modes cannot be dealt with individually, split apart from each other. Moreover, even the harmonised transport should be practically adapted to regional development and urban policy measures, and the order is converse: First, transport should be adapted to regional development, and then the optimal cooperation of transport modes should be developed. As a first step, the leaps forward in the development of private transport should be moderated by offering a competitive community transport alternative instead. This primarily means a modern and highly developed community transport service. Provided that this is done, then measures for decreasing mobility can be implemented (e.g. congestion road tolls, other measures for moderating transport needs, restrictions on car entry to protected areas, increasing overhead costs of private vehicles, changes in approaches in favour of pedestrians). And finally the key challenge for the next 20-40 years is whether the European Union is able to become a federal state from a 'loose' federation of states." (Ref: **CO_5055**)*

***Air transport and globalisation***

- *"In the aviation sector, in order to moderate air traffic and its environmental load, besides further development of the high-speed railway network, the deployment of fewer, high-capacity aeroplanes and wider use of alternative fuels could offer a solution." (Ref: **CO_5055**)*
- *"Some factors acted as a catalyst for the spread of low cost. These are: regulatory framework; degree of entrepreneurship; density of population and relative wealth; travelling culture; airport availability; adherence to internet facilities." (Ref: **CO_5037**)*
- *"International air transport is now a major contributor to globalisation and is continually reshaping to meet the demands of the economic and social integration that globalisation engenders. Some 40% of world trade (by value) now moves by air. To allow the flows of ideas, goods and persons that facilitate efficiency on a global scale, air transport has played a key role in the past, and is poised to continue this role in the future. Yet, as the strong growth in air transport activity is straining air-related infrastructure (such as airports), future economic growth in the sector could well be constrained by capacity limits." (Ref: **CO_1033**)*
- *"Aviation for passenger transport has been the fastest growing mode of transport in the recent past, driven by rising real incomes, the increased willingness to pay for leisure, the globalisation process and the liberalisation of air transport market. Aviation activity is projected to grow at a rate of 3.1% per year in 2005-2030. The need for more long distance travel facilitated by high speed of air travel is expected to drive this rapid growth, despite the increase in air transport prices due to high oil prices. By 2030, the market share of aviation in passenger transport activity is projected to reach 12.2% in 2030, up from 8.1% in 2005." (Ref: **CO_1032**)*
- *"There is a consolidation trend towards a limited number of big LCA[22]s that will have consequences on the market structure and the market behaviour with a possible risk of abuse of market power." (Ref: **CO_5037**).*
- *"Structural changes in the European economy favour the transport of light products with high added-value, while that of raw materials and heavy industrial products is declining." (Ref: **CO_1023**)*

***Transport cost and energy prices***

- *"Transport costs are very sensitive to energy prices, especially to oil. However, traffic flows are less sensitive to transport costs." (Ref: **CO_5048**)*

[22] Low Cost Airlines

- *"80% of traffic is not price sensitive. Transport prices may be internalized in goods' prices, but transport flows are not reduced." (Ref: **CO_5048**)*

#### 1.3.5.2 Energy Availability and Prices

**Driver description**

The Report WEF 'Global Risks' is structured as 10-year outlook that examines the 50 prevalent global risks in terms of perceived impact, likelihood and interconnectedness (Ref: **CO_0024**). The risk of '*the extreme volatility in energy and agriculture prices*' is associated with '*severe price fluctuations make critical commodities unaffordable, slow growth, provoke public protest and increase geopolitical tension'*. This risk is figured in terms of impact as among the top five economic, environmental, societal and geopolitical risks, whereas its likelihood is considered relative low with a raking of 3.5 over 4.5 and five others economic risks classified as more pressing.

In line with this, the driver is described mainly through the extrapolations from two opposite Scenarios:

- ***'New Policies Scenario' at 2035 of the IEA World Energy Outlook** (2011) that is based on the assumptions that governments policy commitments on energy and environment are implemented in a cautious manner – even if they are not yet backed up by firm measures and that oil prices rise but are not subjected severe fluctuations (Ref: **CO_1033**).*
- ***'High Oil Price Scenario' developed by the Project HOP** (2008) for analytical purpose that addresses the impacts of high oil prices in Europeans Economy (Ref: **CO_0026**).*

The driver description is complemented by others studies that foreseen the impacts of high oil prices in particular on the transport sectors.

**New Policies Scenario IEA 2011**

- *"Despite uncertainty over the prospects for short-term economic growth, demand for energy in the New Policies Scenario grows strongly, increasing by one-third from 2010 to 2035. The assumptions of a global population that increases by 1.7 billion people and 3.5% annual average growth in the global economy generate ever-higher demand for energy services and mobility. A lower rate of global GDP growth in the short-term than assumed in this Outlook would make only a marginal difference to longer-term trends. The dynamics of energy markets are increasingly determined by countries outside the OECD. Non-OECD countries account for 90% of population growth, 70% of the increase in economic output and 90% of energy demand growth over the period from 2010 to 2035." (Ref: **CO_1033**)*
- *"The age of fossil fuels is far from over, but their dominance declines. Demand for all fuels rises, but the share of fossil fuels in global primary energy consumption falls slightly from 81% in 2010 to 75% in 2035; natural gas is the only fossil fuel to increase its share in the global mix over the period to 2035. In the power sector, renewable energy technologies, led by hydropower and wind, account for half of the new capacity installed to meet growing demand." (Ref: **CO_1033**)*
- *"Short-term pressures on oil markets may be eased by slower economic growth and by the expected return of Libyan oil to the market, but trends on both the oil demand and supply sides maintain pressure on prices. We assume that the average IEA crude oil import price remains high, approaching $120/barrel (in year-2010 dollars) in 2035 (over $210/barrel in nominal terms) in the New Policies Scenario although, in practice, price volatility is likely to remain." (Ref: **CO_1033**)*
- *"All of the net increase in oil demand comes from the transport sector in emerging economies, as economic growth pushes up demand for personal mobility and freight. Oil demand (excluding biofuels) rises from 87 million barrels per day (mb/d) in 2010 to 99 mb/dn 2035. The total number of passenger cars doubles to almost 1.7 billion in 2035. Sales in non-OECD markets exceed those in the OECD by 2020, with the centre of gravity of car manufacturing shifting to non-OECD countries before 2015. The rise in oil use comes despite some impressive gains in fuel economy in many regions, notably for passenger vehicles in Europe and for heavy freight in the United States. Alternative vehicle technologies emerge that use oil much more efficiently or not at all, such as electric vehicles, but it takes time for them to become commercially viable and penetrate markets. With limited potential for substitution for oil as a transportation fuel, the concentration of oil demand in the transport sector makes demand less responsive to changes in the oil price (especially where oil products are subsidised)." (Ref: **CO_1033**)*

**HOP – High Oil Price Scenario 2008**

- *"Amongst the many mechanisms by which the high oil-price would limit GDP growth, we may underline the shift of consumption from non-energy sectors to the energy sector and the reduction in transport activity. The latter is particularly pronounced for passenger transport activity (some -14% points by a doubling of oil price and some -17% points by a tripling), but can also be observed for the transport of goods (some -11%). The high oil price would also reduce the dominance of road transport in the modal split, even if it still remains the most important mode. As a result of the decreasing activity but also due to the introduction of energy efficiency measures, final energy consumption in the energy sector would reduce by around 16% by 2030 (compared to the reference trend) for a doubling of the oil price, and around 26% at a tripling." (Ref:* ***CO_0026****)*
- *"The HOP! conclusion is that the expected GDP response to an oil price shock would be less pronounced than that observed for the oil price shocks in the 1970s and 80s. This is due to the changed economic framework and technical progress achieved since then that provide for a large variety of dampening effects on both the oil price and its economic impact. Compared to past oil price outbursts, the oil intensity of the European economy has halved and the service sectors have increased their importance at the expense of the more energy-intensive industrial sectors. A broad variety of improved and alternative energy technologies contributed to this reduction of energy intensity and further technologies become competitive at the oil prices assumed. Thus, the share of renewable energy in primary energy demand would increase considerably. Biofuels, both stemming from first and second generation technologies, exploiting imported and domestic raw resources would experience a significant increase within the transportation sector. They could deliver some 20% of the total transport fuel demand by 2030 as a result of the oil price doubling in 2020, increasing even much further afterwards. Also the composition of the vehicles fleet would change in favour of flexi-fuel vehicles and hydrogen- and gas-fuelled cars." (Ref:* ***CO_0026****)*
- *"Yet, all these changes to the energy and transport system require the availability not only of technologies but also of investment. If the level of investments was constrained, the deployment of alternative fuels such as biofuels and the improvement of energy efficiency would rather remain at reference levels. Limited investments would thus significantly restrict the adaptation process of the energy and transport sectors, implying a stronger oil price induced GDP reduction. In the long run this would lead to the most negative scenario – even more negative than the extreme oil price scenarios, in which the energy system responds through extensive adaptation through investments." (Ref:* ***CO_0026****)*

### Interactions within the Economy Domain

*GDP trends*

- *"On the most aggregated level, the oil price increase negatively affects GDP growth of EU27. The assumed doubling of the oil price in 2020 would lower Europe's GDP by -1.5% percent compared with the reference scenario. A further oil price increase such as a tripling from reference levels would result in further reductions of GDP to be some -2.2% below the reference by 2020. However, only oil prices in the extreme scenarios would lead close to stagnation of GDP (and only for a limited time period). Decline of GDP would only be expected when two further external factors become true: a world recession and/or a physical shortage of energy supply. The corresponding impacts on employment are roughly three times larger. The doubling of the oil price by 2020 would reduce employment by -5%, a tripling by close to -8%. This would shift the peak of European employment from 2017, as it is expected in the reference scenario, to about 3 to 5 years earlier. The extreme cases would cause dramatic losses of employment of up to -30%, presupposing that no specific counterbalancing policies to stabilize employment are taken or significant wage reductions are expected." (Ref:* ***CO_0026****)*

*Employment*

- *"As we experienced in the '70s and early '80s, oil price shocks can lead to rising unemployment." (Ref:* ***CO_0194****)*
- *"GDP and employment are negatively affected during the peak period of the oil price increase, employment will be reduced significantly more. The impact after the peak period of oil price increase strongly depends on the mechanisms kicked-off by the price increase. Mitigating the impacts by investing into energy efficiency and alternatives could even lead to a positive*

*economic impact in the medium to long-term, while a world recession or a situation with insufficient energy supply could multiply the negative impacts by factors of 5 to 10." (Ref: **CO_0026**)*

*Foreign trade, globalisation*

- *"As we experienced in the '70s and early '80s, oil price shocks can lead (...) to increasing trade deficits and reduced competitiveness." (Ref: **CO_0194**)*

### Interactions with the Social Domain

*Income structure and distribution*

- *"Costs for energy constitute a larger share of the structural consumption expenditures for low-income households compared to high-income households. Poor households face a treat for utility service cut off if the energy bills are not paid. Such market-based exclusion from energy supply is a comprehensive problem for poor families - and therefore also a threat to the poor older households." (Ref: **CO_0125**)*

*Tourist flows*

- *"Research by the UN-WTO (2006) into rising oil prices concludes that in the short term, rising oil prices have not had any noticeable impact on international tourism. However, the longer term consequences have not being examined." (Ref: **CO_4010**)*

### Interactions with the Environment Domain

No particularly relevant interrelationships have been found.

### Interactions with the Technology Domain

*Traction technologies*

- *"We are assuming that by 2020, the cost of oil will be above USD 120 per barrel and that battery charging stations will be in place. There will be a battery cost reduction of more than 30 % compared to today. All this will boost the electrification of transportation. Hybrid cars will have become the basic technology in passenger cars. From 2020 on, the electric vehicle will take over a major role in passenger car transportation; it could dominate the market from some point between 2020 and 2030." (Ref: **CO_0284**)*

*Energy efficiency*

- *"In response to rising retail fuel prices (e.g. a 50% jump in 1979), travelers reduced other costs of transport, for example by demanding less expensive (and more fuel efficient) new vehicles." (Ref: **CO_0001**)*

### Impacts on Mobility and Transport

**New Policies Scenario IEA 2011**

- *"Demand for mobility is strongly correlated with incomes and fuel prices. So as incomes rise – especially in the emerging economies – the size of the global car fleet will inevitably rise in the long term. However, vehicle usage patterns are also affected by incomes and prices. A rise in fuel prices (whether caused by higher prices on international markets or a rise in domestic prices) or a drop in incomes (such as during the global financial crisis) can lead to short-term changes in behaviour. But vehicle-miles travelled usually tend to rebound as consumers become accustomed to the new level of price or as the economy recovers." (Ref: **CO_1033**)*
- *"Of the projected increase in transport oil demand between 2010 and 2035, 37% comes from road freight traffic, 21% from PLDVs, 18% from international bunkers, 7% from aviation and the remaining 17% from other modes. International aviation and marine bunkers, as well as domestic aviation and navigation, grow with increasing GDP, but the growth is moderated by fuel economy targets recently announced by the International Maritime Organization for shipping and by energy efficiency measures both in aircraft technology and flight logistics." (Ref: **CO_1033**)*
- *"Road transport is expected to continue to dominate total oil demand in the transportation sector. In the New Policies Scenario, road transport is responsible for about 75% of global transport oil demand by 2035, down only slightly from 77% in 2010. Oil demand for road freight grows fastest, by 1.7% per year on average, despite significant fuel-efficiency gains, especially in the*

*United States where recent government proposals for heavy-duty vehicles aim at improving fuel efficiency between 10% and 17% through to 2018." (Ref:* ***CO_1033****)*

- *"Passenger light-duty vehicles (PLDVs) remain the single largest component of transport oil consumption, though their share shrinks from about 45% today to 39% by 2035." (Ref:* ***CO_1033****)*
- *"The increase in demand from road freight traffic comes entirely from non-OECD countries, offsetting a decline in OECD countries resulting from efficiency gains and fuel switching. Road-freight traffic is strongly correlated with economic growth, as increased levels of consumption lead to greater movement of goods. In non-OECD countries, road-freight tonne-kilometres increase by 3.7% annually, slightly more than the resulting oil demand, due to efficiency improvements. Although the tonne-kilometres operated by trucks and lorries grow by 0.5% per year on average until 2035 in the increasingly service-oriented OECD countries, the oil needed to fuel this growth drops in the New Policies Scenario as a result of efficiency improvements." (Ref:* ***CO_1033****)*

**HOP – High Oil Price Scenario 2008**

- *"Also substitutes for the various oil derivates would become more competitive, thus experiencing an increased deployment. For example, biofuels would replace some fossil based petrol and diesel in the transport sector, households and industry may shift from the use of oil to electricity, which is primarily produced from non-oil carriers. However, as a general principle high oil prices would also push the prices of oil substitutes upwards, depending on the technology (e.g. for biofuels energy costs account for up to 15%). Also the prices of natural gas would experience an increase, leading to a rise in the use of coal, renewable energies and nuclear power in the power sector. In return, the higher demand for those energy sources would drive up their prices." (Ref:* ***CO_0026****)*
- *"Even under the assumption of the required investments becoming available, there will be a delay between the oil price shock and the responses shown above, unless preventive action had been taken. The installation of new capacities in the upstream sector can reach some five to eight years. Production of biofuels could not be increased significantly in some weeks or months. Even if large amount of hydrogen could be produced, the development of the distribution infrastructure will take some time. Planning procedures on the construction of new nuclear plants could take a decade even if nuclear energy would become relatively cost competitive." (Ref:* ***CO_0026****)*
- *"A higher oil price leads to an increase in the costs of travel and transport of goods. As for all other goods and services, transport demand is reduced, both for passenger and freight (less trips, lower distances). The cost of public transport modes would comparatively increase less than private modes. Therefore, some modal shift is expected favouring public transport and less energy-intensive modes. The rapidly growing trend for air transportation could be stopped or slowed down considerably. Motorbikes and bikes could also gain market share. On the freight modes side, trucks cost would be increased substantially. As the road haulage market is a very competitive one, profits are very low so there is no room to absorb the increment of fuel cost, which would be probably transferred almost entirely to the user tariffs, so alternative modes (where energy costs are less relevant) become more competitive." (Ref:* ***CO_0026****)*
- *"The reduction of personal mobility would be realised both in terms of a lower number of motorised trips per person and of shorter distances per trip. Leisure trips would be at the top of the list of the avoided trips, especially relatively long trips in the week-end. Shortening travel distances would also be a reaction to higher transport costs. Concentrating mobility on unavoidable trips (working, etc.) and reducing travel distances could have a large impact especially on air demand whose massive rise occurred in the last years is mainly made of generated traffic caused by the significant fall of air fares. When high oil prices made low cost flights commercially unviable, at least part of this new demand would disappear." (Ref:* ***CO_0026****)*
- *"While personal mobility could be at least partially reduced even in the short terms in response to higher transport costs, the impact on mobility of goods is more questionable. The transport of goods is just a segment of a more complex productive and logistics chain, where the relevant variable is total cost. Currently, transport costs often amount to a very low share of total production costs or goods price (see COMPETE, 2006). This is true on the large scale as well as*

*on the medium and short scale, so in the end, the higher transport costs would probably impact on freight transport much less than on personal mobility, at least on the shorter terms."*

**More scenarios**

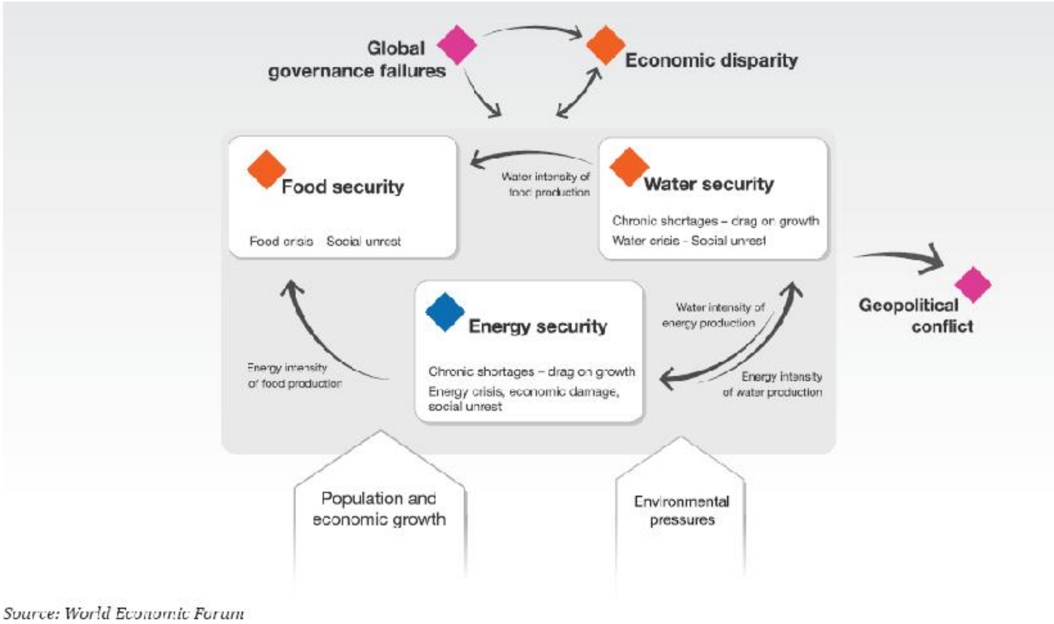
- *"Energy consumers in the transport sector also respond to higher oil prices mainly through lowering their transport activity and shifts towards less energy intensive transport modes. These changes take place despite the fact that the high taxes on transport fuels greatly dampen the impact of further changes in international fuel prices. As a result energy demand in the transport sector in the "Medium gas and soaring oil prices" case is projected to be -1.4% lower from Baseline levels in 2010 and -2.4% lower in 2030. Furthermore, higher oil prices lead to some acceleration in the share of biofuels in gasoline and diesel consumption. The share of biofuels is projected to reach 4.1% in 2010 (compared to 3.9% under Baseline assumptions), 8.3% in 2020 (6.9% in Baseline) and 10.7% in 2030 (8.3% in Baseline). The accelerated penetration of biofuels in transport impacts on the evolution of CO2 emissions in the sector, which are projected to decrease at rates well above those of energy demand over the projection period (reaching -4.7% from Baseline levels in 2030)." (Ref_**CO_1034**)*
- *"The analysis of transportation activity by transport mode and the projections for the EC DGTREN Baseline scenario (Trends to 2030) focuses on energy consumption in the transport sector, which accounted for 31% of total final energy consumption in 2005, up from 26% in 1990. This increasing share of transport in total energy consumption is projected to persist in the EC DGTREN Baseline scenario, achieving a share of 33% in the year 2030." (Ref: **CO_5048**)*
- *"The expectations are that crude oil based fuels will continue being the most important source for satisfying the energy demand in the transport sector up to 2030." (Ref: **CO_5048**)*
- *"(...) road transport is the overwhelmingly most important energy user, it is important to examine the expected development in energy efficiency in this transport segment." (Ref: **CO_5048**)*
- *"It is highly uncertain how societies will respond to the exploding demand yet stagnating supply of energy, especially oil. But it is clear the energy mix that's in place in 2040 will determine what types of mobility systems we have in our cities. For example, if there is a large-scale shift to renewable energy, this could favour electric, solar or hydrogen-powered vehicles. Or if energy is expensive and inaccessible to most, this could favour mass transit over personal motorised transport." (Ref: **CO_5018**)*
- *"Rising energy prices will probably cause only modest mileage reductions during the foreseeable future.(...). As real fuel prices increase during the next few decades, motorists will probably trade in their gas guzzlers for fuel efficient vehicles and only reduce their per capita vehicle mileage by a modest amount." (Ref: **CO_5047**)*
- *"(...) the transport sector's demand for oil is less price sensitive than any other part of the economy. This is in part because demand for transport services is relatively insensitive to price and in part because substitutes for oil in road transport are currently far from cost-effective." (Ref: **CO_5048**)*
- *"In rail transport the substitution from diesel to electricity will continue." (Ref: **CO_5048**)*
- *"Energy consumption by aviation has grown by 4.6% per year in the period 1990 to 2000 and by 1.9% per year between 2000 and 2005. Transportation activity handled by aviation, measured in passenger-km, grew faster during the same period. The average Energy intensity of flights, measured in toe per passenger-km, decreased 16 % during 1990-2005 due to improved design of engines and aircrafts." (Ref: **CO_5048**)*
- *"The costs involved and hence the prices charged for the transportation of people and goods depend on fluctuations in energy prices." (Ref: **CO_6006**)*

### 1.3.5.3 Intensified Competition for Scarce Resources

**Driver description**

- *"China, India, and the United States will emerge as the world's three largest economies in 2050, with a total real U.S. dollar GDP of 70 percent more than the GDP of all the other G20 countries combined. In China and India alone, GDP is predicted to increase by nearly $60 trillion, the current size of the world economy. However, the wide disparity in per capita GDP will remain." (Ref: **CO_2025**)*
- *"The glob Traditional Western powers will remain the wealthiest nations in terms of per capita income, but will be overtaken as the predominant world economies by much poorer countries. Given the sheer magnitude of the challenge of lower-wage competition, protectionist pressures in advanced economies may escalate." (Ref: **CO_1035**)*
- *"Economic transformation will shift international relations in unpredictable ways. To retain their historic influence, European nations will be pressed to conduct foreign policy jointly, an objective implied by their recently ratified constitution, and will need to reach out to emerging powers. Japan and Russia will seek new frameworks of alliances. The largest emerging nations may come to see each other as rivals." (Ref: **CO_2025**)*
- *"Russia, historically a great power, may become a political outlier under this scenario. Geographically the largest country and enormously rich in natural resources, its population in 2050 will be down to 109 million from 140 million today. With China, India, and the United States—not only the world's three largest economies in 2050 but also the world's three most populous—to its south and east, pressure may mount for Russia to increase its economic and security ties with Europe and to promote a balance of power among its large neighbours. Turkey's prospects for joining the EU may be a beneficiary of European concerns to maintain influence in a world of giants. Furthermore, one could imagine Russia becoming a full EU member by midcentury; with Turkey projected to have a smaller population than that of Russia in 2050, it may be easier for Turkey—a Muslim country with a population that will be larger that of any current EU member—to accede." (Ref: **CO_2025**)*
- *"In an era of terrorism and continued heavy dependence on Middle East oil and ultimately gas, concerns over energy security will clearly influence the direction of future world energy trade and production. Concern over security will likely increase as energy supplies become more costly and continued economic growth in such countries as China, India, and Brazil eat into available supplies. China, for example, attempting to diversify its oil supply sources for security reasons, now imports oil from more than 20 countries around the globe. The country may build a blue-water navy in part to safeguard its oil import shipments. To shift emphasis toward domestically produced energy, China recently announced the most ambitious nuclear development plans anywhere in the world, the construction of 24–32 new nuclear reactors by 2020." (Ref: **CO_6014**)*
- *"Pursuits for new energy supplies has also led to geopolitical competition over resources, for example Japanese and Chinese efforts to convince Russia to move East Siberia oil to either Daqing, China or Vladivostok, Russian Far East, where it could be exported to Japan. Japan's interest in the Siberia field for its own energy security is so pronounced that the country has offered billions of dollars towards 'social projects' in Russia as enticement for the Putin government to choose the Pacific coast route." (Ref: **CO_6014**)*
- *"International organizations such as the IMF will be compelled to reform their governance structures to become more representative of the new economic landscape. Those that fail to do so will become marginalized." (Ref: **CO_1035**)*
- *"Water security, food security and energy security are chronic impediments to economic growth and social stability. Figure below shows their interrelatedness: food production requires water and energy; water extraction and distribution requires energy; and energy production requires water. Food prices are also highly sensitive to the cost of energy inputs through fertilizers, irrigation, transport and processing. Economic growth and population growth are common drivers for all three risks, especially as improving living conditions in emerging economies results in more resource-intensive consumption patterns. Environmental pressures also drive resource insecurity – from climate shifts to extreme weather events that alter rainfall and affect crop production." (Ref: **CO_0024**)*

- *"Governance failures in terms of managing shared resources – such as trans-boundary water and energy sources and food trade agreements – create tensions that can lead to conflict, as seen recently in Yemen. Economic disparity also often exacerbates this nexus of risks as governments and consumers seek short-term, unsustainable solutions to economic hardship such as growing high-value, water-intensive export crops in water-deprived regions." (Ref: **CO_0024**)*




Source: Global Risks 2011 (Ref: **CO_0024**)

**Figure 1-54 System diagram for risks associated with the water-food-energy nexus**

- *"Agriculture is the dominant water user, consuming more than 70% of total global water demand. Industrially produced meat is especially water intensive, requiring up to 20,000 litres of water to produce a kilogram, compared to approximately 1,200 litres to produce a kilogram of grain. Both population growth and increasing meat consumption in emerging economies will therefore have a tremendous impact on resource needs. [..] Over the next 10 years, the world population is expected to rise from the current 6.83 billion to approximately 7.7 billion, with most of the growth in emerging economies. The United Nations Food and Agriculture Organization (FAO) projects a 50% increase in demand for food by 2030, and the International Food Policy Research Institute (IFRI) expects a 30% increase in demand for water, with other estimates rising to over 40%. The International Energy Agency (IEA) forecasts that the world economy will demand at least 40% more energy by 2030; producing this energy will draw heavily on freshwater resources. For such increased demand for water, food and energy to be realized, significant and perhaps radical changes in water use will be required as well as new sources for food and energy production exploited." (Ref: **CO_0024**)*
- *"For food production, supply-related challenges may limit the ability of farmers to meet growth in demand. Already, major grain-producing areas – in China, India and the United States, for example – depend on unsustainable mining of groundwater." (Ref: **CO_0024**)*

| Impacts | Direct Impacts | Indirect Impacts |
| --- | --- | --- |
| Impact on governments | • Stagnation in economic development<br>• Political unrest<br>• Cost of emergency food relief<br>• Significantly reduced agricultural yields<br>• Threats to energy security | • Increased social costs linked to employment and income loss as agriculture is negatively effected<br>• National security risks/conflict over natural resources |
| Impact on society / populations | • Increased levels of hunger and poverty<br>• Increased environmental degradation<br>• Severe food and water shortages<br>• Social unrest<br>• Food price spikes | • Migration pressures<br>• Irreparably damaged water sources<br>• Loss of livelihoods |
| Impact on business | • Export constraints<br>• Increased resource prices<br>• Commodity price volatility as shortages ripple through global markets<br>• Energy and water restrictions | • Lost investment opportunities |

*Source: World Economic Forum*

Source: Global Risks 2011 (Ref: **CO_0024**)

**Figure 1-55 Impacts of risks related to the water-food-energy nexus (non-exhaustive)**

## Interactions within the Economy Domain

### *GDP trends*

- *"(...), increased resource prices will inevitably impact economic growth, as higher prices are passed on to consumers. Experts suggest that despite such challenges, efforts to create properly costed systems are critical to the future sustainability of global prosperity, as the cost of severe shortages because of irreparable damage to water and food sources would far exceed the costs incurred through proactive resource management. In regions such as the Middle East and North Africa, market prices may also attract private investment in infrastructure that can better preserve the scarce resources currently being depleted." (Ref: **CO_0024**)*

### *Regional differences in economics*

- *"At the international level,(...) a world of bilateral government deals between energy producers and energy consumers, with national governments competing with each other for favourable terms of supply or for access by their energy companies. There is a strong element of rivalry between consumer governments, but they align with each other where their interests coincide." (Ref: **CO_1010**)*

### *Foreign trade, globalisation*

- *"Globalisation exacerbates the tensions within and between nations, and distracts policymakers from the need to take action and build international coalitions to face the energy and climate change challenges." (Ref: **CO_1010**)*
- *"The looming competition for access to raw materials will – in the ideal case – lead to more competition among importers of raw materials for the markets of the exporting countries (so that they are able to pay for those raw materials) and to a race to improve resource efficiency, but it could also turn into conflicts for territorial and economic control of natural resources." (Ref: **CO_0235**)*

### *Energy availability and prices*

- *"Although business cycle variations continue, energy prices are generally strong. This is not only because of the intrinsic pressures on supply but also because OPEC has learned from the price increases since 2004 that the world can absorb higher energy prices relatively easily. In the economic interests of its members, therefore, OPEC manages oil supply to minimise any* *incipient price weakness. With strong prices and lagging supply, "favourable terms" for importing nations increasingly means just some assurance of uninterrupted supply." (Ref: **CO_1010**)*

- *"Prices are kept artificially low by government subsidies or other regulation in many countries, thereby increasing demand. However, even if they were allowed to rise through market mechanisms, prices would not account for many of the negative externalities created by water, food and energy consumption." (Ref: **CO_0024**)*
- *"Both the cost of local impacts (such as the long-run social and environmental costs of resource exploitation) and global impacts (such as contribution to climate change through carbon emissions) should ideally be included in resource pricing. Without accurate pricing to reflect the full cost of resource use, it is likely that unsustainable decisions regarding resource use will continue." (Ref: **CO_0024**)*

### Interactions with the Social Domain

#### *Planning*

- *"The challenges associated with managing tradeoffs of food, energy and water resources rest with governments. Experts argue that meeting those challenges is undermined by the existence of separate administrative structures and policies for agriculture, water, energy and urban planning. The development of high-level commissions that cut across government departments, stakeholders and country representatives could improve public-sector-led governance, planning and information flows." (Ref: **CO_0024**)*
- *"Multistakeholder coordination on regional infrastructure investment could significantly enhance resilience with regard to food, water and energy security. Pricing has a large role to play in managing demand for food, water and energy." (Ref: **CO_0024**)*
- *"(...) market mechanisms must be managed progressively so as not to endanger social stability by disadvantaging poor consumers; the human cost of higher resource prices should be recognized by stakeholders and solved with careful planning." (Ref: **CO_0024**)*

### Interactions with the Environment Domain

#### *Climate change impacts*

- *"In some regions, such as North Africa and Australia, climate-related changes of precipitation have already critically reduced the levels of freshwater supply. In northeast China, one of the country's main grain-producing regions, climate change could increase drought losses by over 50% by 2030." (Ref: **CO_0024**)*
- *"Climate change is likely to be exacerbated by meeting the growing demand for energy. Over 75% of the global increase in energy use from 2007-2030 is expected to be met through fossil fuels, especially coal, and an estimated 77% of the power stations required to meet demand are yet to be built." (Ref: **CO_0024**)*

### Interactions with the Technology Domain

#### *Technology development in general and innovation diffusion*

- *"Further research and investment in transformative technologies and risk management tools that address the nexus as a whole are needed. Ensuring that such tools are locally appropriate and broadly adopted is key to their success. Many efficiency improvements require new operational management models and access to information. Innovations such as synthetic protein manufacturing, drip irrigation, and hybridization of crops to make them salt resistant could potentially maintain food security while simultaneously achieving water and energy efficiency, but require investment for both development and implementation." (Ref: **CO_0024**)*

#### *Traffic management systems*

- *"The increasing traffic at airports coupled with the constraints on constructing new airports or runways calls for more efficient use of existing ground infrastructure. The advanced surface movement guidance and control system (A-SMGCS) concept has been developed to enable integrated management of airport ground movements." (Ref: **CO_0289**)*

## Impacts on Mobility and Transport

### *Fossil fuel access*

- *"Another example is shale gas extraction, which promises access to new reserves of fossil fuels, but is highly water-intensive and may pose a risk to water quality. Few governments are developing energy policy with a goal of not only enabling economic growth and reducing carbon emissions, but also ensuring water efficiency; the nature of this nexus, however, means pursuing multiple goals will become a necessity." (Ref: **CO_0024**)*

### *Biofuel*

- *"(...) because of policy incentives designed to reduce vehicle emissions, by 2030 the IEA predicts that at least 5% of global road transport will be powered by biofuel – over 3.2 million barrels per day. However, producing those fuels could consume between 20-100% of the total quantity of water now used worldwide for agriculture. This is clearly an unsustainable trade-off." (Ref: **CO_0024**)*
- *"In Scramble, a typical three-step pattern begins to emerge: first, nations deal with signs of tightening supply by a flight into coal and heavier hydrocarbons and biofuels; then, when the growth in coal, oil and gas can no longer be maintained, an overall supply crisis occurs; and finally, governments react with draconian measures — such as steep and sudden domestic price rises or severe restrictions on personal mobility with accompanying disruptions in value chains and significant economic dislocations. By 2020, the repetition of this volatile three-step pattern in many areas of the energy economy results in a temporary global economic slowdown." (Ref: **CO_1010**)*
- *"Large agricultural lobbies are already powerful in developed nations, and a huge push for biofuels develops early in this scenario. This helps meet the rapid growth in demand for liquid transport fuels, but also leads to unintended consequences. First-generation biofuels compete with food production, driving up world market prices, especially in those countries that use maize as a staple. And regions with insufficient production potential, such as the EU, import the shortfall and so indirectly encourage poorer nations to destroy large sections of rainforests and habitats in order to grow palm oil and sugar cane. The result of these land use changes is that significant quantities of CO2 stored in the soils are also released. The reaction to these unintended consequences plays its part in helping to establish second-generation biofuels by 2020 – those that use the woody parts of plants, including waste products such as stalks and leaves from plants grown for food production. Certification systems also emerge to promote sustainability of both first- and second-generation biofuels. A key advantage of second generation biofuels is that energy yields are a lot higher, particularly outside the tropical regions. Most OECD countries, being in temperate regions, encourage and eagerly embrace economic routes to second-generation biofuels." (Ref: **CO_1010**)*

### *Air transport*

- *"As air transport recovers from the global economic crisis, it faces major challenges: it needs to reduce emissions substantially and it needs to make much more efficient use of scarce resources, which include not only oil but also air space and airport capacity." (Ref: **CO_0284**)*

### *Increasing congestion*

- *"A key element of demand management in urban transport is the allocation of road space. As this space is a finite resource, absence of regulation can lead to overuse, which appears in the form of congestion." (Ref: **CO_0289**)*

### 1.3.6 The Fiscal Policy Factor

#### *1.3.6.1 Fiscal Policy*

**Driver description**

Fiscal policy addresses the strategy of reaching a sustainable equilibrium between public revenues and expenditure. In the context of this report, this aspect basically concerns the implications for the fiscal policymaking in facing pension expenditures and involving accumulation of assets in order to meet the long-term outlook for public finances.

The sources for the review of the implications of a sustainable fiscal policy on mobility and transport are drawn from the European Commission outlook on the conditions for long-term sustainability of public finances, i.e. ñThe long-term sustainability of public finances in the European Union (DG ECOFIN*, 2006*) and the study ñA new strategy for the single marketò drafted for the European Commission in 2010.

- *"The global economic and financial crisis that broke out in 2007 had only just started to show signs of being – at least partly – overcome when it returned with full force." (Ref: **CO_0235**)*
- *"The economic and financial crisis has led to an explosion of public debt in Europe and at global level. Within the EU, the massive stimulus packages undertaken by governments at the initiative and with the coordination of the Commission, generated a surge in government deficit and debts. Government headline deficits are forecast to reach, on a EU wide average, 7.5% in 2010 and 6.9% in 2011 while EU level debt will jump to 83.7% in 2011. It is realistic to assume that reduction of huge public debt will require in several countries not only expenditure cuts and fiscal discipline but also tax increases." (Ref: **CO_5052**)*

**Interactions within the Economy Domain**

*GDP trends*

- *"Fiscal policy is defined as sustainable in so far as it does not lead to increasing ratios of the public debt to the GDP or, conversely, to an increasing tax burden." (Ref: **CO_0236**)*
- *"In Hungary, Portugal, Poland and Greece, an adjustment of the structural primary balance of more than 2 % of GDP is required to avoid an unsustainable path for the public finances and in another five countries, the United Kingdom, Germany, France, Italy and Luxembourg, an adjustment of between 1 % and 2 % of GDP would be required. This implies that for these countries the initial budgetary position poses a risk to the sustainability of the public finances and a strengthening of the fiscal position is a matter of urgency, particularly for those which have a high debt/GDP ratio such as Italy and Greece." (Ref: **CO_1004**)*

*Employment*

Suitable fiscal policies tailored to reductions of labour taxation might stimulate employment recovery, if designed to reduce the fiscal burden on the production sector; it could benefit from a fresh investment stimulus.

*Regional differences in economies*

- *"Europe has a highly fragmented tax landscape. In many areas, the operation of 27 different set of rules implies significant compliance costs and administrative burden for citizens and business operating cross-border." (Ref: **CO_0235**)*
- *"In a regime of a single monetary policy, but still largely nationally determined fiscal policy the member states compete for capital investments, production locations and jobs." (Ref: **CO_0235**)*
- *"Tax competition is a widely used practice in an integrated market, as national systems may use the fiscal tool to increase their attractiveness for businesses and capital." (Ref: **CO_5052**)*
- *"A major tax coordination would limit regulatory and tax fragmentation that would distort competition within the single market and increase compliance costs for business. They would also reduce the chances of tax induced asymmetric shocks in the Euro-area, thus facilitating the conduct of monetary policy by the European Central Bank. In short, some measures of coordination have the potential to turn a negative sum game within the Single Market in a game where all actors obtain benefits." (Ref: **CO_5052**)*

*Availability of public and private resources and investments in the transport sector*

- *"A unit elasticity of each revenue item to the relevant tax base is a good proxy of unchanged policy for the long-term analysis of fiscal policy. The very detailed features of the current tax system are not necessary. More importantly it avoids the inflationary bias that for example could result from extending current tax brackets over the long run." (Ref: **CO_1004**)*
- *"(...) governments largely indebted can more easily adjust the dynamics of their debt through changes in the composition of their expenditures rather than through running primary surpluses that require a generalized reduction in spending and/or increases in taxation. This, however, is true only if the initial share of total revenue devoted to current spending is sufficiently large." (Ref: **CO_0235**)*
- *"Thus, for governments that have already a small share of their revenue devoted to current spending, it could be impossible to realize a large debt ratio reduction by leaving their primary budget ratio to GDP unchanged, even though they are largely indebted. In conclusion, there exist situations in which it is impossible to stabilize a fast increasing debt ratio through policies that do not affect the primary budget." (Ref: **CO_0235**)*

*Foreign trade, globalization*

- *"There is an important aspect that gives to the taxation issue a systemic importance for the economic integration process. The functioning of the single market – coupled with the wider globalisation process - places a growing challenge for the operation of domestic tax systems and may erode in the long term their revenue raising capacity, as well as their ability to pursue social and redistribution policies at the national level." (Ref: **CO_5052**)*
- *"An important advantage from more tax coordination would come from minimising the impact on competitiveness when taxation would target products that constitute input for industrial production, as it would be the case for energy taxation." (Ref: **CO_5052**)*
- *"Tax competition, to some extent, serves a healthy purpose of putting pressure on governments to keep spending under control. However, it presents a disturbing asymmetry. The liberalisation of financial markets and the expansion of the single market allow companies to pursue strategies of tax minimisation and regulatory shopping in search of the most convenient taxation area. In response to this phenomenon, the burden of taxation within EU Member States has progressively shifted from more mobile tax basis (capital income a corporate income) towards a more extensive taxation of less mobile tax bases, notably labour." (Ref: **CO_5052**)*

### Interactions with the Social Domain

*Households structure and distribution*

- *"Many high-earning families opt for the considered appeal of more rural peripheral locations, while accepting the consequences of long commuter journeys. Those on lower incomes are frequently forced out by the large differential in prices between central and out-of-town land. Taxation schemes taking greater account of public contributions (such as infrastructure and utilities) to land values could mitigate this situation." (Ref: **CO_0260**)*

*Income structure and distribution*

- *"Rising incomes became increasingly unequally distributed since the distributive power of states and trade unions or employees was weakened by global competition for tax revenues, production locations, investment and jobs in favour of corporations, asset holders and investors. In practice, a rising profit share and a falling wage share can be discerned in all countries, as well as a widening gap between rich and poor as a consequence of the extremely unequal distribution of the fruits of globalisation." (Ref: **CO_0235**)*
- *"So, despite the amazing things that were predicted to happen if taxes on high income groups and big corporations were to be cut, what actually happened (as Krugman reminds us) is further evidence that "when you cut taxes on the rich, the rich pay less taxes; when you raise taxes on the rich, they pay more taxes – end of story." (Ref: **CO_0303**)*

*Planning*

- *"Potential options for urban authorities to limit traffic flows into and through their city centres range from traffic restrictions and the development of 'green zones' favouring low emission* *vehicles; through congestion charging schemes and other forms of road pricing; to parking policies, prioritisation of public transport and strategic infrastructural changes." (Ref: **CO_0260**)*

### Interactions with the Environment Domain

#### *GHG mitigation*

- *"It is also realistic to imagine that consolidation efforts will entail a shift from income taxation towards indirect taxation and a greater emphasis on less growth distorting taxes, notably environmental taxes." (Ref: **CO_5052**)*
- *"An area of relevance for coordination is that of environmental taxation. This is likely to play a key role in the future. It would be of great help to frame discussions on environmental taxation in the broader context of tax coordination so that the benefits in terms of relieving the tax burden on labour would also emerge clearly. " (Ref: **CO_5052**)*
- *"The application of more sustainable consumption patterns, i.e. the attitude of people to consume less carbon-intensive products and services, would be been primarily facilitated by the introduction of carbon tax systems, in particular in North America and in the core group of EU countries (EU15). Carbon taxes are based on fossil fuel carbon content and therefore tax carbon dioxide emissions." (Ref: **CO_5048**)*
- *"Although the regulation mode of governing is the least popular approach adopted by municipal governments, it can be very effective in terms of reducing GHG emissions. (...) different sets of mechanisms are deployed in this mode. First, and least common, local governments may use taxation and charge user fees." (Ref: **CO_0147**)*
- *"Although some low-carbon and energy-efficient technologies are competitive today, many others are considerably more expensive than their fossil-based alternatives. Carbon pricing will be important in helping to redress this gap, but it will not be sufficient on its own." (Ref: **CO_0154**)*

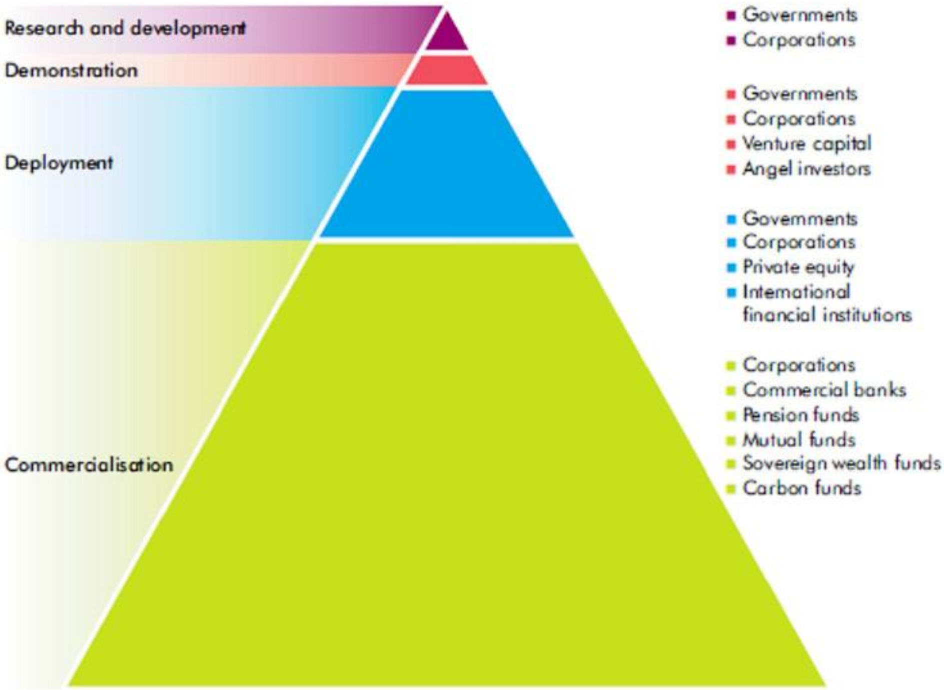
#### *Scarce resources of fossil fuels*

- *"The EU's average annual subsidies for fossil fuels accounted for almost 75% of total EU energy subsidies, with Italy, the Netherlands, and the United Kingdom providing the highest level of support to the oil and gas sector. Subsidies are also significant in Russia." (Ref: **CO_0159**)*

### Interactions with the Technology Domain

#### *Technology development and innovation diffusion*

- *"Technologies at different stages of development need different types and levels of support:*
  - → *For promising but not yet mature technologies (Stage 1), governments need to provide financial support for additional research and/or large-scale demonstration and to start to assess infrastructure and regulatory needs.*
  - → *For technologies that are technically proven, but require additional financial support (Stage 2), governments need to provide support with capital costs, or to introduce technology-specific incentives such as feed-in tariffs, tax credits and loan guarantees, and appropriate regulatory frameworks and standards, to create a market for the relevant technologies.*
  - → *For technologies that are close to competitive (Stage 3), governments need to move towards technology-neutral incentives that can be progressively removed as technologies achieve market competitiveness." (Ref: **CO_0154**)*




Source: The transition from present to 2050 (Ref: **CO_0154**)

**Figure 1-56 Funding options for different stages of technology development**

- *"Government support through financial contributions, tax credits, standard setting and market creation is important for effective technology development, innovation and deployment." (Ref: **CO_0146**)*
- *"The full potential of new technologies – particularly information and communications technology to impact on transport demand remains to be understood. Policy and technological innovations are often mutually reinforcing. For example, ITS have facilitated the implementation of road-user charging, passenger information systems, integrated fare systems, and bicycle sharing. Also, technologies can determine how services are delivered and therefore can impact heavily on the public policies and regulation applied in the sector." (Ref: **CO_0293**)*

*Traction technologies*

- *"Improved efficiency and better demand-side management, fostered through CO2 standards and smart taxation systems, should also advance the development of hybrid engine technologies and facilitate the gradual transition towards large-scale penetration of cleaner vehicles in all transport modes, including plug-in hybrids and electric vehicles (powered by batteries or fuel cells) at a later stage." (Ref: **CO_0194**)*
- *"Subsidies and financing programmes that counterbalance higher initial vehicle costs are needed to support the development of sustainable markets for new transport technologies. Vehicle efficiency strategies should identify and address potential rebound effects, whereby drivers travel farther due to fuel cost savings." (Ref: **CO_0154**)*
- *"(...) CO2 abatement should not be the main rationale for putting a fleet renewal scheme in place. The contributions towards CO2 reduction vary with the class and age of the scrapped vehicles, but unfortunately the analysis does not clarify which age of vehicles to target – replacing younger vehicles delivers more CO2 reductions, but at higher societal economic cost." (Ref: **CO_5017**)*
- *"(...) about a quarter of electric cars in Japan are sold in cities and are driven less than 20 km per day. For this type of use, electric cars are well suited; public procurement and graduated ownership taxes can help diffusion." (Ref: **CO_0284**)*

*Energy efficiency*

- *"Fiscal measures can be used to promote fuel-efficient vehicles and address the second and third elements of the transport challenge – namely using the vehicle at optimum efficiency and* *reducing overall vehicle use. Several studies show that taxing on the basis of vehicle use is a cheaper way to reduce vehicle fuel consumption than fuel economy standards." (Ref: **CO_0247**)*

- *"Car taxation can be used to encourage more widespread purchasing of more fuel-efficient vehicles. Credits for exceptionally efficient vehicles with refunds related to cost savings from reduced fuel consumptions could stimulate the demand for efficiency technologies. Their production rate would be sped up, and therefore the costs would be reduced by scale effects." (Ref: **CO_0017**)*
- *"Fuel efficiency regulations for passenger cars can help to push more fuel efficient vehicles onto the market and – to avoid rebound effects – they should be combined with increased fuel taxes." (Ref: **CO_0017**)*

## Impacts on Mobility and Transport

### *Fuel taxes should be increased to rise government revenues*

- *"It is realistic to assume that reduction of huge public debt will require in several countries not only expenditure cuts and fiscal discipline but also tax increases." (Ref: **CO_5052**)*
- *"A fuel tax is a levy on the consumption of fuel in proportion to its pre-tax price (Gupta and Mahler, 1994). Traditionally it is introduced for several purposes, such as to raise government revenue with low administrative costs; to conserve foreign exchange, and to generate revenue to finance road maintenance, etc. (Gupta and Mahler, 1994)." (Ref: **CO_0212**)*
- *"Although the fuel tax is introduced mainly to generate government revenues, it could have significant impact toward the reduction of emissions and traffic congestion. A number of existing studies (e.g., Eltony, 1993; Hirota et al., 2003; Sterner, 2006) demonstrate how the fuel tax reduces travel demand, fuel consumption, and emissions." (Ref: **CO_0212**)*
- *"In the short-run, a fuel tax results in an increase in fuel price, which in turn, discourages utilization of vehicles and thus over-consumption of fuel and release of emissions. In the long-run, fuel taxes also alter consumers' purchasing behavior, thereby causing them to switch to more fuel-efficient methods (Acutt and Dodgson, 1997)." (Ref: **CO_0212**)*
- *"Costs for motorised individual transport are likely to increase, due to an ongoing increase in the price of oil. Additionally, it is likely that tax burdens, as well as insurance and maintenance costs, will rise. Therefore, especially for low-income groups, the attractiveness of motorised individual transport may decrease." (Ref: **CO_0079**)*

### *Some fiscal policies can optimise demand management*

- *"Demand can also be optimised by ensuring the external costs of transport are internalised. This is particularly true in the case of road transport, for which there is increasing evidence that climate change, air and noise pollution, and health impacts outweigh existing taxes and charges (DfT, 2009) (Defra, 2010). It is accentuated by the fact that whereas access to most roads is free at point of use, many of the costs for private vehicle owners are fixed: depreciation, servicing, maintenance, circulation taxes and insurance." (Ref: **CO_5030**)*
- *"Further possibilities include fiscal stimuli for employers to support workers' use of public transport, and to make greater provision for flexible working hours and tele-working." (Ref: **CO_0260**)*

### *... but other policies still work on the contrary, leading to inefficiency or uncertainties*

- *"Governments must ensure their policies do not actively work against achieving cleaner, more seamless transport by 2030. Road and maritime cabotage rules, for instance, encourage empty-running and cause inefficiencies. Poorly aligned fiscal and regulatory instruments create uncertainty in the private sector regarding investments in greener and seamless transport." (Ref: **CO_0284**)*
- *"Satellite-based road pricing systems, which can adjust prices according to location and time, can address this, allowing price to be used to optimise demand at peak congestion times. Charging schemes which take into account the actual use of the car, replacing existing charges such as registration and circulation taxes, would be supported by half the EU citizens (Eurobarometer, 2010)." (Ref: **CO_5030**)*

- *“Another policy option to reduce total vehicle kilometres travelled is to encourage increased occupancy. Data on average car occupancy across Europe are limited, but available evidence indicates a figure of 1.5 for EU-15 Member States since 2004, and that figures for EU-12 Member States are declining towards these levels. In Europe, policies have not generally been aimed at reducing single-car occupancy rates, but in the United States it has been given much greater attention. A review of American workplace travel plans found that direct financial incentives or subsidies were a very important factor in reducing single-car occupancy rates (Potter et al., 2006) alongside introducing parking permits or charges (UKERC, 2009).” (Ref: **CO_5030**)*
- *“Policies to encourage car-sharing could also be effective in optimising transport demand.” (Ref: **CO_5030**)*

***Subsidies can promote the uptake of clan fuel, or electric vehicles***

- *“A subsidy is a traditionally-used, and probably the most common, fiscal instrument in the transport sector, particularly in developing countries.” (Ref: **CO_0212**)*
- *“Various types of subsidies exist in the transportation sector, e.g. infrastructure subsidies, fare reduction subsidies (railway sector), differences in taxation (the aviation sector is exempted from fuel tax and VAT), etc. The application of subsidies influences traffic volume, vehicle fleet composition, route planning and environmental performance.” (Ref: **CO_0144**)*
- *“Subsidies are key fiscal policy instruments designed to promote clean fuel, particularly the use of biofuels. Subsidies on biofuels are common practice in countries where their production is significant (e.g., Brazil, United States, and Germany).” (Ref: **CO_0212**)*
- *“In the European Union, twenty one countries grant a tax exemption (full or partial) for each liter of biodiesel supplied on the market, whereas twenty countries grant tax exemptions on bioethanol (Kutas et. al., 2007).” (Ref: **CO_0212**)*
- *“From 2006 to 2008 the EU share of renewable energy in the petrol and diesel consumption of transport increased from 2 % to 3.5 %. (...)The increase in renewable energy consumption, mainly based on the use of biofuels, reflects the widespread introduction of support systems at national level. Member States use tax rebates or biofuel obligations to promote renewable energy consumption in road transport.” (Ref: **CO_0197**)*
- *“Subsidies, the provision of special facilities, and tax and charge exemptions can all be used to reward users of eco-friendly forms of transport.” (Ref: **CO_0260**)*
- *“Subsidies can facilitate market penetration of High Efficiency Vehicles (HEV) such as hybrids.” (Ref: **CO_0212**)*

***...but there is the need to compensate revenue losses from fuel taxes***

- *“The introduction of vehicles powered by alternative fuels and the greater use of public transport will reduce revenues from excise duties on gasoline and diesel.” (Ref: **CO_0089**)*
- *“To compensate for revenue losses from taxes to petrol, if a growing percentage of vehicles are electric (or hybrid in the short term), Member States will have to obtain new income from Eurovignette (pay per use of heavy good vehicles on roads in a first phase that will be extended to light vehicles in a second phase) and urban congestion pricing.” (Ref: **CO_5005**)*
- *“<Governments make a lot of money on fuel duty, and this would be displaced by electrons if electric vehicles were mainstreamed – so there will have to be a profound shift in terms of how governments generate income, and structure tax and incentives.> Tom Briggs, Vice President, Policy and Communications, BP Alternative Energy.” (Ref: **CO_5018**)*

***Impacts on the use of most polluting transport modes***

The likely increase of environmental taxation would lead in the near future to the reduction of the use of the most polluting and intensive carbon-use transport means, e.g. cars, and airplanes.

- *“Fiscal measures to internalise the external costs of air travel would be an important element in rationalising demand, although they alone will not guarantee an absolute reduction in aviation travel.” (Ref: **CO_5031**)*

## 1.4 THE ENVIRONMENT DOMAIN

### 1.4.1 Environment Domain Key Factors and Drivers

Within the environmental domain, key drivers have been subdivided in three main factors relating to climate change, resources and pollution. The transport sector has a great variety of impacts on the environment, the vast majority being negative. Transport impacts on the environment for an intensive use of resources: among all sectors transport, together with construction, is the far biggest energy consumer. More and more disruptive events are expected to happen in the future due to increasing global warming. At the same time, the current levels of pollutants (also in terms of noise) registered in most urban areas are affecting seriously health conditions of the population.

In order to tackle these challenges, a wide bulk of actions has been initiated in order to mitigate and reduce GHG and other pollutant emissions.

From a sustainability perspective, the reduction of transport volumes and speeds would help to achieve quite remarkable results in impactsô mitigation, but this scenario seems to be hardly sustainable from an economic point of view (GDP growth and total welfare).

So, alternative ways of addressing these environmental challenges could be to place more emphasis on technological and logistics improvement, to care for a more rational use of energy and renewable energy sources, to invest in mature and eco-friendly planning and land-use as well as to widen the scope of existing pricing schemes or measures of environmental taxation, applying them in a more extensive way.

Among these measures the latter proved to be very effective and have the great advantage to be immediately effective. Incentive schemes and eco-friendly taxation are also key determinants in achieving the targets of limits for pollutants and noise fixed by legislative measures for urban areas.

The figure below summarises the key environmental factors and drivers taken into account for the analysis.

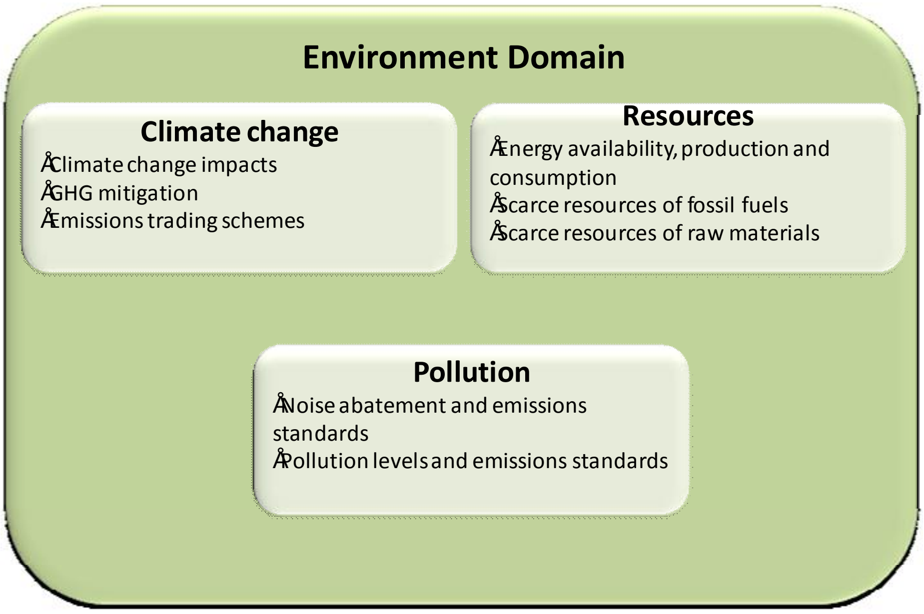



**Figure 1-57 Environment domain key factors and drivers**

### 1.4.2 The Climate Change Factor

#### *1.4.2.1 Climate Change Impacts*

**Driver description**

- *"Climate change in IPCC[23] usage refers to a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural variability or as a result of human activity. This usage differs from that in the United Nations Framework Convention on Climate Change (UNFCCC), where climate change refers to a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods." (Ref: **CO_1016**)*
- *"Many changes in climate and its impacts are already visible globally and in Europe, and these are projected to become more pronounced. In Europe, mountain regions, coastal zones and wetlands and the Mediterranean region are particularly vulnerable. Although there are some positive effects, like an increasing potential for agriculture at high latitudes and reduced cold stress to humans, most impacts are adverse." (Ref: **CO_1027**)*
- *"Scientists warn that climate change may not be a smooth linear process of a world warming gradually and steadily, but rather a series of sudden jolts, like the flips from one stable climate to another, radically different. Ice cores show this happened in the distant past, sometimes in the space of a single decade. The climate can alter very fast; many climatologists say the pace of change is already much faster than they expected ten years ago." (Ref: **CO_0091**)*
- *"Tackling climate change is of vital importance for the well-being of future generations. In the long run, climate change will lead to an increase in average annual temperatures, alter rainfall quantities and patterns, and raise the sea level and the risk of coastal erosion. In the short and medium term, climate change will increase the occurrence of extreme weather events (storms, heavy rainfall, droughts, peak summer temperatures) which will lead to temporary situations resembling those conditions, which we can expect later this century." (Ref: **CO_0016**)*
- *"The most severe effects of anthropogenic climate change are expected in the second half of the century." (Ref: **CO_2023**)*
- *"In Southern Europe, climate change is projected to worsen existing conditions through declining precipitation and drought." (Ref: **CO_0016**)*
- *"Regions subject to the highest pressure are generally located in the South and East of Europe, the whole of Spain, Italy, Greece, Bulgaria, Cyprus, Malta and Hungary, as well as most of Romania and southern parts of France. This situation is mostly due to changes in precipitation and an increase in temperature, which have an impact on vulnerable economic sectors. River floods also contribute to the overall effect in Hungary and Romania." (Ref: **CO_0016**)*
- *"The Arctic region is also likely to be seriously affected, since it is warming more rapidly, and larger changes are projected than in many other areas of the world." (Ref: **CO_1027**)*
- *"The risk of heat waves is expected to increase. (...) By 2050, under a relatively high emissions scenario, the temperatures experienced during the heatwave of 2003 could be an average summer." (Ref: **CO_2024**)*
- *"Projections of climate change and its impacts beyond about 2050 are strongly scenario- and model-dependent, and improved projections would require improved understanding of sources of uncertainty and enhancements in systematic observation networks." (Ref: **CO_1016**)*

**Interactions within the Environment Domain**

***GHG mitigation***

- *"The best guidance today suggests limiting the increase in global mean surface temperature to less than 2° Celsius above pre-industrial levels and keeping the rate of change below 2° Celsius per decade. Recent probability analysis suggests that accomplishing the former with relatively high certainty will require keeping the equivalent CO2 concentration below 400 ppm. It also suggests that stabilizing the equivalent CO2 concentration at 450 ppm would imply a medium*

[23] Intergovernmental Panel on Climate Change

*likelihood of staying below 2°C above pre-industrial levels. And if the equivalent CO2 concentration were to rise to 550 ppm, this outcome would be unlikely." (Ref: **CO_2019**)*

*Pollution levels and emission standards*

- *"A warmer climate will generally enhance the pollution load of nutrients in surface and groundwater. Higher temperatures will increase mineralisation and releases of nitrogen, phosphorus and carbon from soil organic matter and increase run-off and erosion, which will result in increased pollution transport." (Ref: **CO_2023**)*

*Energy availability, production and consumption*

- *"The projected change in river runoff due to climate change will result in an increase in hydropower production by about 5 % and more in northern Europe and a decrease by about 25 % or more in the south. Dam safety may be affected under changed climatic conditions with more frequent extreme flows and possibly natural hazards." (Ref: **CO_2023**)*
- *"Climate change could have an adverse impact on thermal power production as most studies show that summer droughts will be more severe, hence limiting the availability of cooling water in terms of quantity, appropriate temperature and power plant efficiency." (Ref: **CO_2023**)*
- *"In moderate climate zones the demand for energy during the winter months will decline. This may, for example, lead to a decrease in demand for oil and coal in electricity production, having implications for transport of fuels. In zones with higher temperatures, on the other hand, demand for electricity for cooling will increase during summer months." (Ref: **CO_0184**)*
- *"Future projections of climate change suggest reductions in heating degree days in Europe, but increases in cooling degree days. The net change in energy demand is difficult to predict, but there will be strong distributional patterns, with significantly reduced space-heating demand in northern Europe and increased space-cooling demand in southern Europe, with associated costs and benefits. There may also be increases in energy demand associated with adaptation to climate change, e.g. for water supply." (Ref: **CO_2023**)*
- *"A further dimension of competition for energy resources lies in potential conflict over resources in Polar regions which will become exploitable as a consequence of global warming." (Ref: **CO_0120**)*

*Scarce resources of fossil fuels*

- *"(...) because much of the world's hydrocarbon reserves are in regions vulnerable to the impacts of climate change and because many oil and gas producing states already face significant social economic and demographic challenges, instability is likely to increase. This has the potential to feed back into greater energy insecurity and greater competition for resources. (...) As previously inaccessible regions open up due to the effects of climate change, the scramble for resources will intensify." (Ref: **CO_0120**)*

### Interactions with the Social Domain

*Population ageing*

- *"Heat waves have caused significant mortality in Europe in recent decades. Several medical factors can increase the risk of heat-wave mortality, including dehydration, drugs, ageing, and having a chronic disease that affects cardiac output and skin blood flow, as well as being confined to bed. Increasing numbers of older adults in the population will increase the proportion of the population at risk." (Ref: **CO_2023**)*

*Migration flows*

- *"Probably the best available data on environmental migration are the figures on the number of persons displaced by natura disasters. In 2008, for example, 20 million people were displaced as a result of sudden-onset climate-related weather events, compared to 4.6 million internally displaced by conflict and violence." (Ref: **CO_5029**)*
- *"The UN predicts that there will be millions of "environmental" migrants by 2020 with climate change as one of the major drivers of this phenomenon. Some countries that are extremely vulnerable to climate change are already calling for international recognition of such environmentally-induced migration. Such migration may increase conflicts in transit and*

*destination areas. Europe must expect substantially increased migratory pressure." (Ref: **CO_0120**)*

- *"Although the number of disasters has increased significantly over the last two decades (...) there has not been a major impact on international migratory flows, as much displacement is short-lived and temporary, and those who are displaced do not have the resources or networks to migrate abroad." (Ref: **CO_5029**)*
- *"Most commentators agree that migration resulting from environmental change is likely to continue to increase in the foreseeable future. The effects of climate change are likely to exacerbate this trend (...)" (Ref: **CO_5029**)*
- *"(...) parts of the populations that already suffer from poor health conditions, unemployment or social exclusion are rendered more vulnerable to the effects of climate change, which could amplify or trigger migration within and between countries." (Ref: **CO_0120**)*
- *"(...) it is not always appropriate to ascribe environmental changes, that might precipitate migration, to climate change. For example, environmental degradation may be the result of changes in average annual temperatures or rainfall levels, but it may equally be the result of deforestation or poor land management – or a combination of these factors." (Ref: **CO_5029**)*

#### Income structure and distribution

- *"In general, low-income households in both developed and developing countries are most vulnerable to climate change impacts primarily due to the scale and nature of the assets they possess or can draw on." (Ref: **CO_0147**)*
- *"Studies of disaster impacts from extreme weather events in urban areas suggest the majority of those who are killed or seriously injured and that lose most, or all, of their assets are from low-income groups. In the event of a natural disaster, low-income households often lack the resources to mitigate resulting damage through healthcare, structural repair, communication, food and water." (Ref: **CO_0147**)*

#### Gender roles

- *"Climate change impacts magnify gender and racial inequalities, often impacting poor minorities and poor women more than other groups. A vicious cycle then develops whereby marginalized groups bear the greatest burdens of climate change, thus preventing them from escaping poverty and leaving them continuously vulnerable to further change." (Ref: **CO_0147**)*

#### Urbanisation

- *"Evidence is mounting that climate change presents unique challenges for urban areas and their growing populations." (Ref: **CO_0147**)*
- *"Heatwaves or flash flooding, for example, will impact the comfort, cost and reliability of daily urban life." (Ref: **CO_5018**)*
- *"Extreme events are exacerbated in cities by the urban heat-island effect – the tendency of cities to retain heat more than their surrounding rural areas." (Ref: **CO_0147**)*
- *"Climate change may affect water supply, ecosystem goods and services, energy provision, industry and services in cities around the world. It can disrupt local economies and strip populations of their assets and livelihoods, in some cases leading to mass migration. Such impacts are unlikely to be evenly spread among regions and cities, across sectors of the economy or among socioeconomic groups." (Ref: **CO_0147**)*
- *"Coastal zones are the home of about one fifth of the world's population, a number set to rise in the years ahead. Mega-cities, with their supporting infrastructure, such as port facilities and oil refineries, are often located by the sea or in river deltas. Sea-level rise and the increase in the frequency and intensity of natural disasters pose a serious threat to these regions and their economic prospects." (Ref: **CO_0120**)*

#### Planning

- *"Countries need to start adapting and planning to adapt, and to build resilience into natural and man-made systems." (Ref: **CO_0140**)*

- *"Urban authorities should (...) pay particular attention to the importance of adding climate-sensitive features to major infrastructure, especially when they are being designed, as the cost of adding these features will almost always be smaller before the infrastructure is built than they would after it is in place." (Ref: **CO_0147**)*
- *"In addition and just as important is the fundamental need for new visions for urban and regional planning policy that respond to these challenges. These visions must recognise that continued sprawl in the coastal regions of Europe is fundamentally unsustainable." (Ref: **CO_0028**)*
- *"Future climate change may mean that current plans for new areas of settlement are no longer appropriate, for instance due to a higher risk of flooding." (Ref: **CO_0096**)*
- *"The EuroHEAT project concluded that heat-related illnesses and deaths are largely preventable. In the long term, the most important measure is improving urban planning and architecture, and energy and transport policies." (Ref: **CO_2023**)*

*Tourist flows*

- *"Climate change may have several consequences for transport demand on a global and regional scale. The potential changes in patterns of tourism are of special interest." (Ref: **CO_0184**)*
- *"(...) during the summer months Northern parts of Europe become more attractive, while Southern parts become less attractive. Moreover, the length of the holiday season in Northern countries increases. We may therefore expect a decrease in tourism from North to South, and, especially during the summer months, an increase in tourism from South to North. However, during spring and winter the Southern countries become more attractive, which may increase tourism to this region in these periods." (Ref: **CO_0184**)*
- *"Next to tourism during the summer holidays, another substantial part of the tourism industry is related to skiing holidays. The impact of climate change in this respect is clear; the larger the increase in temperature, the smaller the probability of sufficient snow for skiing purposes. This may lead to a decrease in skiing holidays and to a shift towards those areas with higher probabilities of sufficient snow, e.g. areas at higher altitudes." (Ref: **CO_0184**)*
- *"Concerning the 2020s, in the three main seasons (i.e. spring, summer and autumn) climate conditions for outdoor tourism improve in most areas of Europe. Changes are most significant in the Mediterranean region, where the area with very good to ideal conditions increases. On the contrary, for the 2080s, the distribution of climatic conditions in Europe is projected to change significantly." (Ref: **CO_2027**)*
- *"Future projections of climate change suggest that the suitability of the Mediterranean for tourism will decline during the key summer months, though there will be an increase during other seasons (spring and autumn). This can produce shifts in the major flows of tourism within the EU, which will be very important in regions where tourism is a dominant economic sector, though adaptation responses such as economic diversification will be critical to limit economic losses. The tourism industry will therefore face significant adaptation costs." (Ref: **CO_2023**)*
- *"Changes in climate are starting to impact upon the attractiveness of many of the Mediterranean's major resorts, while improving it in other regions." (Ref: **CO_2023**)*

*Education*

- *"For a long time, although the message was as clear as it could be, the audience remained unreceptive. But gradually the efforts to disseminate the warnings of science are beginning to pay off. The apathy and outright resistance are starting to crumble, and the climatologists' message is getting through to many people." (Ref: **CO_0091**)*
- *"Information of climate change science and options for mitigation and adaptation responses should be more widely available. The IPCC, the United Nations and other international organizations need to widen the spectrum of available knowledge on climate change." (Ref: **CO_0147**)*

*Health*

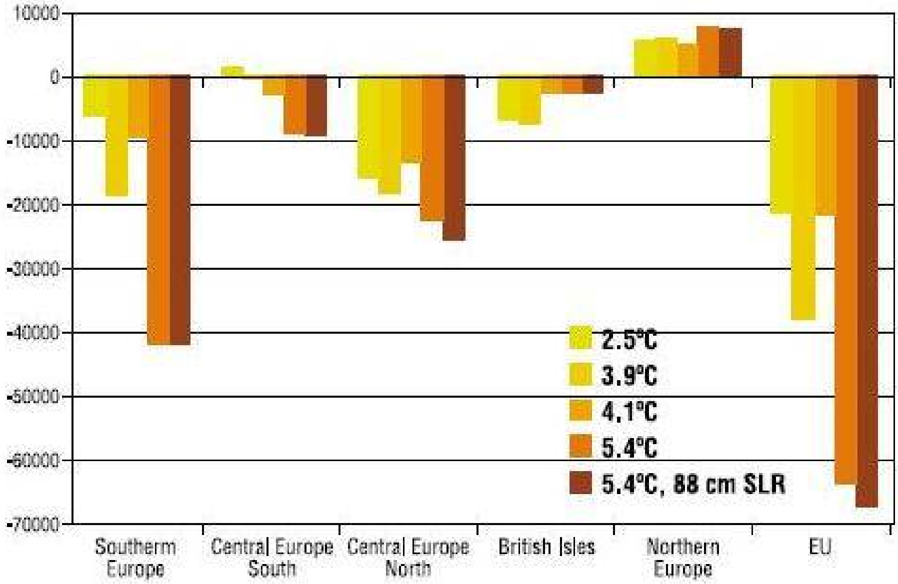
- *"Climate change is already contributing to the global burden of disease and premature deaths. Human beings are exposed to climate change through changing weather patterns (temperature, precipitation, sea-level rise and more frequent extreme events) and indirectly through changes in the quality of water, air and food, and changes in ecosystems, agriculture, industry, settlements,* *and the economy. At this early stage the effects are small but they are projected to increase progressively in all countries and regions." (Ref: **CO_2023**)*

- *"In the 2020s, without adaptation measures and acclimatisation, the estimated increases in heat-related mortality are projected to be lower than the estimated decrease in cold-related mortality. The potential increase in heat-related mortality in Europe could be over 25,000 extra deaths per year, with the rate of increase potentially higher in Central Europe South and Southern European regions. However, physiological and behavioural responses to the warmer climate would have a very significant effect in reducing this mortality (acclimatisation), potentially reducing the estimates by a factor of five to ten. It is also possible that there may be a decline in the sensitivity of mortality to cold, though this is more uncertain." (Ref: **CO_2027**)*

## Interactions with the Economy Domain

### GDP trends

- *"Economic losses due to climate change may increase in the future because of the projected increase in extreme events, although this is uncertain." (Ref: **CO_1027**)*
- *"The IPCC calculated the macroeconomic cost in 2030 at less than 3 per cent (of GDP) for stabilizing the CO2e[24] in the atmosphere between 445 and 535 ppm[25] and the 2008 UNDP[26] Human Development Report estimates that the cost of limiting temperature rise to 2°C could be less than 1.6 per cent of global GDP up till 2030. These estimates, whichever is more accurate, are significant." (Ref: **CO_0091**)*
- *"(...) the cost of keeping CO2 concentrations below a 550 ppm threshold is at around 1 per cent of global GDP by 2050. But if we do not act (...) the overall costs and risks of climate change will be equivalent to losing at least 5 per cent of global GDP each year, now and permanently. If a wider range of risks and impacts is taken into account, the estimates of damage could rise to 20 per cent of GDP or more." (Ref: **CO_0091**)*
- *"Without public adaptation to climate change and if the climate of the 2080s occurred today, the annual damage of climate change to the EU economy in terms of GDP loss is estimated to be between 20 billion € for the 2.5°C scenario and 65 billion € for the 5.4°C scenario (Figure below). Damages would occur mainly in the Southern Europe and Central Europe North regions." (Ref: **CO_2027**)*




Source: PESETA Project (Ref: **CO_2027**)

[24] CO2 equivalence A way of expressing the combined efficiency of all greenhouse gases: carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), and the rarer trace greenhouse gases such as chlorofluorocarbons. Their potency varies according to their chemical makeup and the length of time they persist in the atmosphere.

[25] Stands for ‰parts per millionô and is the usual measuring unit applied to greenhouse gases because of their relatively small quantities in the atmosphere. 0,0001 per cent is 1 ppm.

[26] Stands for ‰parts per millionô and is the usual measuring unit applied to greenhouse gases because of their relatively small quantities in the atmosphere. 0,0001 per cent is 1 ppm.

**Figure 1-58 Annual damage in terms of GDP loss (million €)**

- *"Predicting the future effects of extreme events also remains difficult because of increasing exposure caused by changes in economic development, which increases the value and density of human and physical capital. Disaster losses are expected to rise more rapidly than average economic growth, stressing the importance of risk reduction (Bouwer et al., 2007)." (Ref: **CO_2023**)*

#### Regional differences in economics

- *"(...) impacts tend to reinforce existing inequalities and, as a result, climate change can disrupt the social fabric of cities and exacerbate poverty." (Ref: **CO_0147**)*
- *"The pressures from climate change are (...) not evenly distributed, and in some cases will be felt in regions with low GDP per capita, which thus have a lower capacity for adaptation to climate change." (Ref: **CO_0016**)*
- *"Globally, developing countries are expected to be among the most affected by climate change, and have the least socioeconomic capacity to adapt." (Ref: **CO_1027**)*

#### Availability of public and private resources and investments in the transport sector

- *"Climate change will impact a broad range of economic activities including trade, manufacturing, tourism and the insurance industry. The direct effects of climate change and extreme climate events on industry include damage to buildings, infrastructure and other assets. These effects are especially severe where industrial facilities are located in vulnerable areas such as coastal zones and floodplains. The indirect impacts of climate change on industry include those resulting from delays and cancellations due to climate impacts on transportation, communications and power infrastructure." (Ref: **CO_0147**)*
- *"The insurance industry is also vulnerable to climate change, particularly extreme climate events that impact a large area. Climate change could result in increasing demand or insurance while reducing insurability. The costs of insurance coverage are expected to increase significantly if infrequent but catastrophic events become more common in the future. The uncertainty surrounding the probability of high-loss events in the future is likely to place upward pressure on insurance premiums." (Ref: **CO_0147**)*
- *"Financial resources need to be made more available to support the many vulnerable cities that need additional resources to respond to climate change. In particular, it is essential that action is taken to facilitate the use of the Adaptation Fund and the CDM[27] for initiatives in urban areas." (Ref: **CO_0147**)*

#### Foreign trade, globalisation

- *"Results from a broad based research project into the effects of climate change on food production on a global scale show that especially countries at higher longitudes[28] will become more suited for food production (see Easterling et al., 2007). The climate in countries at lower longitudes, among which the largest part of developing countries, will become substantially less suited, however. This likely results in an increase in freight flows from developed to developing countries (see also Fischer et al., 1994, 2002). (...) The shift of food production from south to north will likely also hold at the regional level, e.g., from South- to North-Europe and from South America to North America." (Ref: **CO_0184**)*

#### Energy availability and prices

Energy prices will be strongly influenced by demand variations and by fluctuations in energy production caused by climate change.

#### Intensified competition for scarce resources use

- *"Climate change will alter rainfall patterns and further reduce available freshwater by as much as 20 to 30% in certain regions. (...) Water shortage in particular has the potential to cause civil unrest and to lead to significant economic losses, even in robust economies. (...) The overall effect is that climate change will fuel existing conflicts over depleting resources, especially where access to those resources is politicised." (Ref: **CO_0120**)*

[27] Clean Development Mechanism
[28] To be intended ñlatitudeò

- *"More disputes over land and maritime borders and other territorial rights are likely. There might be a need to revisit existing rules of international law, particularly the Law of the Sea, as regards the resolution of territorial and border disputes." (Ref: **CO_0120**)*
- *"The rapid melting of the polar ice caps, in particular, the Arctic, is opening up new waterways and international trade routes. In addition, the increased accessibility of the enormous hydrocarbon resources in the Arctic region is changing the geo-strategic dynamics of the region with potential consequences for international stability and European security interests." (Ref: **CO_0120**)*

#### Interactions with the Technology Domain

No particularly relevant interrelationships have been found.

#### Impacts on Mobility and Transport

**Disruptive events due to climate change will put increasing pressure on transport networks especially in urban areas or coastal zones**

- *"To date, the consequences of climate change and weather conditions for the transport sector have received relatively little attention. Still, it is widely known that transport systems on the whole perform worse under adverse and extreme weather conditions. This is especially true in densely populated regions, such as many coastal areas around the globe, where one single event may lead to a chain of reactions that influence large parts of the transport system." (Ref: **CO_0184**)*
- *"(...) climate changes and the degrees to which they will occur are different for different regions. Given these differences in climate change it is obvious that impacts of climate change on the transport sector will also differ across regions." (Ref: **CO_5048**)*
- *"Most writing about climate change and transport emphasises the role of greenhouse gas emissions from transport as a contributory factor towards climate change. However, the inverse impact is also significant, since the transport system is liable to be adversely affected by climate change, particularly as a result of extreme weather events such as floods, hurricanes and heat waves. One particular fear associated with such events is that it is not known what their scale will be and exactly what impacts they will have, though it is clear that there exists the potential for huge disruption." (Ref: **CO_5048**)*
- *"Climate change impacts frequently disrupt transportation systems through weather conditions that have immediate impacts on travel and damages that cause lasting service interruptions. In coastal cities in particular, sea-level rise can inundate highways and cause erosion of road bases and bridge supports. Heavy precipitation and its effects in the form of flooding and landslides can cause lasting damage to transportation infrastructure such as highways, seaports, bridges and airport runways. Higher temperatures, in particular long periods of drought and higher daily temperatures, compromise the integrity of paved roadways and necessitate more frequent repairs. Besides potentially endangering lives, the destruction or damage of transportation systems and prolonged service disruptions greatly impact nearly all aspects of urban life." (Ref: **CO_0147**)*
- *"Although attempts are now being made on a worldwide scale to reduce greenhouse gas emissions and hence climate (...) such measures (even if successful) will be too late to avert climate change and its impacts over the next 50 years. It follows that the transport system needs to have resilience built into it in order to deal with these problems, in order to stop relatively minor events turning into major catastrophes. Two aspects of such resilience can be identified: A "long term" aspect in the sense that the transport system should be constructed and developed according to principles that recognise the likelihood and impacts of extreme weather events; Contingency plans need to be formulated well in advance of such events occurring. In particular, such plans should try to ensure network connectivity of the transport system in the face of any disruption. Firstly this will ensure that "normal activities" can be maintained (as far as possible), thus maintaining territorial cohesion. Secondly, problems of disconnection are likely to have a direct impact upon the effectiveness of emergency services for dealing with the disruption." (Ref: **CO_5048**)*
- *"Storm events can have large impacts on vulnerable systems such as transport, forestry and energy infrastructures, and also on human safety." (Ref: **CO_2023**)*

- *"A higher flood risk increases the threat of loss of life and property as well as damage to sea-dikes and infrastructure, and could lead to an increased loss of tourism, recreation and transportation functions (Nicholls and Tol, 2006; Nicholls et al.,2007; Devoy, 2008)." (Ref: **CO_2023**)*
- *"Changes in lake and river ice may affect winter transportation, bridge and pipeline crossings, and winter sports but no quantitative evidence for such effects yet exists (IPCC, 2007)." (Ref: **CO_2023**)*
- *"It is clear that changes in weather conditions due to climate change will affect the competitive positions of the different transport modes, both within passenger and freight transport." (Ref: **CO_0184**)*

*Road safety*

- *"Adverse weather conditions, and especially rain and snow, increase the number of road accidents, but appear to decrease their severity." (Ref: **CO_0184**)*

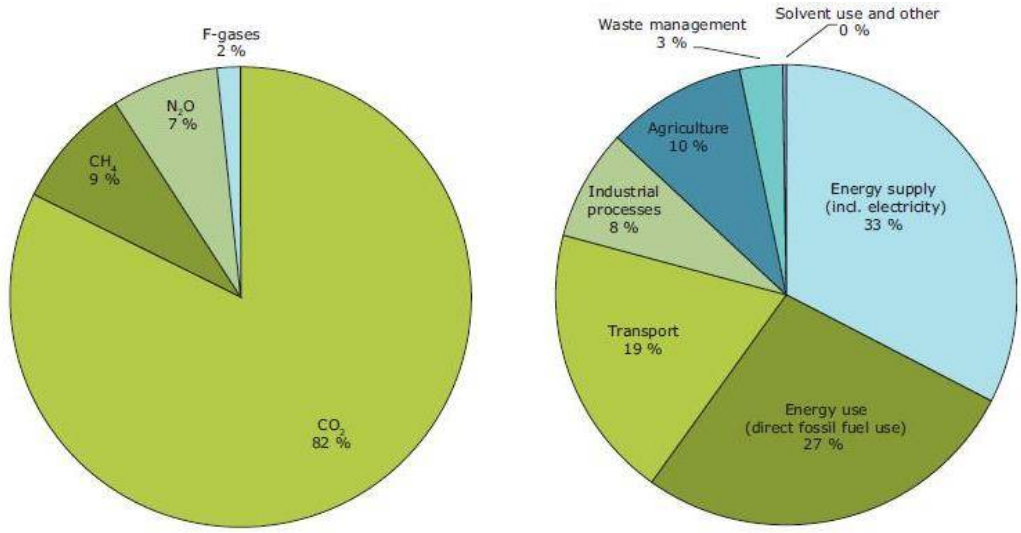
*Freight transport*

- *"An obvious consequence of increasing temperatures is reduced ice cover on rivers and lakes in various regions across the globe, e.g., Great Lakes in Canada, rivers in Russia.(...) This may open up the possibility for sea transport on the Northwest Passage during at least several months per year. This route may provide opportunities for more efficient transport between North-America, Europe and Russia and Asia." (Ref: **CO_0184**)*
- *"Changes in temperature and precipitation also have consequences for water levels in rivers and thereby for the inland shipping sector. Specifically, low water levels in rivers may disrupt transport by water in river basins such as the Mississippi and the Rhine where many goods (bulk freight) are transported by barges. Low water levels will force inland waterway vessels to use only part of their maximum capacity, which may considerably increase transportation costs." (Ref: **CO_0184**)*
- *"Climate change and CO2 emissions are clearly becoming significant factors in logistical decision-making. Over 50% of companies involved in road freight transport operations are likely to see their activities affected by climate change concerns to a significant or large extent by 2015. This is expected to rise to over 80% by 2020." (Ref: **CO_6018**)*

#### 1.4.2.2 GHG Mitigation

**Driver description**

- *"GHGs are a number of different gases and aerosols that have climatic impacts. Scientists compare the climatic impact of these various gases in terms of what is called radiative forcing[29]." (Ref: **CO_5046**)*
- *"As a consequence of the role played by fossil fuel combustion, CO2 is the predominant GHG emitted, accounting for 82 % of total GHG emissions (...). About 93 % of this CO2 originates from the combustion of fossil fuels, and the remaining 7 % from specific industrial processes." (Ref: **CO_0200**)*




**Note:** Emissions from international aviation and international maritime navigation, which are not covered by the Kyoto Protocol, are not included here. Net emissions from LULUCF are not included either. Emissions related to the use of public electricity and heat (generated from fossil fuel combustion) are included in the category 'energy supply'.

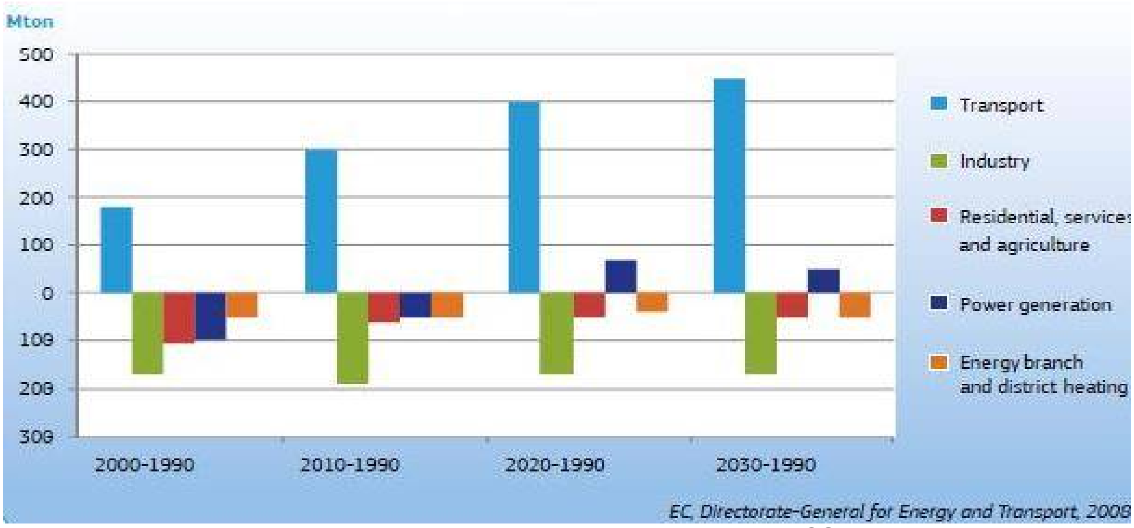
**Source:** EEA, 2011. See www.eea.europa.eu/data-and-maps/data/data-viewers/greenhouse-gases-viewer.

Source: A Roadmap for moving to a competitive low carbon economy in 2050 (Ref: **CO_0194**)

**Figure 1-59 GHG emissions in the EU-27 by gas and by sector (excerpt)**

- *"In order to keep climate change below 2ºC, the European Council reconfirmed in February 2011 the EU objective of reducing greenhouse gas emissions by 80-95% by 2050 compared to 1990 (...). Taking into account necessary efforts from developing countries, this will allow a global reduction of 50% in emissions by 2050." (Ref: **CO_0194**)*
- *"The transport sector is a major contributor to CO2 emissions because of its dependency on fossil fuels in all modes. Statistics indicate that the transport sector contributes 23% of all CO2 emissions in the 27 EU Member States. Despite significant efforts to reduce emissions, transport has not achieved its decarbonising targets. If this trend continues, transport is expected to contribute 50% of all CO2 emissions in the EU by 2050, if not within the next two decades. An overview of historic development of CO2 emissions and estimates for various sectors is shown in figure below. It clearly indicates the expected continuing growth of emissions from transport." (Ref: **CO_0234**)*

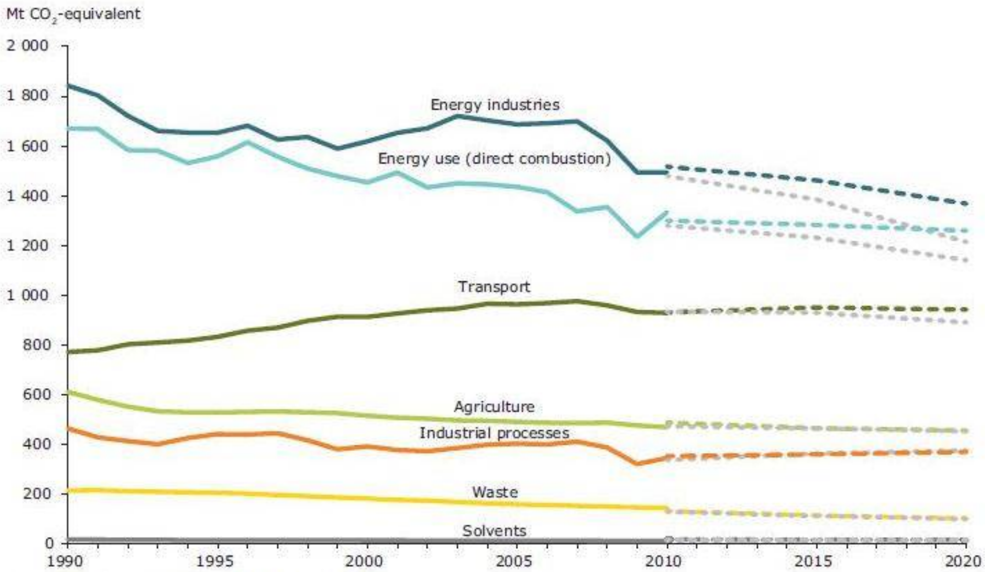
[29] Radiative forcing is a direct measure of the imbalance between the energy flowing into the earth's atmosphere from the sun and the energy being reflected and radiated back out into space; if there is more energy coming into than leaving the atmosphere, the earth is going to heat up. The year 1750, before world industrialization began, is used by many scientists and the Intergovernmental Panel on Climate Change as the baseline or zero point in relation to which radiative forcing is computed




Source: Towards low carbon transport in Europe (Ref: **CO_0234**)

**Figure 1-60 Change of CO2 emissions since 1990**

- *"The largest share of these emissions is generated in industrialized countries. But with rising motorization in many developing countries, the world's vehicle fleet will rapidly grow, and so will emissions. Most estimates of greenhouse gas emissions from transport are close to 13.5 percent of the total." (Ref: **CO_5028**)*
- *"Compared with 1990 levels, in no other sector has the growth rate of GHG emissions been as high as in transport. As the transport sector relies on fossil fuels for 97 % of its needs, the fight against climate change in this sector goes hand in hand with efforts to improve its energy security of supply." (Ref: **CO_0015**)*
- *"For passenger transport, urban transport is responsible for approximately a quarter of CO2 emissions." (Ref: **CO_0234**)*
- *"The intra-EU tourism transport alone contributes 11% of all greenhouse gas emissions in the EU (in 2000) which will rise to 18% (by 2020). The UN Intergovernmental panel on climate change estimates aviation causes 3.5% of man-made global warming and that figure could rise to 15% by 2050." (Ref: **CO_4010**)*
- *"Projections provided by sector indicate that with the existing measures currently in place, emissions will decrease between 2010 and 2020 in the main emitting sectors, except for the transport sector and emissions from industrial processes." (Ref: **CO_0131**)*




**Source:** EEA, 2011a; EEA, 2011b; EEA, 2011e.

(32) Member State projections are by definition not able to take into account interaction between national and EU measures such as decreasing ETS carbon prices due to lower energy demand and a higher share of renewable energy.
(33) Without recalibration, original projections for 2020 range from 14 % (baseline) to 20 % (reference).
(34) Based on projections for 2025 and 2030 reported by 13 Member States. For the other Member States, 2030 projections were gap filled using the 2020–2025 and 2020–2030 relative trends available from the Commission's scenarios based on the Primes and Gains models.
(35) COM(2011)112; the scope of emissions covered includes international aviation.

Source: Greenhouse gas emission trends and projections in Europe 2011 (Ref: **CO_0131**)

**Figure 1-61 Sectoral trends and projections of EU GHG emissions**

- *"Projections from Member States indicate that total EU emissions will not be significantly reduced in the period up to 2020: with the current national domestic measures in place, EU emissions in 2020 will be 19 % below 1990 levels, which is just short of its 20 % reduction target. The gap of 1 percentage point could be filled and the target overachieved by 5 points if Member States implement all additional measures currently being planned, in particular in the transport and residential sectors." (Ref: **CO_0131**)*
- *"In order to do so, we need action on three fronts: targeted public policies, technological progress, and commitment from (...) consumers and citizens." (Ref: **CO_4013**)*
- *"Significant reductions in net greenhouse gas emissions are technically feasible due to an extensive array of technologies and practices in energy supply and demand, waste and land management, and industrial sectors - many at little or no cost to society. However, realizing this technical potential will involve the development and implementation of supporting policies to overcome barriers to the diffusion of these technologies into the marketplace, increased funding for R&D, and effective technology transfer." (Ref: **CO_2019**)*
- *"With the additional measures currently planned, the EU would remain far from a pathway enabling it to achieve the long-term objective of reducing emissions by 80 % to 95 % by 2050, as agreed by European Heads of State and governments. According to the 'Roadmap for moving to a competitive low-carbon economy in 2050', published in March 2011 by the European Commission, costeffective emission reductions consistent with the long-term target could result in domestic emission reductions of about 40 % by 2030." (Ref: **CO_0131**)*
- *"Reducing our GHG emissions means attempting climate change mitigation, trying to reduce the impact we must expect. This will include new policies, innovative technologies and a change in lifestyle for all of us, all of which will certainly come at a price." (Ref: **CO_0091**)*
- *"Given that the Earth's climate has already changed and that further change is inevitable, future alterations need to be mitigated by reducing projected emissions of greenhouse emissions at the same time that countries adapt to climate change." (Ref: **CO_2019**)*

- *"Adaptation and mitigation can complement each other and together can significantly reduce the consequences of anthropogenic climate change – change caused by human activities." (Ref: **CO_0091**)*
- *"The exact nature of the trade-off between mitigation and adaptation is veiled by uncertainty on the actual impacts and on the potential progress of research and development on lower-cost cleaner technology." (Ref: **CO_2019**)*

## Interactions within the Environment Domain

### Climate change impacts

- *"Even if society substantially reduces its emissions of GHGs over the coming decades, the climate system is projected to continue to change over the coming centuries. In addition to taking mitigation measures, society will therefore have to adapt to the consequences of some inevitable climate change." (Ref: **CO_1027**)*
- *"Anthropogenic warming and sea level rise would continue for centuries even if GHG emissions were to be reduced sufficiently for GHG concentrations to stabilise, due to the time scales associated with climate processes and feedbacks." (Ref: **CO_1016**)*
- *"Unmitigated climate change beyond 2ºC will lead to unprecedented security scenarios as it is likely to trigger a number of tipping points that would lead to further accelerated, irreversible and largely unpredictable climate changes." (Ref: **CO_0120**)*

### Emission Trading Schemes

- *"Average 2008–2010 emissions in EU-15 were 9.9 % lower than the base-year level, below the Kyoto target of -8 % for the period 2008–2012. In the sectors not covered by the EU ETS, emissions were lower than their respective target, by an amount equivalent to 1.2 % the country's base-year emissions. LULUCF activities are expected to decrease net emissions by an annual amount equivalent to 0.9 % of base-year level emissions. EU-15 intends to use the flexible mechanisms at government level by acquiring an amount of Kyoto units equivalent to 2.5 % of base-year emissions per year. Taking all these effects in to account, average emissions in the sectors not covered by the EU ETS in EU-15 were standing below their target level, by a gap representing 4.7 % of the baseyear emissions. The EU-15 was therefore on track towards its Kyoto target by the end of 2010. Projections also show that over the full commitment period 2008–2012, EU-15 aggregated emissions will stay well below its Kyoto target with the current policies in place. However, failure by any Member State to comply with its burden-sharing target by the end of the commitment period could actually result in the non-achievement of its target by the EU-15." (Ref: **CO_0131**)*

### Pollution levels and emission standards

- *"There is also an emerging recognition of the important links between air pollution and climate change. Both issues share common sources of emissions — primarily from fuel combustion in industry and households, transport and agriculture — but also through cross-issue pollutant effects. This can be illustrated by the example of particulate black carbon (BC), formed through the incomplete combustion of fossil fuels, biofuels and biomass. BC is both an air pollutant harmful to health but also acts in a similar way as a greenhouse gas by increasing atmospheric radiative forcing." (Ref: **CO_0134**)*
- *"Most strategies to reduce transport GHG emission, also reduce emissions of local conventional pollutants and those that involve reduced vehicle use also reduce traffic congestion." (Ref: **CO_0148**)*
- *"Various scientific studies have identified that an important co-benefit of climate policies that lead to lower fossil fuel combustion is the strong reduction in emissions of air pollutants such as SO2, NOx and particulate matter (PM)." (Ref: **CO_0140**)*
- *"The combined effect of GHG reductions and air quality measures would bring about more than 65% lower levels of air pollution in 2030 compared to 2005." (Ref: **CO_0194**)*

### Energy availability, production and consumption

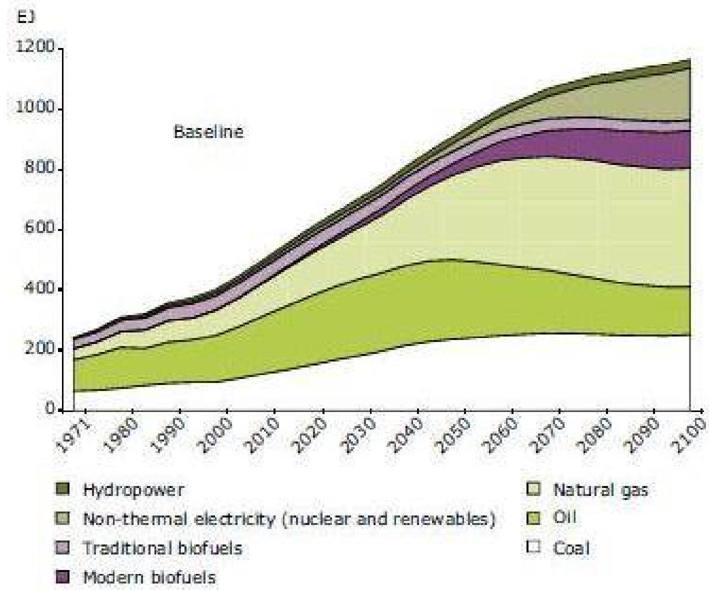
- *"Without further action to tackle climate change, the baseline scenario shows global primary energy consumption increasing by more than 2½ times by 2050, and continuing to rise to 2100.*

*These results are consistent with projections by IEA (IEA, 2004a), which show an increase of almost 60 % in global primary energy demand between 2002 and 2030." (Ref: **CO_1027**)*

- *"The energy sector produces the lion's share of man-made greenhouse gas emissions. Therefore, reducing greenhouse gas emissions by 2050 by over 80 % will put particular pressure on energy systems." (Ref: **CO_0245**)*

*Scarce resources of fossil fuels*

- *"Most strategies to reduce transport GHG emissions also reduce petroleum use, thereby contributing to energy security." (Ref: **CO_0148**)*




Source: Climate change and a European low-carbon energy system (Ref: **CO_1027**)

**Figure 1-62 Global development in energy use (baseline)**

## Interactions with the Social Domain

*Migration flows*

- *"Yet, a failure by governments and international agencies to reduce global GHG emissions and to support rural and urban populations to adapt will bring crisis-driven population movements that make those forced to move very vulnerable." (Ref: **CO_0147**)*

*Urbanisation*

- *"The confluence of a variety of interests and material circumstances in initiatives to mitigate climate change through urban design and development makes them complex and difficult to manage." (Ref: **CO_0147**)*
- *"The built environment provides low-cost and short-term opportunities to reduce emissions, first and foremost through improvement of the energy performance of buildings. The Commission's analysis shows that emissions in this area could be reduced by around 90% by 2050, a larger than average contribution over the long-term. This underlines the importance of achieving the objective of the recast Directive on energy performance of buildings that new buildings built from 2021 onwards will have to be nearly zero-energy buildings." (Ref: **CO_0194**)*

*Planning*

- *"Cities can be seen as part of the problem of climate change and therefore critical places for achieving mitigation. Reducing GHG emissions in cities is a key policy challenge. Municipal authorities are important actors in tackling the challenge of mitigation for three reasons. First, they have jurisdictional responsibility for key processes which shape emissions. Second, the concentration of people and business in urban areas means that mitigation solutions are feasible. Third, municipal governments provide a key interface for engagement with private-*

*sector and civil society stakeholders that also have a significant role in addressing climate change at the urban level." (Ref:* ***CO_0147****)*

- *"Research has shown that a small number of distinct 'modes of governing' by municipalities are being employed to address climate change in the urban arena." (Ref:* ***CO_0147****)*
- *"(...) there are (...) principal means through which municipal authorities have sought to reduce their own GHG emissions. The first is through the management of municipal buildings, fleets and services. The second is through procurement policies, including purchasing renewable energy for the municipality, or in the transport sector, buying alternative low-carbon fuels. The effectiveness of self-governing measures in reducing urban GHG emissions is limited by the extent of the municipal estate and operations. Also, in the majority of cases, municipal GHG emissions constitute a small proportion of the total emissions in a city." (Ref:* ***CO_0147****)*
- *"Mitigating GHG emissions by designing communities that are conducive to shorter vehicle trips and non-motorized travel could achieve a 1 to 2 percent reduction in nationwide vehicle travel by 2035 and a 1.5 to 5 percent reduction by 2050. Further, individual communities with a commitment to creating a travel-efficient environment could do substantially more." (Ref:* ***CO_4013****)*
- *"The political success of the London and Stockholm systems indicate that, at least in cities with fairly high transit-mode share and high-income populations, congestion charging can be politically successful and also successful at controlling the growth of transport sector CO2 emissions." (Ref:* ***CO_0017****)*

#### *Change of lifestyle and values*

- *"Reaching the full greenhouse-gas mitigation potential of energy-efficient and low-carbon energy technologies will depend to a significant extent on influencing consumers' technology choices and behavior." (Ref:* ***CO_0154****)*
- *"There are many policies that could reduce fuel consumption and GHG emissions at zero net cost for the simple reasons that consumers do not highly value, or are unaware of, efficiency considerations in their vehicle purchase decision and ignore many simple practices to reduce fuel use." (Ref:* ***CO_0148****)*

#### *Education*

- *"Energy and CO2 emissions can (…) be reduced through interventions aimed at changing driving behavior, such as reductions in excessive vehicle acceleration and driving speeds, smoothing traffic flows and reducing congestion. Eco-driving represents a set of changes in driving habits that can be learned through training and information guides, including through real-time information being provided by the vehicle to its driver." (Ref:* ***CO_0154****)*

### Interactions with the Economy Domain

#### *GDP trends*

- *"The implementation of policies to cut greenhouse emissions is acting as one of the key drivers for the modernization of the EU economy, directing investment and innovation to sectors with huge potential for growth and employment in the future. As set out in the Europe 2020 strategy, it is one of the core themes in any credible strategy to build sustainable prosperity for the future." (Ref:* ***CO_0201****)*
- *"In 2030 macro-economic costs for multi-gas mitigation, consistent with emissions trajectories towards stabilization between 445 and 710 ppm CO2-eq, are estimated at between a 3% decrease of global GDP (…). However, regional costs may differ significantly from global averages (high agreement, medium evidence)." (Ref:* ***CO_0146****)*
- *"Various forms of low carbon energy sources, their supporting systems and infrastructure, including smart grids, passive housing, carbon capture and storage, advanced industrial processes and electrification of transport (including energy storage technologies) are key components which are starting to form the backbone of efficient, low carbon energy and transport systems after 2020. This will require major and sustained investment: on average over the coming 40 years, the increase in public and private investment is calculated to amount to around € 270 billion annually. This represents an additional investment of around 1.5% of EU GDP per annum on top of the overall current investment representing 19% of GDP in 2009. It would take us back to the investment levels before the economic crisis." (Ref:* ***CO_0194****)*

#### *Employment*

- *"It is important to note that mitigation policies can represent opportunities for cities and their development prospects in terms of creating jobs." (Ref: **CO_0147**)*
- *"On a more macro-economic level, economic opportunities arise from measures taken to reduce GHGs: insulating buildings for example will not only save energy costs, but also give the building sector an enormous boost and create employment." (Ref: **CO_0091**)*

#### *Availability of public and private resources and investments in the transport sector*

- *"It is important to note that mitigation policies can represent opportunities for cities and their development prospects in terms of saving money." (Ref: **CO_0147**)*

#### *Energy availability and prices*

- *"A second impact is that energy costs and prices are likely to increase in most parts of the world as energy systems shift from relatively low-cost fossil energy sources to somewhat more expensive alternative energy systems." (Ref: **CO_0147**)*

#### *Fiscal policy*

- *"It is important to note that mitigation policies can represent opportunities for cities and their development prospects in terms of generating new streams of tax revenues." (Ref: **CO_0147**)*
- *"To make sure deeper GHG cuts in future years are achieved, government tax incentives to industry and consumers will be needed to overcome initial cost, institutional and infrastructure concerns and barriers." (Ref: **CO_0148**)*
- *"Emissions from road, rail and inland waterways could (...) be brought back to below 1990 levels in 2030, in combination with measures such as pricing schemes to tackle congestion and air pollution, infrastructure charging, (...), whilst securing affordable mobility." (Ref: **CO_0194**)*

### Interactions with the Technology Domain

#### *Technology development in general and innovation diffusion*

- *"To achieve deep reductions in GHG emissions and oil dependence, public policy must be multi-faceted, flexible, and adaptive. Policies are needed to pull technology that exists today into the marketplace, support technological development for the future, and correct market failures that have solidified our dependence on fossil fuels. This will require a combination of performance standards, pricing mechanisms, and research, development, demonstration, and deployment." (Ref: **CO_4013**)*
- *"To effectively reduce GHG emissions, energy efficiency, many types of renewable energy, carbon capture and storage (CCS), nuclear power and new transport technologies will all require widespread deployment." (Ref: **CO_5032**)*
- *"CCS[30] is on track to become one of the key technologies for combating climate change – within a portfolio of technologies, including greater energy efficiency and renewable energy." (Ref: **CO_2014**)*
- *"CCS can technically be applied to both coal- and natural gas-fired power plants." (Ref: **CO_2014**)*

#### *New vehicles design*

- *"In the face of the challenges of global climate change, the question arises as to whether the concept of "the car" should itself be re-considered. (...) Are the current requirements of power, size and comfort appropriate in the long term, given the needs of climate protection?" (Ref: **CO_0017**)*
- *"Aircraft fuel consumption and GHG emissions can be reduced by aerodynamic improvements to the airframe that increase its lift-to-drag ratio, material substitution and design changes that reduce the empty weight of the aircraft, and, increased engine efficiency, both in thermodynamics and propulsion." (Ref: **CO_4013**)*

[30] $CO^2$ carbon Dioxide Capture and Storage

*Traction technologies*

- *"The 2007 strategy aimed at reaching the Community objective of an equivalent of 120 gCO2/km by 2012 through a legislative framework addressing supply oriented measures. The package of measures listed the following elements:*
  - *to reach an objective of 130 gCO2/km for the average new car fleet by means of improvements in vehicle motor technology;*
  - *setting minimum efficiency requirements for air-conditioning systems;*
  - *the compulsory fitting of accurate tyre pressure monitoring systems;*
  - *setting maximum tyre rolling resistance limits in the EU for tyres fitted on passenger cars and light commercial vehicles;*
  - *the use of gear shift indicators, taking into account the extent to which such devices are used by consumers in real driving conditions;*
  - *fuel efficiency progress in light-commercial vehicles (vans) with the objective of reaching 175 gCO2/km by 2012 and 160 gCO2/km by 2015;*
  - *increased use of biofuels maximizing environmental performance." (Ref: **CO_0250**)*
- *"In the process of its implementation, the timeframe and the overall ambition of the Strategy have been amended. The main element of the Strategy, Regulation (EC) 443/2009, enters fully into force only in 2015. Also many of the additional implementing measures have different dates for entry into force, usually later than 2012. Furthermore, a new element of a long-term perspective, i.e. the 2020 target, was included in the CO2 from cars regulation and subsequently in the proposal for an equivalent regulation for light commercial vehicles. This longer-term vision should compensate for a delay of short-term reductions. Therefore, it is clear that despite the progress in implementing the Strategy (...), it is unlikely that the objective of an equivalent of 120 gCO2/km will be achieved in 2012." (Ref: **CO_0250**)*
- *"Policies and strategies for CO2 emission reduction have set targets for 2020 to increase the share of biofuels and of alternative hydrocarbon fuels. Targets have also been set for the development of hydrogen and fuel cell technology as economic, safe and reliable alternatives to fossil fuel." (Ref: **CO_0234**)*
- *"Low emission requirements and their maximum range favour the development of electric vehicles especially for urban use." (Ref: **CO_0234**)*
- *"One way to achieve substantial absolute emission reductions often suggested is to switch aviation to biofuels. However, there are doubts about the life cycle reductions to be achieved with alternative fuels and problems such as space use, conflicts with food production, and potential loss of biodiversity. It also appears that initially promising biofuels as Jatropha seeds, depend greatly on where the seeds are planted and may have serious environmental, social and economic problems associated with them. Some researchers recommend using caution when suggesting biofuels such as Jatropha will contribute to large scale greenhouse gas emission reductions." (Ref: **CO_0187**)*
- *"Governments have set targets to achieve 20 million electric vehicles (EVs) on the road by 2020, in line with levels required to achieve the 2DS[31] objectives. Achieving this goal, however, hinges on increasing vehicle production, lowering costs, developing infrastructure and boosting consumer choice and confidence." (Ref: **CO_0185**)*
- *"Up until 2025, the main driver for reversing the trend of increasing greenhouse gas emissions in transport sector is likely to remain improved fuel efficiency." (Ref: **CO_0194**)*

*Booking and payment systems*

- *"In view of the growth of international road traffic, the objective to internalise road externalities has gained particular weight and a number of Member States actively consider introducing extensive electronic road toll systems." (Ref: **CO_0253**)*

*Renewable energy production*

- *"Reducing projected GHG emissions in the energy production and supply sector will require a broad portfolio of technologies, including increased use of renewable energy technologies*

[31] Energy Technology Perspectives 2012 2OC Scenario (ETP 2DS) is a forthcoming publication that demonstrates how technologies can make a decisive difference in achieving the internationally agreed objective of limiting global temperature rise to 2°C above preindustrial levels.

*(biomass, solar, wind, run-of-the-river and large hydropower, and so on), and nuclear power." (Ref: **CO_2019**)*

*Energy efficiency*

- *"Low tyre pressure can increase fuel consumption and CO2 emissions by 4%, reduce tyre lifespan by 45% and can cause accidents. Fitting tyre-pressure monitoring systems (TPMS) should contribute to both greater fuel efficiency and safety." (Ref: **CO_0250**)*
- *"With full implementation of current policies, the EU is on track to achieve a 20% domestic reduction in 2020 below 1990 levels, and 30% in 2030. However, with current policies, only half of the 20% energy efficiency target would be met by 2020." (Ref: **CO_0194**)*
- *"It is possible to cut GHG emissions from the transportation sector cost-effectively by up to 65 percent below 2010 levels by 2050 by improving vehicle efficiency, shifting to less carbon intensive fuels, changing travel behavior, and operating more efficiently." (Ref: **CO_4013**)*

**Impacts on Mobility and Transport**

*Improvement in vehicles' technologies (fuel and energy consumption)*

- *"The main drivers of transportation GHG emissions are population, transport intensity (passenger or freight miles per person), energy intensity (vehicle fuel consumption), and fuel carbon intensity. Three of the four drivers of transportation GHG emissions (transport intensity, energy intensity, and carbon intensity) can also be thought of as levers that technologies and policies can use in order to reduce transport GHG emissions." (Ref: **CO_5046**)*
- *"Emission reductions have to be achieved by increasing efficiency in the transport sector, improving vehicle energy efficiency and extending the use of alternative fuels and propulsion technologies." (Ref: **CO_0234**)*
- *"(…) the decarbonisation of the transport sector is in essence reliant on two major assumptions: the availability of sustainable and very low GHG biofuels, and the use of almost carbon-neutral electricity (in line with the target set for the power sector) in electrified road transport." (Ref: **CO_5030**)*
- *"The European airline industry has set a target of 50% reduction in emissions per passenger kilometer by the year 2020, with 2000 as the benchmark year. Cleaner, more efficient engines will produce a 20% reduction but the remaining 30%—more than half the total figure—is uncertain (Millar, 2005)." (Ref: **CO_4010**)*

*But technologies will not be sufficient alone…*

- *"Technical options alone cannot achieve the European Commission's target of a 60 % reduction in GHGs from transport by 2050. Demand optimization will form an essential part of meeting this target; it can be very cost effective and can also offer environmental co-benefits such as air quality improvements and noise reduction." (Ref: **CO_5030**)*

*A shift to cleaner modes will be part of the solution*

- *"The International Railway Organization UIC foresees a modal shift from road and air traffic to rail traffic over the next decade, partly because of environmental policy (greenhouse gas emission targets). This shift is also recognized in a position paper on railway noise by the European Commission." (Ref: **CO_0144**)*
- *"Research has shown — for example in the CIVITAS initiative — the potential for CO2 reduction by shifting car trips to collective transport or to cycling." (Ref: **CO_0234**)*

*Together with measures for fostering public transport…*

- *"A recent survey of climate change plans in 30 cities worldwide found that the most common climate change mitigation actions in transport were the development of public transport (including bus rapid transit systems), the implementation of cleaner technologies, promotion of non-motorized transport, public awareness campaigns and implementation of cleaner technologies." (Ref: **CO_0147**)*

*Some users' resistances are difficult to overcome*

- *"Studies of cost effectiveness generally find transportation GHG reductions more expensive than reductions in most other sectors. The high cost is due to: low fuel price elasticity by passenger* *car owners (and light trucks); strong demand for personal travel, air travel, and goods transport; the difficulty of introducing new low carbon fuels and new fuel efficient propulsion technologies; deteriorating quality of public transport virtually everywhere; and the increasing share of goods carried by truck." (Ref:* ***CO_0148****)*

#### *1.4.2.3 Emission Trading Schemes*

**Driver description**

- *"For countries that are signatories to the Kyoto Protocol and with legally binding emission targets, a tool to help them is the Emissions Trading Scheme. This is a so-called cap-and-trade scheme, which means countries are allowed a certain amount of emissions which should decrease over time to achieve overall emission reduction. In the Kyoto scheme each allowance is called an Assigned Amount Unit (AAU), equivalent to one tonne of carbon dioxide. These allowances are tradable among countries. At the end of a set period each country must hold the same amount of AAUs as it has emitted tonnes of greenhouse gases. In case the country emitted more, they can add to the AAUs offsets that have been created under the Kyoto Protocol mechanisms in order to balance the additional emissions. This is where the CERs, ERUs and Removal Units from Carbon sinks (RMUs), etc. play their role." (Ref:* ***CO_0091****)*
- *"The EU ETS[32] is a key policy instrument to achieve the climate policy objectives in the European community. It was established by Directive 2003/87/ EC (the Emission Trading Directive) and entered into force on 1 January 2005." (Ref:* ***CO_0131****)*
- *"The EU ETS is being implemented in distinct phases or 'trading periods.' Phase 1, form 1st January 2005 to 31st December 2007, was a three year pilot-phase of "learning by doing" in preparation for the crucial phase 2. It successfully established a price for carbon-free trade in emission allowances across the EU and the necessary infrastructure for monitoring, reporting and verifying actual emissions from the businesses covered. (...) Phase 2, running form 1st January 2008 to 31st December 2012, coincides with the "first commitment period" of the Kyoto Protocol – the five-year period during which the EU and its Member States must comply with their emission targets under the Protocol. (...) Phase 3 will run for eight years, from 1st January 2013 to 31st December 2020.This longer trading period will contribute to the greater predictability necessary for encouraging long-term investment in emission reductions. The EU ETS will be substantially strengthened and extended from 2013, enabling it to play a central role in the achievement of the EU's climate and energy targets for 2020." (Ref:* ***CO_0202****)*
- *"The EU ETS covers CO2 emissions from large stationary sources including power and heat generators, oil refineries and installations for the production of ferrous metals, cement, lime, glass and ceramic materials, and pulp and paper." (Ref:* ***CO_0131****)*
- *"All EU Member States participate in the scheme. Bulgaria and Romania joined the ETS in 2007 as they became Members of the EU. Iceland, Liechtenstein and Norway, which do not belong to the EU, joined the EU ETS in 2008 and must comply with the same rules and regulations as the EU Member States.(...) Switzerland has a separate emissions trading scheme but intends to link its system to the EU ETS." (Ref:* ***CO_0131****)*
- *"The EU's vision is to create a carbon market among member countries of the Organisation for Economic Co-operation and Development (OECD) by 2015 and then to expand this to include the big emerging economies from around 2020. The company-level cap-and-trade systems that have been put in place in Switzerland, New Zealand and the north-eastern US states, the plans to set up such systems in Japan, Australia and California and the interest being shown in establishing a US federal system are all welcome developments in this context." (Ref:* ***CO_0202****)*

**Interactions within the Environment Domain**

***Climate change impacts***

Implementation of the Emission Trading Scheme is expected to have positive impacts in reducing climate change as it is directly targeted to a reduction of CO2 emissions, which are the main cause of global warming.

***GHG mitigation***

- *"The European Union is leading global efforts to reduce greenhouse gas emissions from human activities that are threatening to cause dangerous changes in the world's climate. As the cornerstone of its strategy for cutting its own greenhouse gas emissions cost-effectively, the European Union has developed the EU Emissions Trading Scheme (EU ETS)." (Ref:* ***CO_0202****)*

[32] Emission Trading Scheme

- *"The 2009 verified emissions from the sectors covered by the EU Emission Trading Scheme (EU‑ETS) decreased by 11.6 % compared to 2008 (EEA, 2010b)." (Ref: **CO_0140**)*
- *"A large proportion of the GHG emission reductions achieved in Europe over the last two decades took place during the 1990s as a result of the economic restructuring that occurred mainly in eastern Europe. Further reductions were achieved as a combined result of policies and measures implemented to reduce GHG emissions, such as the EU Emission Trading Scheme (EU ETS), and more recently from the short-term effects of the global economic crisis." (Ref: **CO_0131**)*
- *"The flexibility that the EU Emission Trading Scheme (ETS) is designed to create may be limited by the need to meet national emission ceilings or local air quality limits at the Member State level." (Ref: **CO_0134**)*

*Energy availability, production and consumption*

- *"The EC expects that this regime will provide an incentive to companies to pursue rationalization and efficiency, leading to considerable reductions in the energy consumption levels." (Ref: **CO_5037**)*

*Scarce resources of fossil fuels*

The diffusion of the Emission Trading Scheme will probably boost the technological development of alternative fuels, thus decreasing the dependence of fossil fuels.

### Interactions with the Social Domain

*Tourist flows*

- *"Whilst much debate continues on introducing aviation fuel tax as an emissions trading scheme for airlines it must be borne in mind that, for many developing nations, reliance on the benefits derived from tourism are considerable. Cheap airfares, thanks to the success of budget carriers, are appearing throughout the developing world, leading to increases in passenger volumes." (Ref: **CO_4010**)*

### Interactions with the Economy Domain

*GDP trends*

- *"The EU ETS should allow the European Union to achieve its emission reduction target under the Kyoto Protocol at a cost of below 0.1 % of GDP, significantly less than would otherwise be the case." (Ref: **CO_0202**)*

*Regional differences in economics*

- *"Besides providing a cost-effective means for EU-based industries to cut their own emissions, the EU ETS is also channelling substantial amounts of investment and clean technology to developing countries and economies in transition, thereby supporting their efforts to achieve sustainable development. This is happening because the system allows companies to use credits from emission-saving projects carried out under the Clean Development Mechanism (CDM) and JI to offset a proportion of their emissions." (Ref: **CO_0202**)*

*Availability of public and private resources and investments in the transport sector*

- *"It is estimated that auctioning could raise an EU wide total of € 30-50 billion per year by 2020, depending on the carbon price. Governments have agreed that they should use at least 50% of this income to combat climate change, in both Europe and developing countries." (Ref: **CO_0202**)*

*Foreign trade, globalisation*

- *"The market is EU-wide but taps into emission reduction opportunities in the rest of the world by accepting credits from emission-saving projects carried out under the Kyoto Protocol's Clean Development Mechanism (CDM) and Joint Implementation instrument (JI). The EU ETS is also open to establishing formal links with compatible mandatory cap-and-trade systems in third countries that have ratified the Kyoto Protocol." (Ref: **CO_0202**)*

*Energy availability and prices*

- *"In the first trading period; the price for 1 tonne of CO2 started at around EUR 7 per EUA[33], rising later to a maximum of over EUR 30 per EUA mainly due to limited liquidity in the market. At this time the power sector faced rising gas prices that incentivised a switch to coal power production; as a consequence emissions increased and thus the sector faced a shortage of allowances." (...) The allowances price dropped sharply after the publication of the first verified emissions in April 2006 to below EUR 10 per EUA. (...) Commission's decision on the NAPs for the second trading period market participants expected that, even though allowances of the first trading period lost their value due to the excess of free allocation, the situation would be different in the second trading period. Prices decoupled and the value of 2009 EUAs rose up to nearly EUR 30 in July 2008. Due to the economic crisis, the production of industrial products as well as the demand for electricity and consequently the emissions fell in autumn and winter 2008. Since spring 2009, the prices for EUA have remained at round about EUR 15 for over two years." (Ref: **CO_0131**)*

## Interactions with the Technology Domain

*Technology development in general and innovation diffusion*

- *"Pricing pollution emitted by energy use through environmental policies is an important driver for technological innovation and change (Jaffe et al., 2003)." (Ref: **CO_5009**)*

*Pollution abatement and monitoring*

- *"By putting a price on each tonne of carbon emitted, the EU ETS is driving investment in low-carbon technologies. It has forced the cost of emissions onto the agenda of company boards, thus marshalling the ingenuity and creativity of the business community in finding innovative and least-cost ways to fight climate change." (Ref: **CO_0202**)*

*Renewable energy production*

- *"The EU ETS will be critical in driving a wide range of low carbon technologies into the market, so that the power sector itself can adapt its investment and operational strategies to changing energy prices and technology. For the ETS to play this role on the identified pathway to 2050, both a sufficient carbon price signal and long-term predictability are necessary. In this respect, appropriate measures need to be considered, including revisiting the agreed linear reduction of the ETS cap[34]. Other tools, such as energy taxation and technological support may also be appropriate to ensure that the power sector plays its full part." (Ref: **CO_0194**)*

*Energy efficiency*

- *"The EU ETS (Emission Trading Schemes) is the European Union's main policy instrument for improving efficiency and reducing $CO_2$ emissions in the power and industry sectors. It is the world's largest greenhouse-gas emissions trading scheme. It covers around 12000 installations and nearly 50% of all European Union $CO_2$ emissions." (Ref: **CO_0153**)*
- *"In the implementation of the 20% energy efficiency target, the Commission will have to monitor the impact of new measures on the ETS in order to maintain the incentives in the ETS rewarding low carbon investments and preparing the ETS sectors for the innovations needed in the future. In this respect, appropriate measures need to be considered, including recalibrating the ETS by setting aside a corresponding number of allowances from the part to be auctioned during the period 2013 to 2020 should a corresponding political decision be taken. This would also ensure that the contribution to the energy efficiency target would be made in a cost efficient manner in both, the ETS and non-ETS sectors." (Ref: **CO_0194**)*

## Impacts on Mobility and Transport

*Increased cost for air transport*

- *"From 2012 the EU ETS will also include CO2 emissions from civil aviation. This means airlines of all nationalities will need allowances to cover the emissions from their flights to, from or within the EU. Using emissions trading to tackle the fast-growing emissions from the aviation sector is fully in line with the EU's obligations and which decisions taken by the 2004 assembly of the International Civil Aviation Organization." (Ref: **CO_0202**)*

[33] European Union Allowance
[34] Directive 2003/87/EC as amended by Directive 2009/29/EC foresees a linear reduction of the cap of 1.74 percentage points per year. This reduction is legally enshrined in the ETS and continues after 2020.

- *"The impacts on air transport activity are expected to be somewhat neutral for airlines. Firstly, at economic and social levels, the EC's studies indicate that companies will pass on, to a large extent or even in full, the cost of participating in the scheme to their customers, which by 2020 will represent an increase of €4.6 to €39.6 per flight, which is a value significantly lower than rises due to oil prices change in recent years." (Ref:* ***CO_5037****)*

*The transport sector might be increasingly regulated by similar mechanisms*

- *"Around 40 % of EU greenhouse gas emissions are covered by emission trading. Trading ensures that emissions are reduced as long as allocation plans are made properly, the market is transparent, and monitoring, reporting and verification works properly. At the same time, however, it is also based on a principle that over‐achievements in one year can be banked and used in another year. This way it allows for proper planning and predictability but at the same time makes over‐achievements less likely. Flexibility on emission reduction achievements thus arises mainly from sectors not covered by emission trading. With transport being one of the biggest sectors not covered by trading this means that transport represents, if not a 'low hanging fruit', at least one that may have to be picked." (Ref:* ***CO_0238****)*

### 1.4.3 The Pollution Factor

#### *1.4.3.1 Noise Levels and Emissions Standards*

**Driver description**

- *"(...) 'environmental noise' shall mean unwanted or harmful outdoor sound created by human activities, including noise emitted by means of transport, road traffic, rail traffic, air traffic, and from sites of industrial activity (...)." (Ref:* ***CO_0203****)*
- *"Generally, action to reduce environmental noise has had a lower priority than actions taken to address other environmental problems such as air and water pollution. However, as more information has become available about the health impacts of noise, the need for a higher level of protection for European citizens has come to be recognized." (Ref:* ***CO_0144****)*
- *"On 25 June 2002, Directive 2002/49/EC of the European Parliament and the Council relating to the assessment and management of environment noise (...) Environmental Noise Directive, END was adopted." (Ref:* ***CO_0127****)*
- *"Its main objectives are: to monitor environmental noise, to address local issues, to inform the public about noise issues, to oblige local authorities to draw up noise maps and action plans for reducing noise exposure in and around major cities, roads, railway lines and airports." (Ref:* ***CO_0151****)*
- *"Article 5 of the END[35] introduced noise indicators for reporting but does not set any legally binding EU-wide noise limit values or targets." (Ref:* ***CO_0127****)*
- *"(...) responsibility for setting noise exposure limits remains the competence of national authorities." (Ref:* ***CO_0151****)*
- *"Member States were required to prepare no later than 30 June 2007 strategic noise maps. These requirements apply again on 30 June 2012 and for each subsequent five year period. Such noise maps should be made for all major roads, railways, airports and agglomerations pursuant to article 7 identified in the preceding calendar year." (Ref:* ***CO_0127****)*
- *"The assessment relating to the first round of noise mapping suggests that around 40 million people across the EU are exposed to noise above 50 dB from roads within agglomerations during the night. More than 25 million people are exposed to noise at the same level from major roads outside agglomerations. These numbers are expected to be revised upwards as more noise maps are received and/or assessed." (Ref:* ***CO_0127****)*
- *"Various possibilities must be utilised to achieve effective noise abatement. These include the following types of measures: traffic-related, technical; structural; urban design; planning-related; organisational." (Ref:* ***CO_0150****)*

[35] European Noise Directive

| | |
|---|---|
| **Reducing traffic density**<br>• Promoting public transport<br>• encouraging cycling and walking<br>• traffic management and parking | • Promoting environmentally friendly means of transport, e.g. walking and cycling<br>• Enlarging the public transport system<br>• Providing P+ R facilities<br>• Parking management concepts<br>• Stabilising traffic flows<br>• Reclassifying and / or declassifying roads |
| **Reducing the percentage of heavy goods vehicles**<br>• designating HGV routes<br>• road management, e.g. bypasses | • Traffic bundling on appropriate routes<br>• Designating heavy goods vehicle routes<br>• HGV bans and restrictions at certain times |
| **Speed reduction / traffic calming measures** | • Reducing excessive driving speeds<br>• Designating 30 km/h zones<br>• Redesigning street layout<br>• Designating traffic-calmed (business) zones |
| **Renewal of public transport and (heavy) goods vehicles**<br>Public transport and (heavy) goods vehicles | • Introducing low-noise buses and trams<br>• Promoting low-noise (heavy) goods vehicles |
| **Changing the road surface**<br>• improvements to roads<br>• improvements to tram tracks | • Use of low-noise road surfaces<br>• Tram track rehabilitation and regular track maintenance |
| **Noise screening** | • Noise barriers (with solar cells) and earth banking<br>• Use of building structures for screening<br>• Use of tunnels and troughs |
| **Sound-proof windows** | • Windows with ducted ventilation<br>• Ventilation system |
| **Urban planning** | • Reducing / avoiding traffic by decentralising local amenities into sub-centres of settlement<br>• Interposing less sensitive uses between the noise source and sensitive uses |

Source: Guidelines for Road Traffic Noise Abatement (Ref: **CO_0150**)

**Figure 1-63 Breakdown of available measures to reduce, avoid or relocate the various types of noise source**

- *"Noise reduction measures are naturally also needed in the rail and air traffic sectors. However, the local authorities have very limited scope for action in this area, due to the involvement of national and international administrative bodies. Nonetheless, decision-makers at the local authority level and noise experts should bear this issue in mind when devising noise abatement plans." (Ref: **CO_0150**)*
- *"There are essentially two routes to noise abatement. Firstly, noise emissions can be reduced at their source, through measures relating to vehicles/drivelines, tyres, road surfaces and traffic management. Secondly, noise can be abated by reducing the exposure of people by means of anti-propagation or insulation measures (by increasing the distance between source and recipient, for example, or hampering noise propagation by insulating buildings or constructing noise barriers)." (Ref: **CO_0151**)*
- *"Noise reduction measures at the noise source should be considered before applying noise barriers or protection measures at the receiver (insulation, soundproof windows, etc.)." (Ref: **CO_0144**)*
- *"(...) noise level reduction resulting from noise barriers is 2-25 dB depending on the specific design. This value is valid for façade-road distances of 50-150 m, and receiver heights up to 10 m. At larger distances and receiver heights the noise level reduction can be less. In case of a noise barrier at one side of the road, an increase of the noise level at the opposite side of the road can occur (...). However, barriers are only acceptable for roads where pedestrians do not have to cross and barriers may be visually unattractive." (Ref: **CO_0144**)*

- *"In the near future road traffic volumes will increase, resulting in an increase of noise emissions. The overall increase in road traffic volume tends to counterbalance the real noise reduction achieved by noise mitigation measures." (Ref: **CO_0144**)*
- *"An international standard for noise road surface classification systems should be developed, laying down terms for including acoustic performance in public contracts for road surfacing." (Ref: **CO_0151**)*
- *"To guarantee the European population a healthier living environment, noise exposure standards should be set and enforced for several different environments (outdoor living area, dwelling interiors, schools, etc.), as is the case with current EU air quality standards. In quantifying these standards, the guidelines drawn up by the WHO could serve as a starting point. These exposure standards could then serve as an appropriate basis for the action plans prescribed in the EU Environmental noise directive." (Ref: **CO_0151**)*

## Interactions within the Environment Domain

### *Pollution levels and emissions standards*

- *"The potential for closer co-ordination and integration of air quality and noise management has been suggested frequently. The implementation of the Ambient Air Quality Directive (2008/50/EC) and its predecessors requires similar elements, e.g. the data collection in agglomerations, improvement of assessment methods, preparation of action plans, information of the public and reporting to the Commission." (Ref: **CO_0127**)*

## Interactions with the Social Domain

### *Income structure and distribution*

- *"It is an established fact that people who have no financial constraints on their choice of dwelling prefer ceteris paribus quiet locations to noisy ones." (Ref: **CO_0150**)*
- *"Epidemiological studies show, in accordance with the fact that socially disadvantaged people are more likely to live near busy roads, that noise annoyance due to traffic is often higher in people with a lower socioeconomic position. In addition, social inequalities in objectively assessed noise exposure have been demonstrated (Bolte, Tamburlini and Kohlhuber, 2010). However (...) it must be borne in mind that different transport types (such as road, train and air) may have different inequality profiles." (Ref: **CO_0215**)*
- *"The overall prevalence of complaints about noise from neighbors or from the street varies by country between 10% and 35%, with an average of 22% across EU27 (2009 figures). In the majority of the 30 reporting countries, self-reported noise exposure at home is higher among individuals living in relative poverty, although in six countries this pattern is reversed. Prevalence in EU27 is 25% among individuals below the relative poverty threshold and 22% among those above it. However, when the countries are grouped into subregions, the prevalence difference between the two income categories is present in EU15 countries (26% versus 22%) but disappears in NMS12 countries (21% for both income categories)." (Ref: **CO_0215**)*

### *Urbanisation*

- *"Urbanization, growing demand for motorized transport and inefficient urban planning are the main driving forces for environmental noise exposure. Furthermore, noise pollution is often linked to urban areas where also air quality can be a problem." (Ref: **CO_0127**)*
- *"Road traffic is a main source of noise in urban areas, accounting for about 80 % of total noise pollution." (Ref: **CO_0150**)*
- *"(...) the nature and volume of the present traffic mix continue to raise serious public concern about the effects of noise and vibration in the urban environment. This has been exacerbated in recent years by the proliferation of calming measures, designed to improve safety by reducing average speeds, but giving rise to more frequent deceleration/acceleration events." (Ref: **CO_0260**)*
- *"Sound insulating materials can be applied to buildings in order to reduce noise levels. The noise reduction of insulated glazing and ventilation provisions is typically 5-20 dB (...). Soundproof windows may serve as protection against noise. However, such windows have to be closed to be effective, which may be an unwanted restriction for many people, especially during the summer. Also reductions up to 20 dB can be obtained in case of closed façades (no windows that can be*

*opened) or dwellings integrated in noise barriers. However, in these cases the closed façade and noise barrier side must preferably be situated to the north or east." (Ref: **CO_0144**)*

*Planning*

- *"The limiting of noise in urban areas should play an essential role in present city planning." (Ref: **CO_0144**)*
- *"New housing areas should be planned from the outset in a way that ensures that at least the central area is quiet. This involves designating the centre of new areas as pedestrian and cycling zones, or at least providing traffic calming measures." (Ref: **CO_0150**)*
- *"The building orientation with respect to the road is an important parameter that influences noise level. Whether or not building blocks close to roads are connected influences noise propagation. The noise reduction potential is dependent on the specific situation. Furthermore, the reduction of noise propagation could be taken into account in road design and construction." (Ref: **CO_0144**)*
- *"Mixing of land-uses can reduce the need to travel, leading to less transport noise." (Ref: **CO_0144**)*
- *"While one aim of planning is to reduce loud noise at black spots, another important goal is to preserve areas which are still tranquil." (Ref: **CO_0150**)*
- *"Land-use planning and management is an effective means to ensure that the activities taking place nearby airports are compatible with aviation. Its main goal is to minimize the population affected by aircraft noise by introducing land-use zoning around airports. Compatible land-use planning and management is also a vital instrument in ensuring that the gains achieved by the reduced noise of the latest generation of aircraft are not offset by further residential development around airports. Aircraft-noise management measures in the 'Land-use planning and management' category include both planning of the (urban) area in the vicinity of an airport and planning of new runways of an airport (or a new airport). In general, from an environmental point of view new runways or a new airport should be planned as far as possible from urban areas." (Ref: **CO_0144**)*

*Education*

- *"Good information for the public about noise abatement measures is important for acceptance by the public, certainly where restrictions are imposed. It is important to raise awareness among the urban population about the effect of its choice of transport mode on the quality of the urban environment in general and the noise climate specifically. However, it is also the duty of local authorities to promote the use of more sustainable transport modes and to provide alternatives for people to walk, cycle and use public transport instead of driving alone." (Ref: **CO_0144**)*
- *"To achieve a high degree of acceptance for the realization of noise-abatement measures by the public, a well structured participation and consultation process is crucial. Based on the principles of dialogue, discussion, and exchange of experience, it will become clear to the public that noise pollution is everyone's business and that everyone can contribute to the reduction of annoyances and disturbances from noise." (Ref: **CO_0150**)*

*Health*

- *"Environmental noise is a significant environmental problem across the EU. Increasingly more information is becoming available about the health impacts of noise." (Ref: **CO_0127**)*
- *"Noise pollution can annoy, disturb sleep, affect the cognitive function in schoolchildren, cause physiological stress reactions and can cause cardiovascular problems in chronically noise exposed subjects. Stress can trigger the production of certain hormones which may lead to a variety of intermediate effects, including increased blood pressure. Over a prolonged period of exposure these effects may in their turn increase the risk of cardiovascular disease and psychiatric disorders." (Ref: **CO_0127**)*
- *"In the current Directive, Member States are required to use specified noise indicators of $L_{den}$[36] and $L_{night}$[37] and report the noise exposure of the population of 55 dB and 50 dB or more, respectively. However, the current reporting neglects the fact that there is a considerable share*

[36] day-evening-night noise indicator
[37] day-evening-night noise indicator

*of EU population exposed to noise pollution at lower levels which are still likely to cause harmful effects on health. According to the latest WHO[38] recommendations, reporting bands of the indicator values of $L_{night}$ should be lowered to 40 dB, $L_{night}$ in order to achieve a much more realistic assessment of noise pollution impacts across the EU." (Ref:* ***CO_0127****)*

- *"Of all the adverse effects of traffic noise the most widespread is simply annoyance." (Ref:* ***CO_0151****)*
- *"Annoyance is an emotional state connected to feelings of discomfort, anger, depression and helplessness." (Ref:* ***CO_0128****)*
- *"Sleep disturbance and annoyance, mostly related to road traffic noise, are the key health issues. At least one million healthy life years are lost every year from traffic-related noise in western European countries, including the EU Member States (WHO, 2011)." (Ref:* ***CO_0215****)*

### Interactions with the Economy Domain

#### *GDP trends*

- *"The social cost of road traffic noise in the EU22 is estimated to be at least 38 (30 - 46) billion per year, which is approximately 0.4% of total GDP in the EU22. For rail, estimates of social costs due to noise are about 2.4 (2.3 - 2.5) billion per year (about 0.02% of total EU22 GDP). It should be noted that this takes into account only effects related to noise levels above 55 dB(A), while people may also be adversely affected by noise below this level. Hence, the social cost estimates presented here probably underestimate the actual costs." (Ref:* ***CO_0151****)*

#### *Availability of public and private resources and investments in the transport sector*

- *"Economic costs of noise pollution include devaluation in house prices, productivity losses from health related impacts and distributional impacts. Social costs are related to premature death or morbidity (poor concentration, fatigue, hearing problems)." (Ref:* ***CO_0127****)*
- *"According to the 2011 Commission's White Paper on Transport, the noise-related external costs of transport would increase to roughly 20 billion € by 2050 unless further action was taken." (Ref:* ***CO_0127****)*
- *"Noise abatement policies will have major economic benefits. Less people will be annoyed by traffic noise and the incidence of health problems will decline. With their sleep less disturbed, people may also be more productive at work." (Ref:* ***CO_0151****)*
- *"Noise abatement policies will generate cost savings for government, too. Expenditures on the health system will be lower due to a decline in noise-related health problems." (Ref:* ***CO_0151****)*
- *"There are several ways to minimize the costs of noise mitigation measures. In case of already existing noise sources, noise mitigation measures can be applied simultaneously with renovation or maintenance activities (e.g. renovation of buildings can be combined with applying soundproof windows). In case of constructing new noise sources or new noise sensitive buildings near noise sources, it is most cost effective to reduce noise levels by taking it into account in the planning process (so that noise source and receiver are separated sufficiently, for example)." (Ref:* ***CO_0144****)*

#### *Fiscal policy*

- *"Taxes can be applied for several purposes, e.g. to cover costs (for the road being used) or to influence the public's behavior. A differentiation of motor vehicle taxes may be applied. In Germany and Austria use of low-noise vehicles is stimulated by lower taxes and these vehicles are also excluded from night time restrictions." (Ref:* ***CO_0144****)*
- *"Fuel taxes can be an incentive to reduce noise as they influence the distance travelled." (Ref:* ***CO_0144****)*

### Interactions with the Technology Domain

#### *Technology development and innovation diffusion*

- *"The field of transportation has many areas for innovation.(...) Noise is another issue that is calling for innovation (…)." (Ref:* ***CO_0284****)*

[38] World Health Organization

*New vehicles design*

- *"Much of the research on aircraft noise over the past 30 years has been aimed at reducing noise at the source. Aero planes and helicopters built today are required to meet the latest ICAO[39] noise certification standards." (Ref: **CO_0144**)*

*Material technology*

- *"The greatest road traffic noise reduction may be obtained by technical measures at source applied to the power train, tyre/road interaction, and the road surface." (Ref: **CO_0144**)*
- *"Renewing road surfaces or replacing rough paving with smooth asphalt is another action that can be taken to reduce sound levels and noise impact. Measures need to be taken to ensure that vehicle speeds do not increase following the resurfacing of the road." (Ref: **CO_0150**)*
- *"In addition to power train and tyre/road measures, application of low-noise road surfaces such as thin-layer, double layer, porous and poroelastic asphalt leads to considerable noise level reductions. Depending on driving speed and surface type the noise level reduction may be up to 8 dB." (Ref: **CO_0144**)*

*Energy efficiency*

- *"For aircraft, noise levels and fuel consumption can go in opposite directions. For example, a move to efficient open-rotor designs would increase noise." (Ref: **CO_0154**)*
- *"For cars, the emergence of low-rolling-resistance tyres and near-silent electric propulsion systems offer the potential for significantly quieter vehicles and less energy use. A minimum level of noise may need to be generated by electric vehicles (EVs) to avoid increases in vehicle-pedestrian accidents." (Ref: **CO_0154**)*
- *"Train technologies are becoming generally quieter. Improving energy efficiency in most cases helps reduce noise levels." (Ref: **CO_0154**)*

## Impacts on Mobility and Transport

*Reduction of speed of motor vehicles and traffic volumes in urban areas*

- *"Limiting traffic speeds leads to a reduction of noise. Decreasing traffic speeds in urban areas by 10 km/h leads to a reduction in noise levels of 0.7-2.1 dB for speeds between 50 km/h and 100 km/h. The speed reduction measures should not lead to an increase in braking and accelerating or gear changing, since this could even lead to a net increase of noise levels. For example, traffic restraints like humps will reduce speed. Application of round-top road humps has a noise reduction potential of 2 dB. However, application of flat-top humps may even increase noise up to 6 dB (...)." (Ref: **CO_0144**)*
- *"Reducing traffic volumes reduces noise in the case that other conditions do not change. However, traffic volume and speed are generally related; a decrease in volume usually leads to an increase in speed." (Ref: **CO_0144**)*
- *"For traffic volume reductions between 10% and 50% a noise reduction between 0.5-3.0 dB may be obtained." (Ref: **CO_0144**)*

*Different measures shall be applied to different vehicle fleets' compositions*

- *"The effect of various noise mitigation measures can depend on fleet composition. This composition may be different for different countries; e.g. the Mediterranean fleet contains a relatively large number of two-wheeled motor vehicles (Rome and Barcelona have the largest numbers of two-wheel motor vehicles). Furthermore the percentage of heavy-duty vehicles contained in the fleet influences noise emissions. Should the percentage of heavy duty vehicles be lowered from 10% to 0% a noise reduction of 1.4 dB and 1.9 dB is obtained at traffic speeds of 50 km/h and 80 km/h respectively. It should be noted that these reductions seem rather high; the Dutch road model yields 1.4 and 0.1 dB, respectively." (Ref: **CO_0144**)*
- *"Only in regions where motorcycles make up a significant fraction of the overall vehicle fleet they are a major contributor to ambient noise levels. Although it is mainly in urban settings that this noise problem is noticed and reported, their annoyance potential is also high elsewhere because of the high percentage of illegal noise-increasing mufflers fitted and often aggressive driving*

[39] International Civil Aviation Organization

*behaviour. A Swedish noise annoyance study identified motorcycle noise as by far the most annoying form of vehicle-related noise. Consequently, measures to address the use of such mufflers need to be given the highest priority." (Ref: **CO_0151**)*

***Stricter noise restrictions should be applied to new motor vehicles***

- *"Furthermore, local authorities are in the right position to influence noise mitigation by requiring ambitious noise specifications when vehicles are purchased." (Ref: **CO_0144**)*

***Fostering the use of public transport***

- *"Travelling by public transport instead of in private cars generally leads to less congestion and is more energy efficient, less air polluting, and less noisy (the noise emission per capita is lower). An advantage of public transport concerning noise is that the noise source is more concentrated, making it easier to apply noise mitigation measures at the source." (Ref: **CO_0144**)*

***Increase in measures tackling noise for railway (vehicles, tracks, research activities)***

- *"In general, railway noise affects less people than that of road and air traffic, and moreover, people are more tolerant towards railway noise than towards road and air traffic noise. As a consequence of the modal shift (...), however, one can expect that without noise reduction measures the number of people affected by railway noise will increase" (Ref: **CO_0144**)*
- *"Noise is one of the most significant environmental impacts of rail traffic." (Ref: **CO_0151**)*
- *"Noise pollution from railways remains one of the main barriers for expanding their use in urban areas and along densely populated rail freight corridors." (Ref: **CO_0089**)*
- *"Railway noise abatement is also part of the EC Greening transport package, which aims to move transport further towards sustainability. One of the objectives is a 50% reduction of the perceived noise from existing rail freight trains. Seventeen instruments for railway noise abatement: retrofitting of existing railway rolling stock, noise reception limits, noise emission ceiling, access restrictions for noisy vehicle types/trains, noise emission regulations for vehicles, programmes to manage rail roughness, track upgrading or new design, regulations for tracks, specifications for noise emissions in procuring/ordering new vehicles and tracks, incentives for the use of low noise vehicles, public funding for noise abatement programmes, voluntary agreements, Member State and EU funding for research and development, information to stakeholders, improved measurement standard for railway exterior noise, comprehensive noise prediction scheme, information and participation of the public." (Ref: **CO_0144**)*

***Increase in measures tackling noise for air mode (engines, airport design and related infrastructures)***

- *" (…) aircraft noise is often the reason for the difficulty of expanding airport capacity at major European hubs." (Ref: **CO_0089**)*
- *"Noise abatement procedures enable reduction of noise during aircraft operations to be achieved at comparatively low cost. There are several methods, including preferential runways and routes, as well as noise abatement procedures for take-off, approach and landing. The appropriateness of any of these measures depends on the physical layout of the airport and its surroundings, but in all cases the procedure must give priority to safety considerations." (Ref: **CO_0144**)*
- *"In general, aircraft-noise reduction strategies and measures should comply with the so-called 'balanced approach' to aircraft noise management around airports, as formulated by the International Civil Aviation Organization (ICAO). The ICAO 'balanced approach[40]' was implemented in EU legislation by Directive 2002/30/EC, which deals with the establishment of rules and procedures with respect to the introduction of noise-related operating restrictions at EU airports." (Ref: **CO_0144**)*
- *"In 2020, aircraft are cleaner and quieter and the aeronautics sector's contribution to a sustainable environment is widely understood and appreciated. Aircraft noise is no longer a*

[40] ñThe 33rd ICAO Assembly has adopted Resolution A33/7 introducing the concept of a ôbalanced approachô to noise management, thereby establishing a policy approach to address aeroplane noise, including international guidance for the introduction of operating restrictions on an airport-by-airport basis. The ôbalanced approachô concept of aircraft noise management comprises four principal elements and requires careful assessment of all different options to mitigate noise, including reduction of aeroplane noise at source, l and-use planning and management measures, noise abatement operational procedures and operating restrictions, without prejudice to relevant legal obligations, existing agreements, current laws and established policies.ò(Ref. **CO_0218**)

*political and social issue. It has ceased to be a nuisance to people living close to airports thanks to a concerted effort to develop quieter engines, optimise operational procedures and improve land planning and use around airports." (Ref:* ***CO_2043****)*

### 1.4.3.2 Pollution Levels and Emission Standards

**Driver description**

- *"Emissions of a range of air pollutants and greenhouse gases occur as a result of almost all economic and societal activities, including electricity generation and industrial production; transport; residential heating; and product use; agriculture and waste treatment." (Ref: **CO_0134**)*
- *"Within the EU, the National Emission Ceilings (NEC) Directive (EC, 2001b) imposes ceilings (or limits) that must be met by 2010 for emissions of four key air pollutants (NOX, SO2, NMVOC and NH3) that harm human health and the environment. Internationally, the issue of air pollution emissions is also addressed by the United Nations Economic Commission for Europe (UNECE) Convention on Long-range Transboundary Air Pollution (the LRTAP Convention) and its protocols (UNECE, 1979). The Gothenburg 'multi-pollutant' Protocol to the LRTAP Convention (UNECE, 1999) also contains 2010 national emission ceilings for those countries that have ratified the protocol. For the EU Member States, these ceilings are either equal to or less ambitious than those in the NEC Directive. Both the NEC Directive and Gothenburg Protocol are currently under review." (Ref. **CO_0226**)*
- *"In terms of the main activities responsible for air pollution, the top polluting sources across Europe in 2008 included agriculture and fuel combustion by power plants, passenger and heavy-duty vehicles, and households." (Ref: **CO_0134**)*
- *"At present, PM[41] and O3 are Europe's most problematic pollutants in terms of harm to health." (Ref: **CO_0129**)*
- *"Emissions of primary particulate matter from road transport decreased by around 14 % between 1990 and 2005, mainly due to improvements in diesel-fuelled vehicles. Without the introduction of the Euro standards for road transport vehicles, emissions would have been more than doubled during this period." (Ref: **CO_0226**)*
- *"Traffic-related emissions of air pollutants continue to contribute to air quality problems and associated health effects in most European urban areas. Traffic emissions of particulate matter (PM10 and PM2.5) and NOx are the local pollutants of most concern as the daily limit value of PM10 and the annual limit value for NO2 are exceeded most extensively (...). Road traffic may also contribute to high levels of benzene and poly-aromatic hydrocarbons (PAH) in some conurbations." (Ref: **CO_0102**)*
- *"Ozone is a strong photochemical oxidant. In elevated concentrations it causes serious health problems and damage to materials and vegetation such as agricultural crops. The main sectors that emit ozone precursors are road transport, power and heat generation plants, household (heating), industry, and petrol storage and distribution." (Ref: **CO_0220**)*
- *"The road transport group is nevertheless a major source of the ozone precursors NOX and CO in the European Union, in 2009 contributing 42 % and 34 % of total EU-27 emissions respectively. It is also a major source of NMVOC, PM2.5 and PM10 emissions. Passenger cars and heavy duty vehicles are the principal contributors to NOX emissions from this sector, whereas for CO passenger cars alone contribute around 73 % of the emissions from the same sector." (Ref: **CO_0233**)*
- *"It is important to note, however, that a number of NOX vehicle emission standards have not been as effective in reducing real-world NOX emissions as was originally anticipated, especially for diesel vehicles (both passenger vehicles and heavy- and light-duty vehicles). Much of the past reduction in NOX from road transport can thus mainly be ascribed to gasoline passenger cars and not diesel vehicles." (Ref: **CO_0224**)*
- *"In contrast to the road transport sector, emissions of NOX from aviation have increased significantly since 1990. Emissions from both domestic and international flight activities increased by 79 % between 1990 and 2009 (but decreased by 6 % from 2008 to 2009)." (Ref: **CO_0233**)*

[41] Particulate matter (PM) is the general term used for particles with a wide range of sizes and chemical compositions. PM2.5 refers to 'fine particles' with a diameter of 2.5 micrometres or less. PM10 refers to the particles with a diameter of 10 micrometres or less.

- *“For the sector 'road transport' the main heavy metal is Pb, showing high relative emission reduction (– 99 %) between 1990 and 2009. However over the last years, little progress has been made in reducing emissions further; total emissions of Pb have remained largely constant.” (Ref: **CO_0224**)*
- *“(...) under the current policy scenario, emissions of the main air pollutants, excepting NH3, are all projected to decline by 2020 for the EEA-32 and Western Balkan countries. Compared with 2008 emission levels, the largest decreases in percentage terms are projected for emissions of NOX and SO2.” (Ref: **CO_0134**)*
- *“A time horizon of 2050 has been suggested as an aspirational target year by which Europe's long-term objectives of achieving levels of air pollution that do not lead to unacceptable harm to human health and the environment should be met. Preliminary assessments indicate that in order to meet these objectives, for SO2 there should be an emissions reduction in the range 40–60 % compared with 2010, especially in northern and central Europe. For NOX and NH3 the required reductions are in the range of 70–90 % and for O3 precursors 70–80 %, in particular in southern, western and central Europe. In urban areas a 40–60 % emission reduction of PM would be needed (Maas et al., 2009).” (Ref: **CO_0134**)*
- *“EU action has focused on establishing minimum quality standards for ambient air and tackling the problems of acid rain and ground level ozone. Polluting emissions from large combustion plant and mobile sources have been reduced; fuel quality improved and environmental protection requirements integrated into the transport and energy sectors. Despite significant improvements, serious air pollution impacts persist.” (Ref. **CO_0225**)*

## Interactions within the Environment Domain

### *Climate change impacts*

- *“In addition to their impacts as air pollutants, tropospheric O3 and some constituents of PM affect the radiative forcing of the atmosphere. Their impacts are complicated to assess, but in general emissions of primary PM, such as black carbon and tropospheric O3 increase radiative forcing leading to a net warming effect in the atmosphere, while secondary PM formed from precursor emissions reduces atmospheric radiative forcing (IPCC, 2007).” (Ref: **CO_0134**)*
- *“Air pollution may also impact the Earth's climate. Some air pollutants interfere with the Earth's energy balance and are therefore known as 'climate forcers'. These can either be gases (e.g. ozone) or airborne particulate matter (aerosols). Some climate forcers reflect solar radiation (e.g. sulphate aerosols) leading to net cooling, while others (e.g. black carbon aerosols) absorb solar radiation, thereby warming the atmosphere. In addition, aerosols influence the formation, microphysics and optical properties of clouds, resulting in indirect climatological effects. Deposition of certain aerosols (e.g. black carbon) may also change the Earth's surface reflectivity (albedo), especially on ice- and snowcovered surfaces, thereby accelerating melting.” (Ref: **CO_0129**)*
- *“Several air pollutants are also climate forcers, having a potential impact on the planet's climate.” (Ref: **CO_0129**)*

### *GHG mitigation*

- *“In the EU‑15, the implementation of air pollution control measures for large combustion plants (the LCP Directive, later reinforced by the IPPC Directive) produced important co-benefits for GHG emissions by encouraging efficiency improvements and fuel switching to cleaner fuels. These positive developments took place despite the fact that such policies were not specifically designed to reduce GHG emissions.” (Ref: **CO_0200**)*

### *Emission trading schemes*

- *“It is important to note, however, that efforts to control emissions of one group of pollutants can have either synergistic or sometimes antagonistic effects on other pollutants, in turn leading to unforeseen benefits or disadvantages. (...) The flexibility that the EU Emission Trading Scheme (ETS) is designed to create may be limited by the need to meet national emission ceilings or local air quality limits at the Member State level. Governments may thus need to impose air pollutant control measures at ETS facilities going beyond Best Available Techniques, which in turn could increase emissions of greenhouse gases. The extent to which such additional policies effectively constitute negative impacts on the ETS sector is unclear.” (Ref: **CO_0134**)*

*Noise levels and emissions standards*

- *"In many cases noise reduction is a side effect of socio-economic measures that are primarily implemented for other purposes such as air pollution or traffic safety." (Ref: **CO_0144**)*

*Energy availability, production and consumption*

- *"The energy production and distribution sector remains by far the most important source of SOX emissions and is also a major source of NOX[42], Cd[43], Hg[44] and PCB[45] emissions, despite some significant reductions of these pollutants in the past." (Ref: **CO_0233**)*

*Scarce resources of raw materials*

- *"Ground water is (...) expected to become even more polluted in the coming decades, since nitrates and pesticides filtrate into groundwater very slowly. While rivers are now recovering from severe pollution as a result of a sharp reduction in point source pollution, diffuse pollution will continue for decades to come and will pose a threat to the quality of drinking water in numerous areas, both in Eastern and in Western Europe." (Ref. **CO_1023**)*

## Interactions with the Social Domain

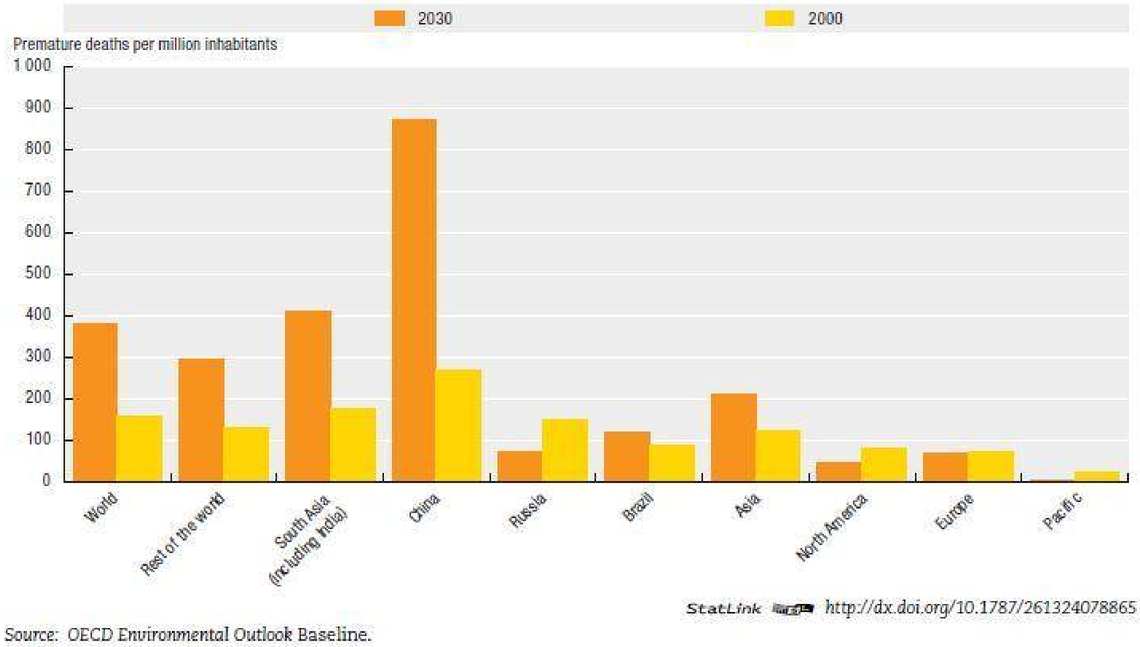
*Population ageing*

Through its impact on health, high level of pollution can speed the ageing process in human being.

*Health*

- *"Air pollution is a major environmental risk to health. Numerous scientific studies have linked air pollution to health effects including: harm to the respiratory system, leading to the development or aggravation of respiratory diseases, decreased lung function, increased frequency and severity of respiratory symptoms such as coughing and difficulty breathing, or increased susceptibility to respiratory infections; harm to the cardiovascular system; harm to the nervous system, affecting learning, memory and behaviour; harm to the reproductive system; cancer." (Ref: **CO_0129**)*
- *"Exposure to air, water and soil pollution, to chemicals in the environment, or to noise, can cause cancers, respiratory, cardiovascular, cerebrovascular and communicable diseases, as well as poisoning and neuropsychiatric disorders. A recent World Health Organization (WHO) study suggests that 24% of the global burden of disease and 23% of all deaths are attributable to environmental factors." (Ref: **CO_5009**)*
- *"At first glance, the health impacts of ozone may appear to be less extreme than those associated with exposure to PM10. However, the impact of ozone on health could be underestimated, as the assessment assumed a cut-off of 35 ppb. According to the WHO (2006), it is not possible to identify a lower threshold for the effects of ozone on mortality." (Ref: **CO_5009**)*
- *"In the year 2000, exposure to particulate matter, particularly PM2.5, was estimated to reduce average statistical life expectancy by approximately nine months in the EU-25. This equates to approximately 3.6 million life years lost or 348 000 premature mortalities per annum. Significant progress triggered by current legislation is expected in reducing harmful emissions of particulate matter and its precursors between now and 2020 such that the average loss in statistical life expectancy is expected to reduce to around 5.5 months. This would still equate to 272 000 premature deaths per annum in 2020. The associated health costs of particulate matter would still amount to several billions of euros per annum." (Ref: **CO_0102**)*
- *"For 2030, the worldwide number of premature deaths and years of life lost are estimated to be 3.1 million and 25.4 million, respectively." (Ref: **CO_5009**)*

42 Nitrogen oxides
43 Cadmium
44 Mercury
45 Polychlorinated biphenyls




Source: OECD Environmental Outlook to 2030 (Ref: **CO_5009**)

**Figure 1-64 Premature deaths from PM10 urban air pollution for 2000 and 2030**

## Interactions with the Economy Domain

### *Fiscal policy*

- *"The promotion of unleaded petrol within the EU and in other EEA member countries through a combination of fiscal and regulatory measures has been a particular success story. EU Member States have for example completely phased out the use of leaded petrol, a goal that was regulated by Directive 98/70/ EC. Nevertheless, the road transport sector still remains an important source of Pb, still contributing around 10 % of total Pb emissions in the EU‑27." (Ref:* ***CO_0233****)*

## Interactions with the Technology Domain

### *Pollution abatement and monitoring*

- *"The application of technology has been the primary means of reducing the environmental impacts of transport in the last two decades. It has also been identified as the most important means to achieve the European Commission's proposed target of a 60 % reduction in GHGs from transport by 2050. Biofuels and electricity (and potentially hydrogen) are expected to be the key energy carriers utilized to reduce GHG from transport in the long term; however, there are still issues to be addressed." (Ref:* ***CO_5030****)*
- *"To further reduce road transport's impact on air quality, diesel NOX emissions could for example be targeted. Specific NOX abatement technologies for diesel-powered vehicles such as selective catalytic reduction (SCR) (especially for heavy-duty vehicles) are one possible option." (Ref:* ***CO_0226****)*

## Impacts on Mobility and Transport

### *Increasing development of regulative measures for pollutant emissions*

- *"The European Union has been committed over the past 20 years to developing and implementing policies aimed at a cleaner European vehicle fleet in terms of air pollutant emissions. The Euro standards have been, and continue to be, introduced in phases, with the introduction times and actual standards varying by pollutant, vehicle category and vehicle weight class or engine volume and fuel type (see Table below for a summary of the introduction dates for each of the Euro standards)." (Ref.* ***CO_0226****)*

| Vehicle category | Euro 1 | Euro 2 | Euro 3 | Euro 4 | Euro 5 | Euro 6 |
|---|---|---|---|---|---|---|
| Passenger cars | Jul 1992 | Jan 1996 | Jan 2000 | Jan 2005 | Sep 2008 | Sep 2013 |
| Light commercial vehicles (N1-I) | Oct 1993 | Jan 1996 (gasoine, LPG) 1998 (diesel) | Jan 2000 | Jan 2005 | Sep 2009 | Sep 2014 (diesel only) |
| Light commercial vehicles (N1-II & III) | Oct 1993 | Jan 1996 (gasoine, LPG) 1998 (diesel) | Jan 2001 | Jan 2006 | Sep 2009 | Sep 2015 (diesel only) |
| Trucks and buses | 1992 | 1995 | 1999 | 2005 | 2007 | |
| Motorcycles | 2000 | 2004 | 2007 | | | |
| Mopeds | 2000 | 2004 | 2007 | | | |

**Note:** (*) All vehicles need to meet the standards a year after the given date. The dates from which Euro standards apply simply provide a guide to what the emissions standards a vehicle will have, depending upon when it was manufactured. Exceptions exist for some vehicles, since some vehicle models met standards earlier than they were legally required to, and a few low production models are given extensions for compliance.

Source: Impact of selected policy measures on Europe's air quality (Ref: **CO_0226**)

**Figure 1-65 Introduction dates (*) of the Euro emission standards for road vehicles**

- *"Directive 2009/33/EC on the Promotion of Clean and Energy Efficient Road Transport Vehicles (EC, 2009c) aims at stimulating broad market introduction of environmentally friendly vehicles. The Directive requires that energy and environmental impacts linked to vehicle operation be incorporated in purchase decisions. These lifetime impacts include vehicle energy consumption, CO2 emissions, and emissions of the regulated pollutants of NOx (Nitorgene Oxide), NMHC (Non-Methane Hydrocarbon) and PM (particulate matter)." (Ref.* ***CO_0234****)*
- *"Green Public Procurement (GPP)[46] is a powerful market mover for the introduction of new technologies and stimulates procurement of energy-efficient and low-carbon vehicles. This initiative is directed to national, regional and local contracting authorities and contracting entities and operators of public transport services." (Ref.* ***CO_0234****)*

[46] Green Public Procurement (GPP) means that public authorities and services take account of environmental factors when procuring products, services or works. (Ref: CO_0137)

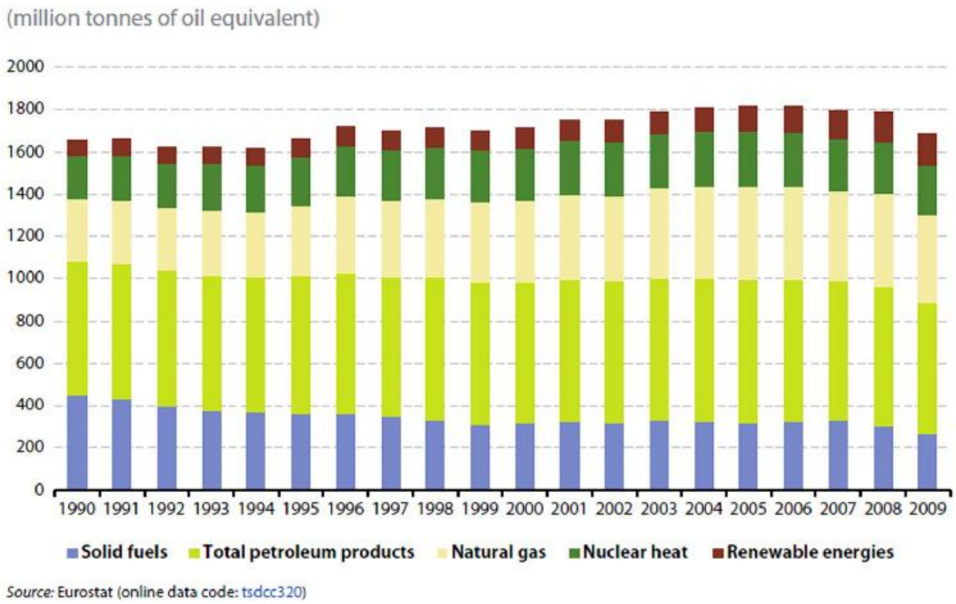
### 1.4.4 The Resources Factor

- *"Resource-efficiency policies need to address appropriately trade-offs. In order to make the right choices both now and for the longer term, we need to consider the whole life-cycle of the way we use resources, including the value chain, and the trade-offs between different priorities. Having the information needed to weigh different choices will help policy makers decide where to focus efforts." (Ref: **CO_0195**)*

#### *1.4.4.1 Energy Availability, Production and Consumption*

**Driver description**

- *"Energy is a basic need for production, heating, households and transportation." (Ref: **CO_5048**)*
- *"Energy trends, particularly with respect to the availability of different types of energy, have a considerable impact, not only on the transport sector but also on society as a whole." (Ref: **CO_5048**)*
- *"Worldwide demand for energy is growing at an alarming rate. The European "World Energy Technology and Climate Policy Outlook" (WETO) predicts an average growth rate of 1.8% per annum for the period 2000-2030 for primary energy worldwide." (Ref: **CO_0018**)*
- *"By 2030, projections suggest, world energy use will probably have increased by more than 50 per cent." (Ref: **CO_0091**)*
- *"[Worldwide] Coal has met almost half of the increase in global energy demand over the last decade. Whether this trend alters and how quickly is among the most important questions for the future of the global energy economy. Maintaining current policies would see coal use rise by a further 65% by 2035, overtaking oil as the largest fuel in the global energy mix." (Ref: **CO_0152**)*
- *"[In Europe] In absolute numbers, energy demand fell by 22 million tonnes of oil equivalent (TOE) between 2000 and 2009. Looking closer, energy demand increased by 77 million TOE from 2000 and 2008 and then sharply dropped by 99 million TOE to 2009. As consumption of fossil fuels, crude oil and nuclear energy fell, the rise in energy demand was met with an increase in natural gas and renewable energy consumption." (Ref: **CO_0197**)*
- *"2009 is the first year in the period that the EU used less energy than in 2000. This 1.2% decrease is likely due to the economic crisis." (Ref: **CO_0197**)*

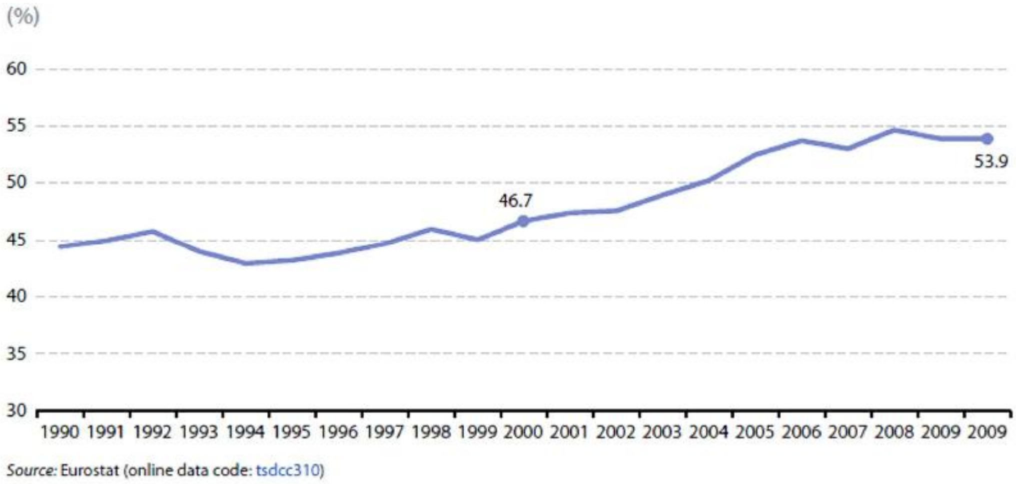



Source: Sustainable development in the European Union (Ref: **CO_0197**)

**Figure 1-66 Gross inland energy consumption, by fuel, EU-27**

- *"In comparison with the 1990s, small changes in the fuel mix have occurred since 2000. After plummeting from 27 % to 18.5 % in the previous decade, the share of solid fuels in total consumption fell to 15.7 % in 2009. The share of crude oil and petroleum products also* *decreased slightly from 38 % to 36.5 % between 2000 and 2009. Natural gas consumption, on the other hand, increased from 23 % to 24.5 %, and renewables consumption went up from 6 % to almost 9 % during the same period. Nuclear energy was the only energy source that experienced a trend reversal: after growing from 12 % to 14 % in the 1990s, consumption fell slightly to 13.5 % in 2009." (Ref: **CO_0197**)*

- *"Energy dependence shows how much an economy relies on imports to meet its domestic energy demand. Between 2000 and 2009, EU dependence on energy imports grew from 46.8 % to 53.9 %." (Ref: **CO_0197**)*




Source: Sustainable development in the European Union (Ref: **CO_0197**)

**Figure 1-67 Energy dependence, EU-27**

- *"In 2009, 17 out of the 27 EU Member States showed dependence rates over 50 %. Dependence was close to 100 % in the small countries Cyprus, Luxembourg and Malta. Eight Member States, mainly from northern and eastern Europe, had energy dependence levels well below 50 %. The lower import share reflects the larger availability of indigenous energy sources in these countries, ranging from coal (Poland, Czech Republic and Romania) to oil and gas (Denmark, UK and Netherlands) and renewable resources like biomass and hydro power (Sweden, Estonia)." (Ref: **CO_0197**)*
- *"Differences among countries can be explained by a number of factors, including the carbon intensity of fossil fuel production (i.e. fossil fuel mix), the penetration of renewables, the existence of nuclear power for electricity generation, the efficiency in the transformation of primary energy into useful energy as well as the penetration of combined heat and power, the actual energy demand of end users, and energy efficiency improvements (and savings) linked to that demand." (Ref: **CO_0140**)*
- *"In 2009 dependence was highest for crude oil with an import share of 83.5 %, followed by natural gas (64 %) and hard coal (62 %)." (Ref: **CO_0197**)*

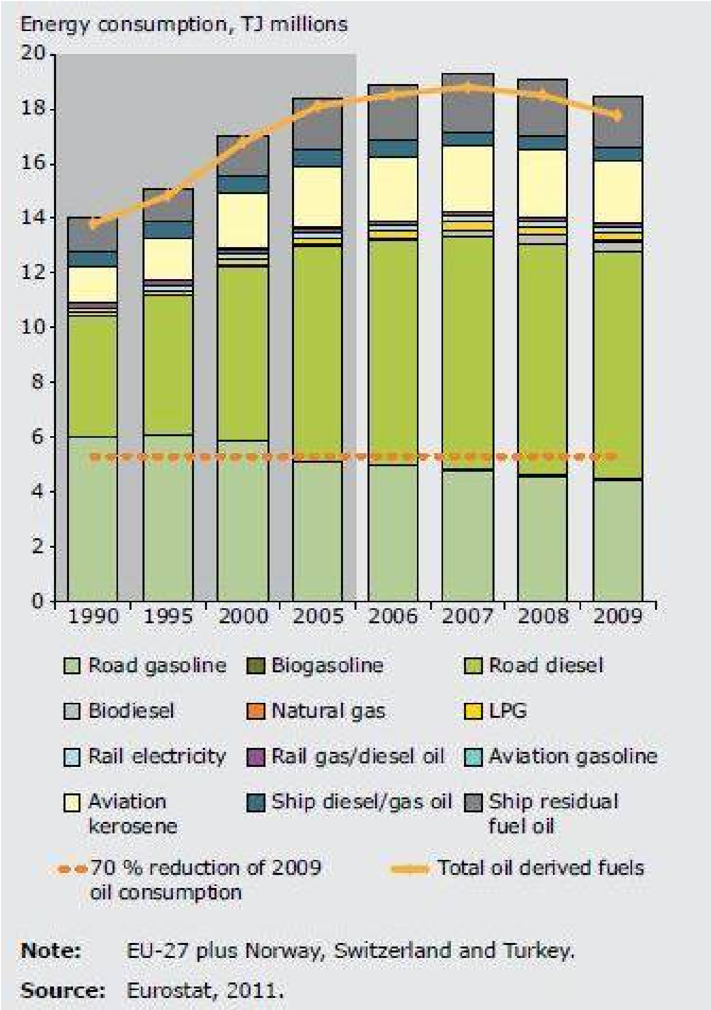

Source: Sustainable development in the European Union (Ref: **CO_0197**)

**Figure 1-68 Energy dependence, by country, 2009**

- *"Europe's external context will also continue to be characterised by growing external energy dependency, especially in the field of fossil energy sources (oil, gas, coal), but also in that of nuclear energy sources (uranium)." (Ref:* ***CO_1023****)*
- *"Two factors have the potential to bring about fundamental changes in energy production systems in the timescale up to 2050: energy resource scarcity and technological development." (Ref:* ***CO_5048****)*
- *"One of the objectives of the EU Sustainable Development Strategy is 'reaching an overall saving of 9 % of final energy consumption[47] over nine years until 2017' as set in the Directive on energy end-use efficiency and energy services. Furthermore, the Europe 2020 Strategy includes 'moving towards a 20 % increase in energy efficiency' by 2020 as one of its five headline targets." (Ref:* ***CO_0197****)*
- *"(...) in the forecasts from the International Energy Agency up to 2030 (...) nuclear energy maintains a constant share of energy production worldwide. Also the Commission's assessment of the energy future in EU notes that nuclear energy is being dismantled in some of the EU countries and presently the expansion plans are stalled in other countries. Therefore, the forecast for nuclear energy up to 2030 in EU is a slight decrease." (Ref:* ***CO_5048****)*
- *"Despite uncertainty over the prospects for short-term economic growth, demand for energy in the New Policies Scenario grows strongly, increasing by one-third from 2010 to 2035. The assumptions of a global population that increases by 1.7 billion people and 3.5% annual average growth in the global economy generate ever-higher demand for energy services and mobility. A lower rate of global GDP growth in the short-term than assumed in this Outlook would make only a marginal difference to longer-term trends." (Ref:* ***CO_0152****)*
- *"(...) the road transport energy paradigm can be split into three main parameters: $E_{road\ transport}$ = (vehicle fuel efficiency) x (vehicle travel) x (the vehicle population) where the vehicle fuel efficiency is determined by the technical energy efficiency; vehicle travel denotes the type of travel/driving and the number of miles driven; and the vehicle population is the number of vehicles on the road.." (Ref:* ***CO_0247****)*
- *"Road transport represents the largest energy consumer, accounting for 73 % of total demand in 2009. It has also been the least affected by the downturn, falling by only 2.8 % between 2007 and 2009. Because the recent changes are so closely associated with the economic downturn,*

[47] The final energy consumption by sector expresses the sum of energy supplied to the final consumer's door for all energy uses, broken down by consuming sector (transport, industry, households, services, agriculture, other).

*the long-term trend is still expected to be an upward one; total transport energy consumption has increased by 32 % between 1990 and 2009." (Ref: **CO_5030**)*




Source: Laying the foundations for greener transport. TERM 2011: transport indicators tracking progress towards environmental targets in Europe (Ref: **CO_5030**)

**Figure 1-69 Transport energy consumption (EEA-30)**

## Interactions within the Environment Domain

### *Climate change impacts*

- *"(...) climate change is mentioned as one of the main threats to sustainable development, and energy use is explicitly linked to this by proposing limitation of climate change and increase in the use of clean energy together as a priority objective." (Ref: **CO_1027**)*
- *"Climate change is likely to be exacerbated by meeting the growing demand for energy. Over 75% of the global increase in energy use from 2007-2030 is expected to be met through fossil fuels, especially coal, and an estimated 77% of the power stations required to meet demand are yet to be built." (Ref: **CO_0024**)*
- *"Transport accounted for about 26% (IEA, 2009b) of all energy-related CO2 emissions in 2007 and is likely to account for a higher share in the future unless strong action is taken." (Ref: **CO_0153**)*

### *GHG mitigation*

- *"The burning of fossil fuels (coal, lignite, oil and natural gas) is the largest source of carbon dioxide emissions, and the extraction of coal, oil and gas as well as leaks from gas pipelines are among the main sources of energy-related methane emissions. Therefore, most measures to reduce greenhouse gas emissions in some way target energy consumption and the fuel mix. One such measure is shifting from solid fuels, which are high-carbon sources of energy, to* *lower-carbon sources such as natural gas. This, however, has been one of the underlying causes of greater energy dependence in the EU." (Ref: **CO_0197**)*

- *"The greenhouse gas intensity of energy consumption[48] in the EU steadily decreased between 2000 and 2009, mainly due to the switch from solid fuels to gas and, to a lesser extent, renewable energies." (Ref: **CO_0197**)*
- *"Current trends in energy supply and use are unsustainable – economically, environmentally and socially. Without decisive action, energy-related greenhouse gas (GHG) emissions will more than double by 2050 and increased oil demand will heighten concerns over the security of supplies." (Ref: **CO_5032**)*
- *"Analysis for the European Commission 2050 roadmap indicates a reduction of 70 % on present levels of oil consumption in transport will be needed by 2050 in order to achieve the long-term GHG reduction target." (Ref: **CO_5030**)*
- *"Urban infrastructure – in particular energy (electricity and gas) networks, and water and sanitation systems – is critical in shaping the current and future trajectories of GHG emissions." (Ref: **CO_0147**)*

#### Scarce resources of fossil fuels

- *"Electricity production accounts for 32% of total global fossil fuel use and around 41% of total energy related CO2 emissions. Improving the efficiency with which electricity is produced is therefore one of the most important ways of reducing the world's dependence on fossil fuels, so helping both to combat climate change and improve energy security." (Ref: **CO_0183**)*
- *"Without a significant change in policies, global electricity generation will continue to be largely based on fossil fuels to 2050 and beyond." (Ref: **CO_0153**)*
- *"We can attain energy security only if we move from fossil fuels to fossil free alternatives." (Ref: **CO_0091**)*
- *"The age of fossil fuels is far from over, but their dominance declines. Demand for all fuels rises, but the share of fossil fuels in global primary energy consumption falls slightly from 81% in 2010 to 75% in 2035; natural gas is the only fossil fuel to increase its share in the global mix over the period to 2035." (Ref: **CO_0152**)*

### Interactions with the Social Domain

#### Households structure and distribution

- *"Global energy use in the household sector increased between 1990 and 2005 by 19% to reach 82 EJ[49]. Households are the only major end-use sector where the increase in energy consumption since 1990 has been greater in OECD countries (+22%) than in non-OECD countries (+18%)." (Ref: **CO_0183**)*
- *"The household sector includes those activities related to private dwellings. It covers all energy-using activities in apartments and houses, including space and water heating, cooling, lighting and the use of appliances. It does not include personal transport (...)." (Ref: **CO_0183**)*
- *"Per capita CO2 emissions in OECD countries are on average more than five times higher than in non-OECD countries. This difference can be explained by a combination of lower per capita household energy use in non-OECD countries and a lower carbon intensity of the energy mix, due to a high share of renewable energy." (Ref: **CO_0183**)*

#### Urbanisation

- *"The energy consumed to operate residential, commercial and public service buildings accounts for around 25-40% of final energy consumption in OECD countries." (Ref: **CO_5009**)*
- *"Yet affordable energy is an essential driver of the development engines of many cities." (Ref: **CO_0147**)*
- *"Cities uniquely concentrate energy demand and rely on energy sources beyond their boundaries." (Ref: **CO_0210**)*

[48] The greenhouse gas intensity of energy consumption is the ratio between energy-related greenhouse gas emissions and gross inland energy consumption.
[49] Exajoule

- *"Water resource issues will (...) put pressure on peri-urban development, particularly in arid climates and/or areas vulnerable to flooding. Renewable energy sources such as biomass are often sited in peri-urban areas, and may start to influence the pattern of development." (Ref: **CO_0097**)*
- *"But cities have the potential to either dissipate the distribution of energy or optimise their efficiency by reducing energy consumption and adopting green energy systems including renewable micro-generation, district heating, and combined heat and energy plants." (Ref: **CO_0210**)*

*Planning*

- *"The energy infrastructure which will power citizens' homes, industry and services in 2050, as well as the buildings which people will use, are being designed and built now. The pattern of energy production and use in 2050 is already being set." (Ref: **CO_0245**)*
- *"Higher energy prices and rising congestion require central and municipal planners to develop mass transit systems to cope with inner city and suburban traffic such as: bus rapid transit, urban trams and relatively cheap light railway systems, in addition to subways for larger, higher density metropolitan centres. Such systems lead to large gains in energy efficiency and reduced emissions as passengers transfer from private cars to public transport." (Ref: **CO_2024**)*

*Education*

- *"The social dimension of the energy roadmap is important. The transition will affect employment and jobs, requiring education and training and a more vigorous social dialogue. In order to efficiently manage change, involvement of social partners at all levels will be necessary in line with just transition and decent work principles." (Ref: **CO_0245**)*

**Interactions with the Economy Domain**

*GDP trends*

- *"Secure, reliable and affordable energy supplies are fundamental to economic stability and development." (Ref: **CO_0153**)*
- *"Many macroeconomic projections of energy use and greenhouse gas emissions rely on historical data to estimate price and income elasticities for energy demand and then use projections of GDP and energy prices to generate energy and emissions projections." (Ref: **CO_0105**)*
- *"Achieving significant energy savings will require a stronger decoupling of economic growth and energy consumption as well as strengthened measures in all Member States and in all economic sectors." (Ref: **CO_0245**)*
- *"The economic downturn (...) implies in the short term less economic activity and consumption. This causes a reduction of energy consumption, but also a reduced investment and capital turnover which slows energy efficiency progress." (Ref: **CO_2028**)*

*Regional differences in economics*

- *"The dynamics of energy markets are increasingly determined by countries outside the OECD. Non-OECD countries account for 90% of population growth, 70% of the increase in economic output and 90% of energy demand growth over the period from 2010 to 2035." (Ref: **CO_0152**)*

*Market regulations*

- *"Significant restructuring of the energy system will require energy-sector reform, including: removal of subsidies to reflect the true cost of energy supply, internalization of the costs of externalities (such as local and regional air pollution) through markets, taxes, or subsidies; establishment of credible legal and regulatory frameworks that provide the stability on rules and prices that will induce investments into financially viable products." (Ref: **CO_2019**)*

*Energy availability and prices*

- *"The progressive depletion of the North Sea resources and the increase of oil and gas prices at world scale with the possibility of oil peaking will make the issue of Europe's energy security a central pillar in its future foreign and security policy." (Ref: **CO_1023**)*

*Intensified competition for scarce resources use*

- *"The majority of Russia's exports continue to go westwards to traditional markets in Europe, but a shift towards Asian markets gathers momentum. Russia gains greater diversity of export revenues as a result: the share of China in Russia's total fossil-fuel export earnings rises from 2% in 2010 to 20% in 2035, while the share of the European Union falls from 61% to 48%." (Ref: **CO_0152**)*
- *"China's emergence as a net coal importer in 2009 led to rising prices and new investment in exporting countries, including Australia, Indonesia, Russia and Mongolia." (Ref: **CO_0152**)*

*Fiscal policy*

- *"(...) taxes and subsidies on the use of energy or other resources can be used both to steer behaviour leading to reduced and more efficient consumption and to help restructure public finances away from labour taxation, which benefits job creation and economic growth." (Ref: **CO_0195**)*

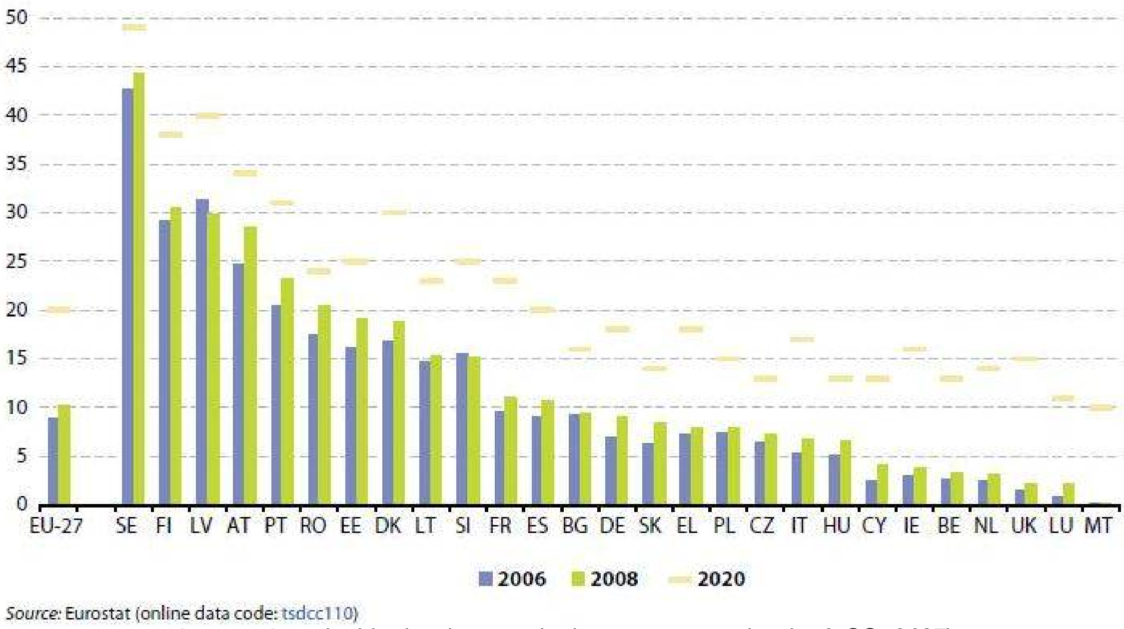
## Interactions with the Technology Domain

*Information systems*

- *"The information and communication technologies have an important role to play in improving the efficiency of major emitting sectors. These technologies offer potential for a structural shift to less resource-intensive products and services, for energy savings in buildings and electricity networks as well as for more efficient and less energy consuming intelligent transport systems." (Ref: **CO_0257**)*
- *"Innovation can play a major role in reducing energy consumption. Intelligent transport systems (ITS) for example call on information and communication technologies to smooth and speed up transport and services by road, rail, air and water." (Ref: **CO_0269**)*

*Renewable energy production*

- *"In 2050, the EU's total primary energy consumption could be about 30% below 2005 levels. More domestic energy resources would be used, in particular renewables. Imports of oil and gas would decline by half compared to today, reducing the negative impacts of potential oil and gas price shocks significantly." (Ref: **CO_0194**)*
- *"Between 2006 and 2008 the share of renewables in gross final energy consumption grew steadily. If growth were to be sustained at the rate observed over this short period, the EU would meet its 2020 target." (Ref: **CO_0197**)*




Source: Sustainable development in the European Union (Ref: **CO_0197**)

**Figure 1-70 Share of renewable energy in gross final energy consumption, by country (%)**

- *"The analysis of all scenarios shows that the biggest share of energy supply technologies in 2050 comes from renewables. Thus, the second major prerequisite for a more sustainable and secure energy system is a higher share of renewable energy beyond 2020." (Ref: **CO_0245**)*
- *"Nuclear energy will be needed to provide a significant contribution in the energy transformation process in those Member States where it is pursued. It remains a key source of low carbon electricity generation." (Ref: **CO_0245**)*

*Energy efficiency*

- *"The most important contribution to reaching energy security and climate goals comes from the energy that we do not consume." (Ref: **CO_0152**)*

### Impacts on Mobility and Transport

*The energy factor has recently grown in importance in the transport sector…*

- *"The transport sector has grown over recent years to become the largest energy-consuming sector in the EU27, accounting for around one third of final energy consumption in 2008 (EEA, 2010e)." (Ref: **CO_0134**)*
- *"Between 1990 and 2007, annual transport energy consumption in the EEA member countries showed continual growth. However, this upward trend reversed in 2008 (with the economic recession likely to be the primary reason) and the most recent data for 2009 indicates an accelerating decline. Total energy demand in 2009 has fallen by over 4 % from its peak in 2007. Energy use for aviation, rail transport and domestic navigation also fell by 4.9 % to 5.6 %." (Ref: **CO_5030**)*

*… but it is not easy to assess the intensity of the phenomenon*

- *"While there was agreement that electricity will have a role in transport, opinions diverged on how large its potential is. Some see a broad scope, arguing that electricity is the way forward even if electricity production releases carbon, simply because electric engines are more efficient than internal combustion engines. This view was challenged on the grounds that the additional electricity produced for transport will come from carbon-intensive fuels until the extra demand is large enough to justify investments in other sources." (Ref: **CO_0284**)*

*Adequate policies will help reversing the trend of increasing consumption*

- *"Global energy use in the transport sector is forecast to increase on average by 1.6% annually up to 2030, unless significant policy action is taken (IEA, 2009a)." (Ref: **CO_0247**)*
- *"The main factor driving increased passenger transport energy use is the level of underlying activity. Passenger travel in the IEA18[50], as measured by passenger kilometres, increased by 30% between 1990 and 2005. Passenger air transport increased most quickly, followed by car travel." (Ref: **CO_0183**)*

*However the role of energy efficiency in securing energy will play a major role*

- *"There will be a broad range of possibilities for future transport energy provision and it is clear that the private economic cost of transport fuels will be far higher than those of today, whatever mix of sources, carriers, and conversion systems there may be in the future. Therefore, the role of efficiency becomes critical, not only in terms of environment, but also in terms of the affordability of mobility." (Ref: **CO_0017**)*

*Many improvements are expected in railway stock*

- *"Railway services, including urban rail systems, run mainly on electricity, which will remain the major source of power for railways. Further electrification of rail tracks wherever feasible will contribute to CO2 emission reduction as will the use of sustainable fuels for energy. Power generation is on a path of decarbonisation through the 'Emission Trading System' and renewable energy targets also apply to railway services." (Ref: **CO_0234**)*
- *"Reducing the energy used in rail travel will depend on the introduction of more efficient rolling stock, modernizing infrastructure and optimizing operations." (Ref: **CO_0248**)*

[50] IEA18 member countries are: Australia, Austria, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, the Netherlands, New Zealand, Norway, Sweden, Switzerland, the United Kingdom and the United States

- *"Most urban rail systems are powered by electricity. Electric motors are very efficient, so improving them will be challenging. As urban rail rolling stock is frequently accelerating and decelerating, reducing its weight is one of the most important ways of improving efficiency. Using regenerative breaking devices will also help reduce energy needs." (Ref: **CO_0248**)*

#### 1.4.4.2 Scarce Resources of Fossil Fuels

**Driver description**

- *"Most of the changes in the state of the environment (...) are ultimately driven by unsustainable consumption and production patterns. These have resulted in unprecedented levels of greenhouse gas emissions and the depletion of renewable environmental resources, such as clean water and fish stocks, as well as non-renewable ones, such as fossil fuels and raw materials." (Ref: **CO_0141**)*
- *"(...) we may soon run short of the fossil fuels (gas and oil) which keep modern society going. Not only do they provide heat, light and electricity. Agriculture, pharmaceuticals, communications and most of the other features of life we take for granted depend on the reserves of fossil fuels, directly (e.g. for plastics) or indirectly." (Ref: **CO_0091**)*
- *"Fossil fuel reserves are concentrated in a small number of countries. Some 80 % of the coal reserves are located in just six countries and the EU has just 4 % of the global total. The EU share of the world's reserves decreased from 4.6 % in 1980 to 1.3 % in 2009 and these reserves are expected to be exhausted before 2030. More than half of the global stock is found in only three countries: Iran, Qatar and Russia, which accounted for 24 % of the total in 2009 and is a major gas supplier for the EU." (Ref: **CO_0274**)*
- *"Oil is one of the most threatened, and increasingly difficult to access, resources in the world." (Ref: **CO_5018**)*
- *"Oil production has long been expected to peak. Some think that this is now imminent at least within the next 10 years. For others the scarcity of oil supplies, including unconventional sources and natural gas liquids, is very unlikely before 2025. This horizon could be extended to 2040 by adopting known measures to increase vehicle efficiency and focusing oil demand on the transport sector." (Ref: **CO_5048**)*
- *"Even though we cannot say with certainty that we will run out in the next thirty years, extracting and delivering the remaining oil to market is becoming increasingly difficult." (Ref: **CO_5018**)*
- *"Gas resource uncertainty is significant. Scarcity could occur as early as 2025, or well after 2050. Gas is considered by many to be scarcer than oil (WETO-H2, 2006), constraining expansion. But the key issue is whether there can be timely development of the infrastructure to transport remote gas economically." (Ref: **CO_5048**)*
- *"Some economists believe that the scarcer and more expensive a commodity becomes, the more effort will go into finding it, and that the market will ensure plentiful supplies of fossil fuel for many years ahead. But there are rational grounds for thinking we risk the exhaustion of recoverable reserves of oil and gas as well as an unpredictably warmer Earth if we do not kick the CO2 habit." (Ref: **CO_0091**)*
- *"(...) both on the supply and demand sides point to a bright future, even a golden age, for natural gas." (Ref: **CO_0152**)*

**Interactions within the Environment Domain**

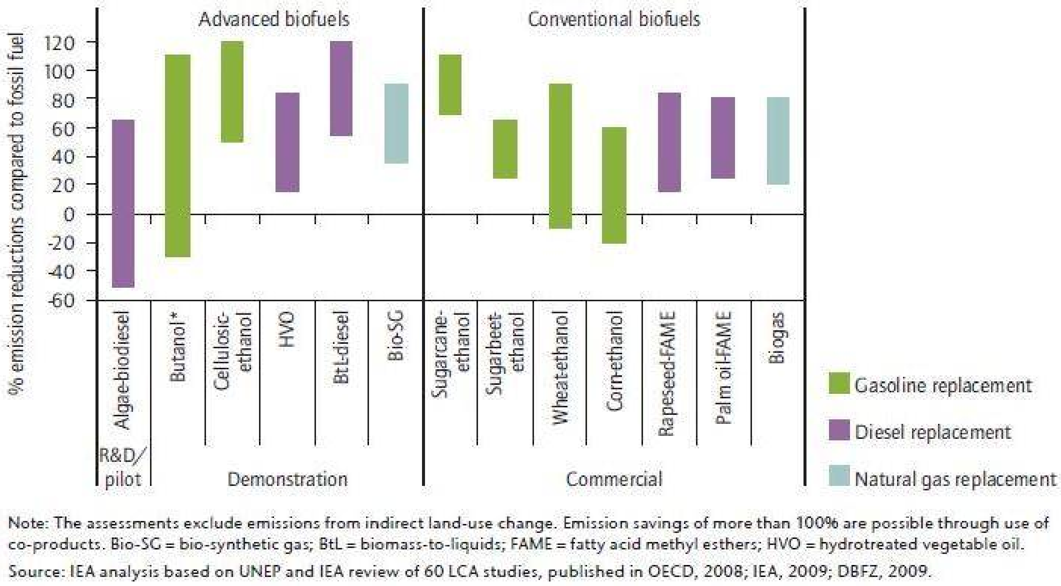
*Climate change*

- *"The different studies seem to concur in identifying agriculture and food consumption, as well as the use of fossil fuels among the most important drivers of environmental pressures." (Ref: **CO_0135**)*
- *"As Europe uses up reserves that are easy to access, it will have to rely more on less concentrated ores, less accessible resources and fossil fuels with lower energy content, which are expected to cause higher environmental impacts per unit of material or energy produced." (Ref: **CO_0141**)*
- *"(...) fossil fuels that we now extract from deposits (...) would have been considered uneconomic two decades ago. All this also requires more transport and more energy and there is a clear — if rarely acknowledged — problem: all this extra energy use will accelerate climate change." (Ref: **CO_0135**)*

- *"The main sources of man-made GHG emissions globally are the burning of fossil fuels for electricity generation, transport, industry and households — which together account for about two-thirds of total global emissions." (Ref: **CO_0141**)*
- *"Natural gas is the cleanest of the fossil fuels, but increased use of gas in itself (without carbon capture and storage) will not be enough to put us on a carbon emissions path consistent with limiting the rise in average global temperatures to 2°C." (Ref: **CO_0152**)*

*GHG mitigation*

- *"The role of bioenergy systems in reducing GHG emissions needs to be evaluated by comparison with the energy systems they replace using life-cycle assessment (LCA) methodology. A number of such analysis methodologies have been developed (...)." (Ref: **CO_5032**)*
- *"Figure below is based on a number of "well-to-wheel" LCA studies that compare the GHG emissions associated with different biofuels against the replaced fossil fuel. The figure covers mature, emerging and innovative processes. The data show a large range for each biofuel, depending on the details of the process and way the feedstock is produced, including the amount of fertilisers used." (Ref: **CO_5032**)*




Source: Technology Roadmap Biofuels for Transport (Ref: **CO_5032**)

**Figure 1-71 Life-cycle GHG balance of different conventional and advanced biofuels and current state technology**

- *"Concerns have been raised that the GHG benefits of producing and using biofuels can be reduced or negated by carbon emissions associated with land-use change (LUC)." (Ref: **CO_5032**)*
- *"When biofuel production involves a change in land use then there may be additional emission impacts – positive or negative – that must be taken into account in calculating the GHG balance. The land-use change can be: direct, as when biofuels feedstocks are grown on land that was previously forest; indirect, when biofuel production displaces the production of other commodities, which are then produced on land converted elsewhere (perhaps in another region or country)." (Ref: **CO_5032**)*
- *"For biofuels to provide the envisaged emission reductions in the transport sector, it is essential to avoid large releases of GHG caused by land-use changes. However, emissions related to current biofuel production generate only around 1% of the total emissions caused by land-use change globally (Berndes et al., 2010), most of which are produced by changes in land use for food and fodder production, or other reasons." (Ref: **CO_5032**)*
- *"The European Union has introduced regulations under the Renewable Energy Directive (RED) that lay down sustainability criteria that biofuels must meet before being eligible to contribute to the binding national targets that each member state must attain by 2020 (EC, 2009). In order to*

*count towards the RED target, biofuels must provide 35% GHG emissions saving compared to fossil fuels. This threshold will rise to 50% as of 2017, and to 60% as of 2018 for new plants." (Ref: **CO_5032**)*

- *"Not all biofuels in the market today, however, can actually reduce GHGs on the scale needed to meet the targets in the 2DS[51]. Improving the efficiency of conventional fuels, and commercially deploying advanced biofuels, will clearly still be required." (Ref: **CO_0185**)*
- *"Switching from fossil fuels to public electricity as an energy source, both for industrial users and for households, results in a transfer of the emissions linked to electricity or heat use from these sectors to the energy supply sector." (Ref: **CO_0200**)*

### Emission trading schemes

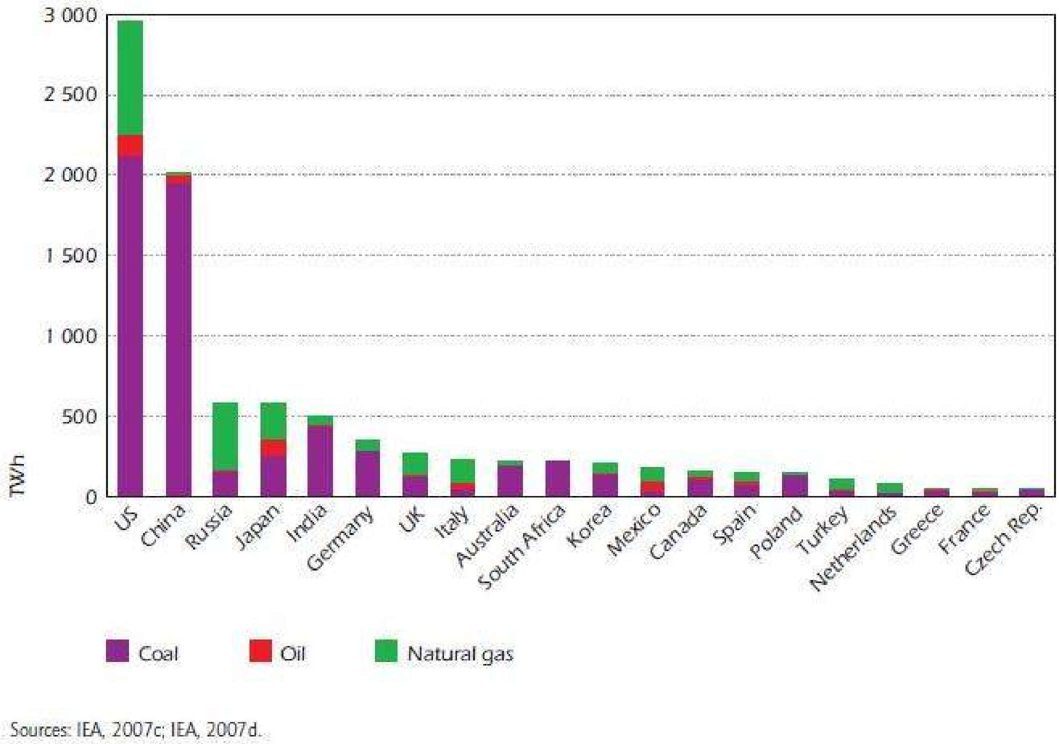
- *"(...) emissions from fossil fuel power plants are covered in (...) ETS sector." (Ref: **CO_0131**)*

### Pollution levels and emissions standards

- *"CO2 emissions are almost entirely produced by burning fossil fuels, which is also an important source of several air pollutants." (Ref: **CO_0227**)*

### Energy availability, production and consumption

- *"Fossil fuels are the source of 66% of global public electricity production. The share in OECD countries is slightly lower at 61%, while in developing and transition countries it averages 72%. The share of electricity production from fossil fuels in individual countries varies considerably. Countries with a high share of fossil fuel use for public electricity production include Poland (98%), South Africa (94%), Luxembourg (93%), Australia (93%), Ireland (93%), Greece (89%), the Netherlands (89%), Portugal (84%), Italy (83%), China (82%) and India (80%). The 20 countries shown in Figure below account for 80% of current global electricity production from fossil fuels (coal, oil and natural gas). The United States and China have by far the highest absolute levels of fossil-fuelled electricity production, together accounting for 44% of the global total. Many OECD countries also have significant electricity production from fossil fuels, as do Russia, India and South Africa. Globally, most fossil-fuelled electricity production is from coal (63%), followed by natural gas (29%) and oil (9%)." (Ref: **CO_0183**)*




Source: Worldwide Trends in Energy Use and Efficiency (Ref: **CO_0183**)

**Figure 1-72 Electricity Production by Fossil Fuels in Public Electricity and CHP[52] Plants, 2005**

[51] ETP (Energy Technology Perspectives) 2012 2°C Scenario

- *"We also need to think about what a low-carbon energy mix will mean for comprehensive energy security. On the one hand, reduced dependence on imported fossil fuels and broader development of alternative energy sources can help alleviate some of the current concerns around security of supply for these fuels. Yet as the demand for decarbonised electricity and also for biofuels increases, so new challenges will no doubt emerge requiring innovative policies to ensure that we have the affordable and reliable energy supplies that we need." (Ref:* ***CO_0153****)*

## Interactions with the Social Domain

### Urbanisation

- *"Rural land use is shaped by increasing global food consumption that stimulates production, and the shift to biomass resources to replace fossil fuels in energy generation and for the chemical industry." (Ref:* ***CO_0132****)*
- *"The EU target for 2030 is to cut the number of fossil-fuelled vehicles in urban areas by half and to phase out these vehicles by 2050. CO2-free transport and logistics in large cities is the target for 2030." (Ref:* ***CO_0234****)*

### Tourist flows

- *"The majority of tourism trips that are undertaken worldwide entail the use of oil at some point, and many of these trips could not be undertaken by using alternative fuel sources, such as electricity derived from renewable power sources, with current technologies. There are means, however, for tourists to switch away from oil, and in the event of extreme oil price rises it would be inevitable that some would take this course of action." (Ref:* ***CO_4010****)*

## Interactions with the Economy Domain

### GDP trends

- *"More efficient use of resources and pollution control can be major drivers of economic growth, as is shown by Europe's eco-industry. The sector has grown by around 8% per annum in recent years, and its annual turnover of €319 billion accounts for about 2.5% of Europe's GDP." (Ref:* ***CO_0243****)*

### Employment

- *"Substitution of employment will take place, for example due to shifting from fossil fuels to renewable energy sources (...)" (Ref:* ***CO_0126****)*

### Regional differences in economics

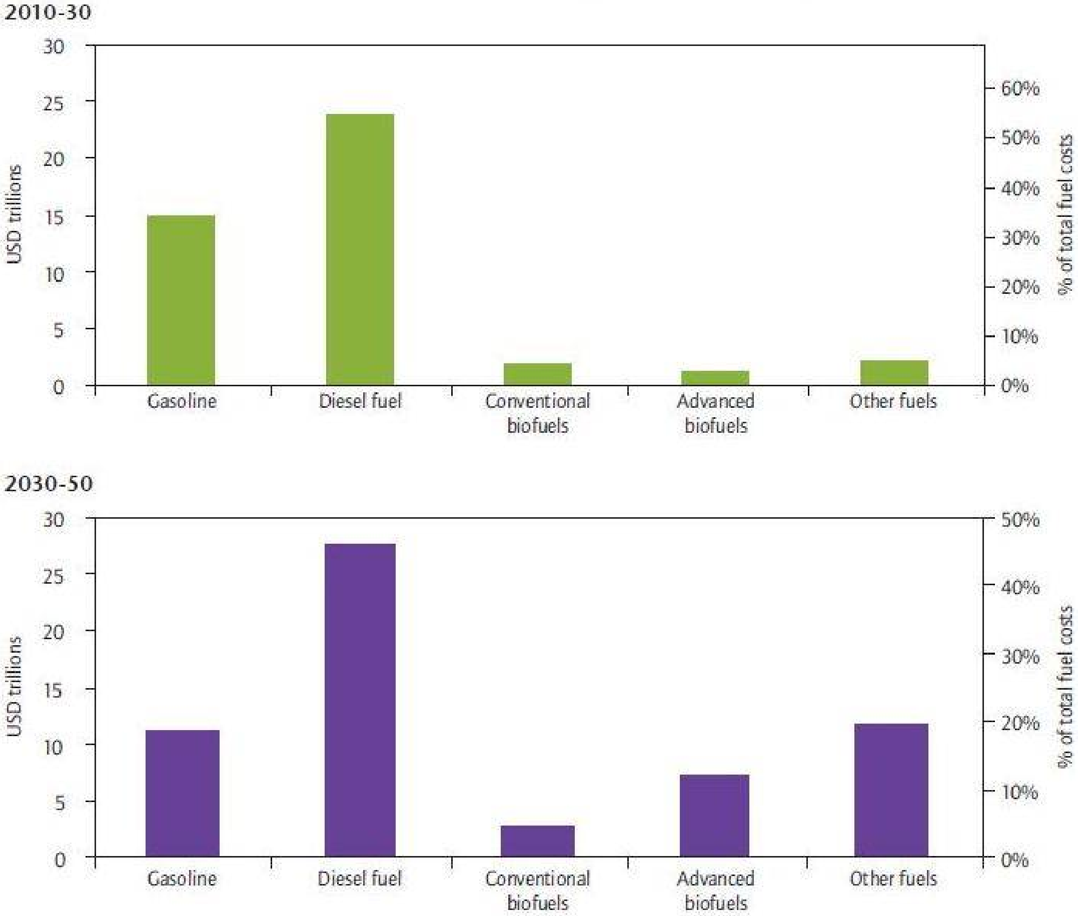
- *"We expect to experience a marked shift in transport fuel demand from the developed countries to the developing ones, mostly China and India." (Ref:* ***CO_0159****)*
- *"All of the net increase in oil demand comes from the transport sector in emerging economies, as economic growth pushes up demand for personal mobility and freight. Oil demand (excluding biofuels) rises from 87 million barrels per day (mb/d) in 2010 to 99 mb/d in 2035." (Ref:* ***CO_0152****)*
- *"Insufficient development of biofuel infrastructure – including feedstock supply, conversion and end-use related infrastructure, can form a non-economic barrier to the growing biofuel production envisioned (...). In developing countries, in particular, poor rural infrastructure may form a barrier to feedstock supply and fuel transport. Infrastructure should best be developed as part of an overall land use and rural development strategy that helps to attract urgently needed investments in agricultural infrastructure and promote overall rural development." (Ref:* ***CO_5032****)*
- *"Biofuels tend to be regional phenomena, mostly concentrated in the Americas, with sugar cane biofuels being dominant in Brazil and corn ethanol being the dominant biofuel in United States." (Ref:* ***CO_0159****)*

### Availability of public and private resources and investments in the transport sector

- *"The total cost of biofuel use to 2030 is projected to be around USD 2.5 trillion (low-cost scenario) to USD 2.9 trillion (high-cost scenario) (...). Total expenditures on transport fuels, by*

[52] Combined heat and power

*contrast, are estimated at USD 43 trillion to 44 trillion between 2010 and 2030. Thus, the total expenditure on biofuels accounts for roughly 6% to 7% of all transport fuel spending. After 2030, biofuel production ramps up considerably and the total cost of biofuels from 2030 to 2050 is projected to be about USD 8.2 trillion (low-cost scenario) to USD 9.9 trillion (high-cost scenario) (...). The total cost of transport fuels is between USD 58 trillion and USD 61 trillion – thus biofuels account for about 14% to 16% of spending on transport fuels (Figure below)." (Ref: **CO_5032**)*




Source: Technology Roadmap Biofuels for Transport (Ref: **CO_5032**)

**Figure 1-73 Total cost for all transport fuels production (high-cost scenario)**

- *"For all biofuels, there is scope for cost reductions that will help to improve competitiveness with fossil fuels and drive commercial deployment: capital costs are expected to come down as a result of scaling up (particularly for advanced biofuels). Co-location with existing biofuel plants, power plants or other industrial facilities reduces capital costs and can bring further benefits such as more efficient use of by-products; conversion costs can be brought down through scaling up and technology learning. Further improvement of conversion efficiency (e.g. through more efficient enzymes) and energy efficiency should also help to reduce costs; feedstock costs cannot be predicted and are subject to agricultural commodity prices, oil prices and other factors. Enhancing feedstock flexibility will create access to a broader range of biomass sources with potentially low costs (such as residues) and reduced price volatility. Improving and creating transport infrastructure could further reduce biomass supply costs." (Ref: **CO_5032**)*
- *"Although some low-carbon and energy-efficient technologies are competitive today, many others are considerably more expensive than their fossil-based alternatives. Carbon pricing will be important in helping to redress this gap, but it will not be sufficient on its own. To avoid the lock-in of high-emitting, inefficient technologies during the next decade, governments will need to intervene on an unprecedented level with targeted technology policies to address the cost-competitiveness gap." (Ref: **CO_0154**)*

- *“Scale and efficiency improvements will reduce biofuel production costs over time. In a low-cost scenario, most biofuels could be competitive with fossil fuels by 2030. In a scenario in which production costs are strongly coupled to oil prices, they would remain slightly more expensive than fossil fuels.” (Ref: **CO_5032**)*
- *“There is an urgent need to scale up investment in low-carbon energy technologies. Current investment levels are insufficient to make the necessary transition to a lowcarbon energy system. Investment in traditional fossil-based technologies needs to be shifted towards low-carbon energy technologies.” (Ref: **CO_0154**)*

*Intensified competition for scarce resources use*

- *“Economic growth is continuing globally and is accelerating in BRIC countries and other newly emerging economies. Demand for fossil fuels and other subsoil and natural resources is likely to grow in absolute terms despite continuing and partly successful efforts to increase the resource- and energy-efficiency of economic activities.” (Ref: **CO_0274**)*
- *“Ten countries (of which eight are OPEC members) have 80 % of the world's oil reserves. Some of these countries may exercise their power to restrict supply or influence the price (NIC, 2008). EU dependence on imported fossil fuels — currently accounting for over 50 % of fuels consumed — is slowly rising.” (Ref: **CO_0274**)*
- *“A key non-economic barrier to development of biofuels is uncertainty regarding their sustainability. The sometimes controversial public debate on competition with food production and the potential destruction of valuable ecosystems has put biofuels in the centre of a sustainability discussion that concerns all forms of bioenergy and which (in parts) is relevant to the entire agricultural and forestry sector.” (Ref: **CO_5032**)*

*Fiscal policy*

- *“(...) inefficient fossil fuel subsidies must be removed, while ensuring that all citizens have access to affordable energy. In 2010, fossil fuel subsidies were estimated at USD 409 billion (up more than 37% from 2009), against the USD 66 billion allotted for renewable energy support.” (Ref: **CO_0185**)*
- *“A taxation system based on the environmental and energy performance of individual fuel types, including a carbon tax (as is already the case in Sweden) is one way of placing value on biofuels’ environmental and societal contribution, and of reducing gaps in competitiveness with fossil fuels.” (Ref: **CO_5032**)*
- *“The economics of conversion processes need to be further improved for biofuels to be competitive with fossil fuels without subsidies in the longer term (given sound policy framework conditions, including CO2 emission pricing). As a first step, fossil fuel subsidies, which are still applied in many countries (...), should be phased out. Introducing a CO2 price through a global carbon market will be an important element in fostering the deployment of biofuels and other low-carbon technologies in the longer term and would help considerably to improve their competitiveness.” (Ref: **CO_5032**)*
- *“The support requirements for conventional biofuels differ from those of advanced biofuels, which are in an earlier stage of technology development and still subject to comparably high production costs.” (Ref: **CO_5032**)*

### Interactions with the Technology Domain

*Traction technologies*

- *“One of the most important tasks facing the world today is the need to reduce its dependence on oil and other fossil fuels.(...). In response, car manufacturers around the world are focusing intensely on developing prototype electric vehicles. China, for example, has set a target that 50% of new vehicles on its roads should be electric by 2020.” (Ref: **CO_0258**)*
- *“As oil becomes more scarce, expensive and a security risk, we need implement greater energy efficiency measures, and shift the way we power our vehicles from petrol to renewable, low carbon fuel sources.” (Ref: **CO_5018**)*
- *“Fuel carbon intensity can be reduced by switching to, or blending in, lower-carbon alternative fuels (including biofuels, hydrogen, or electricity).” (Ref: **CO_5046**)*

- *"Scale and efficiency improvements will reduce biofuel production costs over time. In a low-cost scenario, most biofuels could be competitive with fossil fuels by 2030. In a scenario in which production costs are strongly coupled to oil prices, they would remain slightly more expensive than fossil fuels." (Ref: **CO_5032**)*
- *"While improving vehicle efficiency is by far the most important low-cost way of reducing CO2 emissions in the transport sector, biofuels will need to play a significant role in replacing liquid fossil fuels suitable for planes, marine vessels and other heavy transport modes that cannot be electrified." (Ref: **CO_5032**)*

*Renewable energy production*

- *"Renewable energy sources are important for cutting greenhouse gas emissions and reducing the EU's dependence on imported fossil fuels." (Ref: **CO_0197**)*

*Energy efficiency*

- *"We are reducing our reliance on fossil fuels by increasing energy efficiency and developing alternatives." (Ref: **CO_0195**)*
- *"Despite significant efficiency improvements, fossil fuel combustion continues to increase." (Ref: **CO_0140**)*

### Impacts on Mobility and Transport

*Breaking the dependence on fossil fuels will be the major challenge in the future*

- *"(Transport) is the fastest growing sector in terms of energy use, with the strongest reliance on fossil fuel." (Ref: **CO_0198**)*
- *"Transport depends heavily on fossil fuels (96% of all transport uses fossil fuels)." (Ref: **CO_0237**)*
- *"Global transport will remain heavily dependent on fossil fuels with a strong rise in demand for diesel, fuel oil and jet fuel compared to gasoline. This will have potentially significant implications for refiners and the downstream sector as a whole, especially in Europe, where there is a large emphasis on diesel fuels." (Ref: **CO_0159**)*
- *"(...) the challenge is to break the transport system's dependency on fossil fuels without sacrificing efficiency and compromising mobility." (Ref: **CO_0234**)*
- *"Reduction in oil dependence is an objective of EU policy, not least because it is closely related to decreasing GHG emissions. Targets and measures (...) for moving to a competitive low-carbon economy in 2050 require efforts from all sectors. Although the new white paper has not stated any specific target for reducing oil dependency, the 60 % GHG emissions reduction target means that transport-sector oil dependence should be significantly reduced by 2050, compared with the 96 % level today. In addition, decarbonisation of the energy system is significantly linked with decarbonisation of transport." (Ref: **CO_5030**)*

*..but growing demand for fuel, especially for diesel is still expected*

- *"Between 2010 and 2050, total fuel demand in all transport modes will increase by 30%-82% over 2010 levels. This growth is mainly driven by trucks, buses, trains, ships, and airplanes: demand for these forms of transport is expected to increase by 64%-200%..(...) In addition, the transportation sector will still depend heavily on gasoline, diesel, and jet fuel, since they all constitute the bulk of transport market fuels (80%–88%)." (Ref: **CO_0159**)*
- *"The global demand increase for diesel is largely driven by demand from the heavy transport, agriculture, and mining sectors. In these segments replacement of conventional fuels with new types of fuel technologies is unlikely to occur prior to 2050. The same holds true for fuel oil in shipping and jet fuel for aviation." (Ref: **CO_0159**)*

*Biofuels will have an exponential growth*

- *"In transport, a mix of several alternative fuels will be needed to replace oil, with specific requirements of the different modes." (Ref: **CO_0245**)*
- *"(...) vehicles fuelled with biodiesel or biogas show the greatest promise in the short term for medium and long-distance journeys." (Ref: **CO_0234**)*

- *"Biofuels' (…) use will increase almost four-fold. The demand for other fuels (electricity, hydrogen, CNG, and methanol) will increase six- to seven-fold." (Ref: **CO_0159**)*
- *"The maximum level of biofuels in the liquids markets is expected to be around four times above current market levels. Water and land use restrictions will prevent much further growth. The use of biofuels in Europe is largely a result of government mandates. As for the alternative fuels including natural gas, electricity and hydrogen, the maximum level is expected to be six to seven times above the current levels depending on the degree of government intervention." (Ref: **CO_0159**)*
- *"Biofuels will probably be a main option for aviation, long-distance road transport, and rail where it cannot be electrified." (Ref: **CO_0245**)*
- *"While aviation will continue to rely on liquid kerosene, promising sustainable alternatives to fossil kerosene are synthetic biomass-derived fuels and second generation biofuels. As a result of extensive research, biofuels were approved for use in 2011 and demonstration and commercial flights are now being carried out using add-on biofuels." (Ref: **CO_0234**)*

#### 1.4.4.3 Scarce Resources of Raw Materials

**Driver description**

- *"Non-energy, non-agricultural raw materials can be defined as raw materials that are mainly used in industrial and manufacturing processes, semi-products, products and applications and are not primarily used to generate energy. (...) Furthermore, crude oil and gas can be also considered as raw materials for industrial production." (Ref: **CO_0239**)*
- *"The key factors driving the demand for raw materials are global economic and population growth and new technological applications. In particular, the growing appetite of the emerging economies for raw materials is seen as major force driving global demand." (Ref: **CO_0239**)*
- *"Over the past 50 years the world's population has doubled, gross domestic product (GDP) has grown tenfold, and agricultural and industrial production has boomed. This growth and these competing uses have put water resources under ever-increasing strain." (Ref: **CO_0136**)*
- *"(...) the EU has become the largest net importer of resources in the world, effectively shifting environmental burdens elsewhere." (Ref: **CO_0135**)*
- *"It is worth noting that the high EU dependence on imported resources is a long-term structural trend. EU27 imports in tonnes increased by 30 % during the period 1999–2008, and the slight decline in 2008 was only due to the global economic crisis.(...) the most dramatic growth was in imports of fuels and lubricants. For the most part, this high dependence on imports is the result of macro-economic restructuring the decline of basic and heavy industries, rising domestic costs of production, the availability of cheaper products from abroad, and the removal of trade barriers." (Ref: **CO_0135**)*
- *"While EU economies are creating more and more wealth out of the resources they use, total use of material resources continues to increase." (Ref: **CO_0135**)*
- *"As we move towards a genuinely consumption based, sustainable materials management or a "circular economy", where waste becomes a resource, a more efficient use of minerals and metals will result." (Ref: **CO_0244**)*
- *"Securing uninterrupted access to resources will become a strategic economic challenge for some critical materials. The methodological problems with measuring the environmental impacts of resource use do not seem to have a ready solution. This is doubly important given that all projections envisage continued growth in global resource use." (Ref: **CO_0135**)*
- *"(...) due to the gradual exhaustion of high-quality ore deposits, we are increasingly turning to less concentrated ores the extraction of which causes higher impacts per tonne of processed material." (Ref: **CO_0135**)*
- *"(...) historic data show that following an economic decline or slow-down, subsequent periods of growth have tended to be accompanied by an increase in the use of resources and energy (…). Hence, even the current serious economic downturn may well turn out to be just a temporary break in a long-term upwards trend in energy and resource use." (Ref: **CO_0135**)*
- *"Europe relies on the rest of the world for many resources, such as fuel and raw materials, which are embedded in products imported from outside the EU. Scarcities and volatile commodity prices could bring instability to many regions of the world, so using resources more efficiently is imperative for us all." (Ref: **CO_0243**)*
- *"Water is a vital resource for human health and an essential input for agriculture, tourism, industry, transport and energy." (Ref: **CO_0244**)*
- *"By 2030 more than a third of the world's population will be living in river basins that will have to cope with significant water shortages, including many in countries and regions that drive global economic growth. (...) in just 20 years global demand for water will be 40 % higher than it is today, and more than 50 % higher in the most rapidly developing countries. The report estimates that, assuming historic rates of supply expansion and efficiency improvement, it will only be possible to close a fraction of this gap." (Ref: **CO_0136**)*
- *"Water shortage will become an increasingly serious problem in Southern Europe due to the alarming increase in the drought trend for this area, calling for a number of new strategies*

*(desalinisation of sea water, water transfer between river basins, limitation of irrigation and of the expansion of tourist resorts, changes in agricultural production etc.).” (Ref.* ***CO_1023****)*

- *“Compared with the global situation, with many regions facing serious water shortages in the coming decades, water stress in Europe may be easier to manage. Based on projections of population, economic development and agricultural production, demand for water in most of Europe is expected to be stable or to decrease. The decrease is expected to be driven by more the efficient use of water by all sectors together with a generally stable population and the projected limited change in the area of irrigated land.” (Ref:* ***CO_0136****)*
- *"Resource efficiency is thus an important element in efforts to sustain economic development while maintaining natural systems. By itself, however, resource efficiency will not guarantee steady or declining resource use. Growing consumption can mean that resource use increases despite efficiency gains. Indeed, resource efficiency can actually contribute to increased resource use because when a sector becomes more efficient prices may drop, increasing demand and offsetting the efficiency gain (the rebound effect). Even if improved resource‑efficiency results in declining resource use, it may still put excessive demands on the environment.” (Ref:* ***CO_0240****)*

## Interactions within the Environment Domain

### Climate change impacts

- *“In addition, future climate change is projected to reduce water availability in many places and further increase the population affected by water scarcity.” (Ref:* ***CO_0136****)*
- *“Climate change is projected to lead to significant changes in yearly and seasonal water availability across Europe. Water availability will generally increase in northern regions, although summer flows may decrease. Southern and south-eastern regions, which already suffer most from water stress, will be particularly exposed to reductions in water availability and suffer an increase in the frequency and intensity of droughts.” (Ref:* ***CO_0136****)*

### GHG mitigation

- *“Furthermore, transport activities on such a global scale contribute significantly to energy use and GHG emissions.” (Ref:* ***CO_0135****)*
- *“Improving the efficiency of resources use — a flagship initiative of the Europe 2020 strategy, will not only help to address some of these economic and strategic concerns, but could also be a step towards achieving targets for reducing GHG emissions.“ (Ref:* ***CO_0135****)*

### Pollution levels and emissions standards

- *“Quantifying the environmental impacts of resource use is notoriously difficult, due to the lack of robust methodologies and operational indicators. Tools and methods to measure these impacts are still at an early stage of development.” (Ref:* ***CO_0135****)*
- *“While the EU has many raw material deposits, their exploration and extraction is hindered by increased competition for land use and the higher costs of safeguarding the environment and human health.” (Ref:* ***CO_0239****)*
- *“While this reliance on imports may be economically advantageous — or even inevitable for materials that are not available in Europe — it has also led to a shift of environmental burdens abroad, whereby the environmental degradation associated with extraction and manufacture takes place in the producing country.” (Ref:* ***CO_0135****)*
- *“Environmental damage may be further aggravated by the fact that some exporting countries have lower social and environmental standards than the EU.” (Ref:* ***CO_0135****)*
- *“Moreover, emissions and wastes emitted during the processing and conversion of resources into goods and services have caused further damage to the natural environment and human health.” (Ref:* ***CO_0137****)*
- *“High use of natural resources increases pressures on both the source function of ecosystems - for example maintaining the availability of supplies and ensuring sustainable yields - and on their role as sinks - absorbing pollution or neutralising discharges.” (Ref:* ***CO_0135****)*
- *“Pressures can be expressed in terms of quantities of pollutants discharged, weights or volumes of resource extracted or material consumed, volumes of fish or timber harvested, or, at the most*

*aggregated level, material flows in tonnes. However, converting these pressures, which are sometimes referred to as impact potentials, into environmental impacts is much more challenging." (Ref: **CO_0135**)*

## Interactions with the Social Domain

### Urbanisation

- *"Many countries and big cities face water scarcity as a fundamental challenge to economic and social development." (Ref: **CO_0136**)*

### Planning

- *"Land management and land-use planning are essential to the management of water resources in water-scarce areas. Important wetlands, which help to store water, have been drained throughout Europe. One priority should be to retain rainwater where it falls, enabling water infiltration, through the re-establishment of wetlands and increased recharge of aquifers." (Ref: **CO_0136**)*

### Tourist flows

- *"Water scarcity has severe consequences for most sectors, particularly agriculture, tourism, energy, and the provision of drinking water. Activities that depend on high water abstraction and use, such as irrigated agriculture, tourism and the use of cooling water, are affected by changed flow regimes and reduced water availability." (Ref: **CO_0136**)*

### Change of lifestyle and values

- *"In recent decades, changing patterns of resource use have shown that progress on resource efficiency is perfectly possible. Over the last 20 years, recycling has become standard practice for both businesses and households across the EU, with major consequences for industries like paper, glass and resource extraction." (Ref: **CO_0243**)*
- *"(...) changes in lifestyles and habits, such as the desire for a green lawn during summer, or more baths, jacuzzis and swimming pools, can have the opposite effect and boost household water use. Raising awareness through education, information campaigns and eco-labelling schemes can play a crucial role in changing habits and lifestyles." (Ref: **CO_0136**)*
- *"(...) policy-makers need to find ways of bringing the proper value of natural resources into consideration in decisions, enabling the improved management of our natural resource base. Learning to value – and to put a price on – ecosystem services and natural resources will ease the pressure on the environment." (Ref: **CO_0243**)*

### Health

- *"Environmental degradation due to over-use of natural resources is likely to lead to serious consequences for human well-being and health." (Ref: **CO_0137**)*

## Interactions with the Economy Domain

### GDP trends

- *"The use of materials is intimately connected with economic growth — a 37-year time-series available for the EU15 shows that domestic material consumption (DMC) decreased only during periods of recession or slow economic growth." (Ref: **CO_0135**)*
- *"All in all, it is generally accepted that there are physical limits to continuing global economic growth based on the current patterns of resource use." (Ref: **CO_0135**)*
- *"In recent years, the concept of 'double decoupling' has gained prominence in the resource policy debate. A distinction is made between decoupling resource use from economic growth — fewer resources used per unit of GDP — and decoupling resource use from the environmental impacts it causes — lower impacts per unit of quantity. Opinions vary on the relative significance of the two components. Some experts argue that the increase in the quantity of resources used is not the most significant problem because the impacts can be reduced by closing material loops, recycling and recovery or the wider use of end-of-pipe measures. Others believe that the growth in quantities is a problem in itself, given finite amounts of non-renewables and potentially irreversible impacts on ecosytems. Furthermore, there are currently methodological difficulties in*

*measuring decoupling of environmental impacts from quantities of resources used." (Ref: **CO_0135**)*

- *"Due to the significant time lag in the availability of data on material flows, it is not possible at the time of writing to estimate the decline in Europe's use of resources that may have resulted from the economic crisis." (Ref: **CO_0135**)*

#### Regional differences in economics

- *"Demand for natural resources worldwide has increased tremendously over recent decades. The main drivers have been growth in population, wealth and consumption, with high population growth mainly in developing countries and highest levels of wealth and consumption in developed countries." (Ref: **CO_0137**)*
- *"Consumption of resources is also unbalanced. An average European citizen uses about four times more resources than one in Africa and three times more than one in Asia (...). The EU‑27 uses on average less resources per capita than many industrialised countries — about half that of Australia, Canada and United States, but there are large differences between individual countries within the EU." (Ref: **CO_0135**)*
- *"The overall consumption of material resources is known only for some countries although Eurostat's MFA[53] indicators have been compiled for quite some time and the OECD has carried out similar work for its member states." (Ref: **CO_0135**)*
- *"Extraction of resources is distributed unevenly across the world's regions. Of the estimated total of about 58 billion tonnes of materials extracted and used (DEU) in 2005, Asia accounted for 43 %, North America for 19 %, Europe and Latin America for 13 % each, and Australia and Oceania for 3 % (SERI et al., 2009). The total would be almost twice as high if unused overburden were added, that is materials such as mining waste which are extracted to gain access to the resources but which do not enter the economic sphere." (Ref: **CO_0135**)*
- *"In some countries, extraction of resources may also have negative social impacts due to land appropriations, population displacements and human rights violations." (Ref: **CO_0135**)*
- *"Unless local, national and global communities come together and dramatically improve the way they consider and manage water, there will be many more hungry people and degraded environments — and economic development itself will be at risk in many countries." (Ref: **CO_0136**)*

#### Market regulations

- *"The increased need for strategic resources may stimulate political monopolisation of access (for example China's moves to secure resources in parts of Africa in recent years), which may complicate access for other purchasers, including the EU." (Ref: **CO_0247**)*

#### Foreign trade and globalisation

- *"A significant share of the raw materials and semimanufactured input materials needed for the functioning of European economies is now imported from other parts of the world as, on the whole, activities in heavy industry, extraction (except for construction minerals) and basic metal production have declined in Europe over recent decades." (Ref: **CO_0135**)*
- *"(...) global trade in materials and commodities is easier than ever." (Ref: **CO_0135**)*

#### Intensified competition for scarce resources use

- *"Frequently there are also social impacts of resource use, most often affecting the poor through competition for land, access to water, or forced relocations." (Ref: **CO_0135**)*
- *"Prices of bulk resources (fossil fuels and a selection of metals such as copper, aluminium, iron, tin, nickel, zinc, lead and uranium) may be seen as reflecting their scarcity. Data show a fairly constant price level throughout the 1990s and an increase in the 2000s disturbed by the 2008–2009 economic crisis (...). This may indicate a continuing availability of these resources at the global level with shocks inducing short-term price increases (IMF, 2010; World Bank, 2009)." (Ref: **CO_0274**)*

[53] Material Flow Analysis

*Fiscal policy*

- *"Water pricing is a key mechanism for achieving the more sustainable use of water in all sectors. It is also fundamental to the WFD*[54] *requirement that the pricing of water services reflect their full costs. The WFD obliges Member States to implement water-pricing policies that provide adequate incentives to use water resources efficiently." (Ref: **CO_0136**)*
- *"Water pricing and metering have been highly effective in changing consumer behaviour in many countries." (Ref: **CO_0136**)*

## Interactions with the Technology Domain

*Technology development in general and innovation diffusion*

- *"Stocks of 14 groups of raw materials are considered 'critical' due to their high economic importance and high supply risk within the next 10 years. The EU has very few reserves of some, such as gallium (used in photovoltaics and microchips), tantalum (used in microelectronic capacitors), germanium (used in fibreglass cables) and neodymium (used in high performance magnets), which are essential for high-tech applications (Fraunhofer and IZT, 2009; EC, 2010)." (Ref: **CO_0274**)*
- *"An EU 2007 study estimates that water efficiency could be improved by nearly 40 % through technological improvements alone" (Ref: **CO_0136**)*

*Energy efficiency*

- *"Any significant long-term reduction in European resource use will require a sharp increase in resource efficiency in the processing and manufacturing sectors, a shift towards less resource-intensive services, a decrease in the energy intensity of economies, and an increase in the use of renewable resources. While some of these can be achieved through gradual technological improvements, long-term sustainability of our production and consumption may need to be critically reviewed." (Ref: **CO_0135**)*

## Impacts on Mobility and Transport and Transport

*Vehicle production may be hampered*

- *"The accessibility and affordability of non-energy, non-agricultural raw materials is crucial for ensuring the competitiveness of EU industry. The competitiveness of several European sectors such as electronics, cars, chemicals or construction can be hampered by a limited or more costly supply of certain raw materials." (Ref: **CO_0239**)*
- *"Production of vehicles and transport infrastructure require large amounts of materials. Such material use accounts for 20–40% of the consumption of major materials: aggregates, cement, steel, and aluminium (OECD, 2000). Moreover, the production of vehicle and transport infrastructure requires large amounts of energy: approximately 20% of the energy consumption during a vehicle's life cycle." (Ref: **CO_5003**)*
- *"The automotive industry, as a downstream industry, feels the indirect effects of limited access to raw materials. Due to rising raw material input costs in the steel and non-ferrous metals industry, it faces serious challenges, since cars are complex products consisting largely of steel, non-ferrous metals, as well as polymers, rubber and glass" (Ref: **CO_0239**)*
- *"The industry is also affected by the risk associated with the use of critical raw materials. As a result of the future developments in car- design, the demand for critical raw materials is expected to increase." (Ref: **CO_0239**)*
- *"Environmental standards and requirements and customer convenience play an especially crucial role here. According to the European Automobile Manufacturers Association (2010), the demand for rare earths and lithium will rise, due to more use of advanced electronics, magnetic materials, new surface treatment systems and alternative propulsion technologies." (Ref: **CO_0239**)*

*Higher prices for vehicles*

- *"Rising prices of raw materials may have a significant negative impact on the materials input costs of the sector, so customers are expected to face higher prices for end-products. A study on*

[54] Water Framework Directive ï 2000/60/EC

*resource productivity points out that if the prices of more raw materials inputs used in the car production go up, the product price for the final customer would also go up significantly." (Ref:* ***CO_0239****)*

*Increasing importance of recycled materials and scrap cars*

- *"Since cars consist of numerous different parts, the automotive industry is one of the best examples to illustrate how soaring prices for raw material, along with lack of supplies and environmental regulations, have led to more efficiency and more use of non-primary raw materials. Resource-efficient technologies and the use of recyclates and substitutes are the two main strategies the automotive industry is deploying to reduce dependency on raw materials." (Ref:* ***CO_0239****)*
- *"The recycling of scrap cars is of key importance, which is adequately regulated by the End-of-Life Vehicle Directive[55].The Directive on Reusability, Recyclability and Recoverability of motor vehicles[56] set new requirements for vehicle recycling. In 2008 total reuse, recovery and recycling rates varied between 79.8-92.9% in the Member States, with Germany having the highest rate in Europe." (Ref:* ***CO_0239****)*
- *"A technical approach to finding substitutions is at the core of the automobile manufacturing industry's R&D agenda. ACEA[57] estimates that the first significant volumes for recycling of electrical vehicles, which contain rare earths, cobalt and lithium, will come around 2025-2030 at the earliest. Demand for these materials is expected to boom around 2015-2020, so the industry hopes to have a new generation of batteries based on other materials by 2025-2030." (Ref:* ***CO_0239****)*
- *To meet environmental, safety and price demands, the use of light, smart and innovative materials, such as composites, and the efficient use of high value-added metals will be inevitable in car manufacturing. Research activity focuses on materials such as carbon fibers, natural/glass fibers, high strength steel/aluminum, magnesium technologies, and hybrid materials." (Ref:* ***CO_0239****)*

*Delocalization of production by car manufacturers*

- *"However, from a general sector perspective, current critical raw materials might be substituted for various raw materials before they can be recycled. Yet the same materials might be in great demand for applications in other industries, which will then definitely require adequate recycling technologies as a valuable option to sustain future access to critical raw materials. As regards organizational strategies responding to raw material challenges, outsourcing of manufacturing cars or car parts can be seen as an option to secure access to raw materials. This concerns not only rare-earths, but also aluminum where China has recently turned from net exporter to net importer. Setting up part of the production in China and South-East Asia may enable access to raw materials at better prices. The European car manufacturers have increased production capacities in these emerging countries, which could enable access to input materials at a lower cost by avoiding export restrictions." (Ref:* ***CO_0239****)*

[55] ELV Directive 2000/53/EC
[56] Directive 2005/64/EC
[57] European Automobile ManufacturersôAssociation

## 1.5 THE TECHNOLOGY DOMAIN

### 1.5.1 Technology Domain Key Factors and Drivers

- *"Technological innovation can help the transition to a more efficient and sustainable European transport system by acting on 3 main factors: vehicle efficiency through new engines, materials and design; cleaner energy use through new fuels and propulsion systems; better use of networks and safer and more secure operation through information and communication systems." (Ref:* ***CO_0194****)*

The technology development can be assumed as a key driver with respect to all the domains introduced in this project. Broadly speaking, it is acknowledged that whatever the improvement is designed, it potentially could enhance peopleǿs well-being; moreover, consequent and related benefits may arise in manifold and even unforeseeable manners.

Firstly, when referring to the transport sector, technology advancements and processes of innovation diffusion are expected to reduce impacts generated by environmental externalities. In this respect, improvements of vehicles design, material and traction technologies, as well as pollution abatement methodologies will be investigated to figure out how they can contribute within the plan.

Secondly, the survey will be focused on innovation efficiency gains that could also provide tangible improvements when dealing with scarce resources. Technology advancements reveal positive impacts also when relating them to the economy field, not only about potential economic growth, but also referring to the labour market. In particular, attention will be devoted in finding the assumptions under which the labour force could enjoy benefit from labour-intensive technologies that are supported by continuous innovation processes.

Interest will be diverted also to the spatial effect of innovations, since technological and industrial clusters are more likely to foster the economic growth of the regions wherein they operate (e.g. agglomeration economies).

Following the conclusions of the economy domain, the survey will also consider technology advancements with respect to what economics argues for example on GDP variations, as reliable indicator to represent the very gains of efficiency.

Effects of innovations ought to be verified also under the social perspective, when considering the influence on people lifestyle, because the direction along which the interaction occurs is not clearly identifiable at a first glance. Advancements influence how people is accustomed to behave by modifying their current habits; for example, access to the worldwide web did not arisen from consumers needs, even though it has deeply influenced lifestyle ever after. On the other hand, individuals ask (sometime unwittingly) for technological goods that provide a better quality of life (e.g. advanced health care services, teleworking, etc).

A final point will deserves attention, namely how R&D is financed to support the advancements designed.

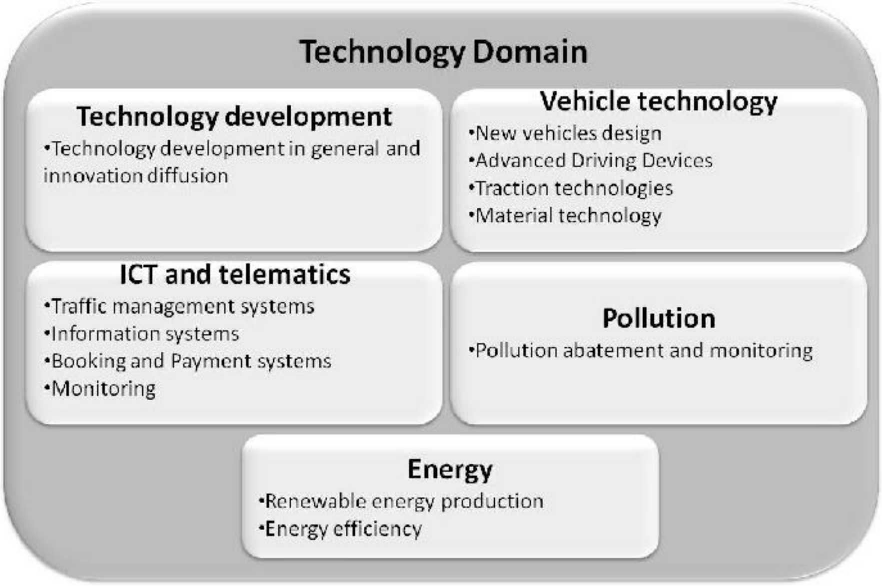


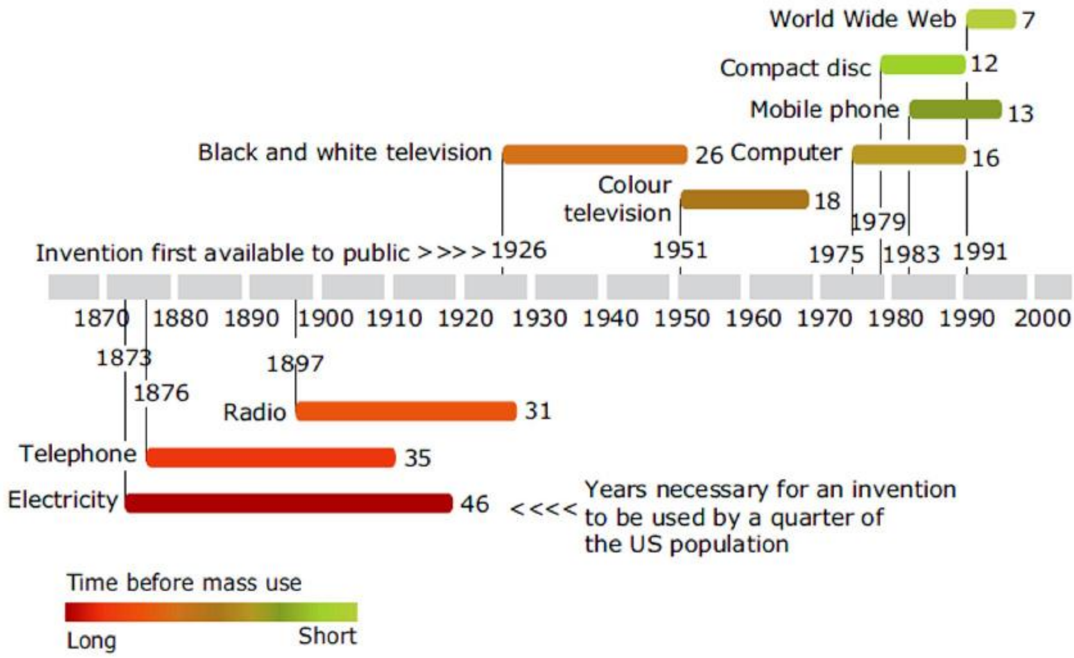

**Figure 1-74 Technology domain key factors and drivers**

### 1.5.2 The Technology Development Factor

#### *1.5.2.1 Technology Development in General and Innovation Diffusion*

**Driver description**

- *"Over the last 50 years the pace of innovation and technological change has accelerated consistently. The time needed for basic inventions to enter mass use has steadily decreased. Cycles of technology-induced societal and economic change are becoming faster. And cycles of innovation and technology change are very likely to accelerate further. The history of technological progress provides compelling evidence that change is not linear but exponential (Kurzweil, 2001). The dynamics will increasingly come from the convergence of sciences and technologies: This acceleration technological change will also affect economic sectors that have been slower to change in the past, notably energy and transport." (Ref:* ***CO_0274****)*




**Source:** Kurzwell, 2005.

Source: The European environment State and outlook 2010 ï Assessments of megatrends (Ref: **CO_0274**)

**Figure 1-75 Shortening time lapse before mass adoption of new technologies**

- *"The general acceleration of innovation and technological change is a stable trend. But the concrete direction and speed of innovation and diffusion is very uncertain." (Ref:* ***CO_0274****)*
- *"The processes of creating, owning and sharing knowledge are changing in a highly interlinked world; any outlook is fraught with considerable uncertainties. For example, open access to information will continue to empower bottom-up innovation processes, opening new routes for knowledge creation. But private battles may arise, with access to information and user rights becoming more fiercely contested by corporate and private interests." (Ref:* ***CO_0274****)*
- *"(...) range of drivers for innovation:*
  - → *Costs with the increasing price of oil;*
  - → *Material scarcity and security of supply;*
  - → *Capital investment flows being globalised;*
  - → *Demand led growth by the Third world with massive energy and resource pressures;*
  - → *Customers with significant consumer interest but little informed knowledge;*
  - → *Population growth and the aging demographic;*
  - → *Loss of habitat and biodiversity." (Ref:* ***CO_5011****)*
- *"The importance of services for the economy has increased steadily over time in most OECD countries. Especially important in this development are knowledge intensive business services (KIBS[58]) which have become increasingly important over time as sources of innovation, technologies and as inputs for the whole economy." (Ref:* ***CO_0239****)*
- *"The need to create and implement innovation in transport results from the continuing low efficiency of many of its technical elements and processes, leading to unsatisfactory levels of productivity, capacity and reliability, waste of time and resources, and higher operating costs. Another reason behind the search of new solutions in transport is the necessity to improve its*

[58] KIBS are defined as computer and related activities, R&D and other business services.

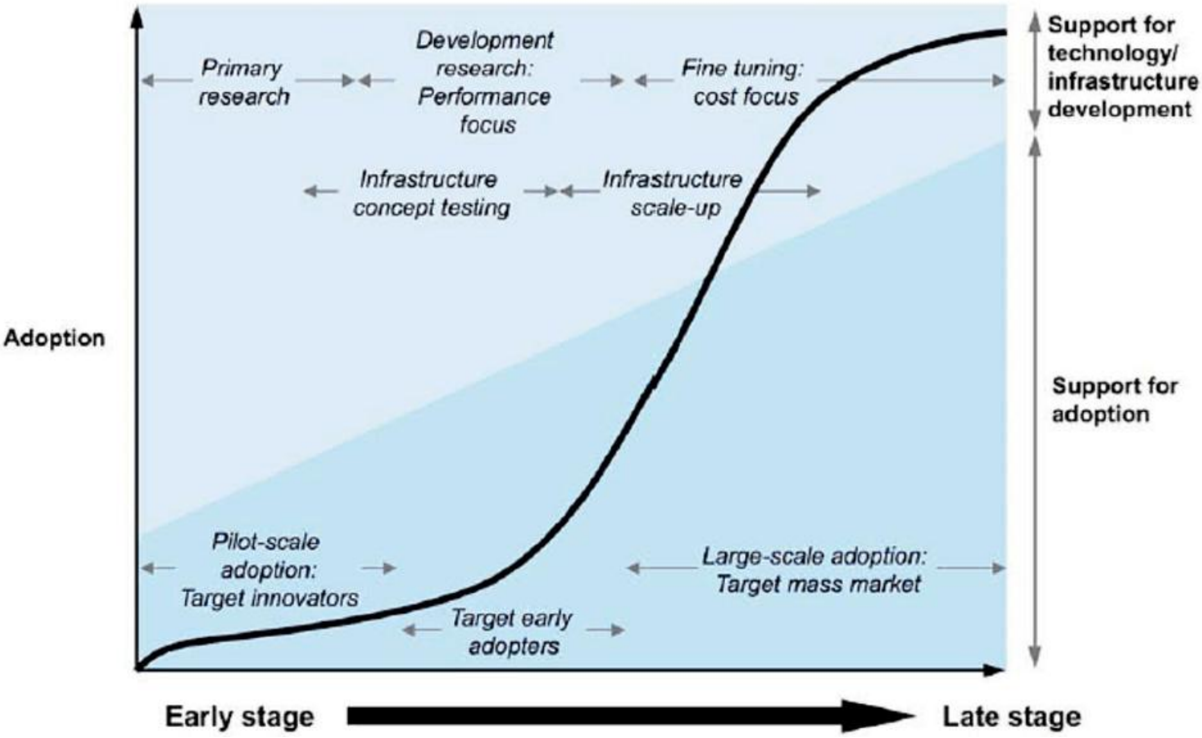
*relations with the world outside by greater accessibility in time and space, better quality of service and lower environmental impact." (Ref: **CO_5065**)*

- *"A number of key influences are driving a process of accelerating technological change in land transportation. Traffic congestion is encouraging new technologies to be adopted in traffic management. Concerns about traffic safety are leading to a consideration of new technologies, particularly road design and automated vehicle control. The availability and price of crude oil is encouraging research and development on fuel economy, the use of alternative fuels, and the development of fuel cell-powered engines. Air pollution problems in urban areas are encouraging the development of technologies to reduce harmful emissions, and concerns about global warming are further adding to the search for low-emission transportation. These concerns are also reflected in the adoption of new regulatory policies by governments in such areas as fuel standards and fuel economy standards for new motor vehicles." (Ref: **CO_0272**)*
- *"As we move forward, solutions to many transportation challenges will increasingly depend on innovation." (Ref: **CO_0284**)*
- *"It is clear that innovation is indispensable to the transport sector as it seeks to improve performance and better meet the needs of users." (Ref: **CO_0284**)*
- *"Today's innovation landscape shows an increasing shift from technology-push policies towards demand-pull policies. Promoting applications, user-driven innovation, innovation in services and in the public sector and addressing societal challenges have increasingly shaped the innovation policy agenda." (Ref: **CO_5053**)*
- *"Innovation means more than research and development. While R&D is important, innovation also includes the application of new ideas, policies and practices in ways that bring about improvements in overall processes. Technology has an important role to play in improving transport. But "soft" innovations – such as changes to policy and practices – are equally important. In many instances, the most effective innovations involve putting in place policy options that have long been seen as best practices; examples include more direct charging of road users, innovative funding mechanisms, road safety measures, traffic management and parking policies, among others." (Ref: **CO_0293**)*
- *"Many promising technological solutions are already available or could be available in a short time but are being poorly implemented." (Ref: **CO_0274**)*

### Interactions within the Technology Domain

#### *New vehicles design*

- *"Transport technology innovations might include further changes in vehicle design, propulsion systems and energy sources to address congestion, carbon emissions and safety." (Ref: **CO_5018**)*
- *"(...) in China (...) the number of e-bikes has grown from near-zero levels ten years ago, thanks to technological improvements and favourable policy. Improvements in e-bike designs and battery technology made them desirable, and the highly modular product architecture of electric two-wheelers (E2Ws) resulted in standardization, competition and acceptable pricing." (Ref: **CO_0246**)*
- *One of the biggest obstacles for such (groundbreaking) technologies is called "path dependency", which refers to innovations that make resulting products incompatible with existing infrastructure. Electric vehicles, for example, cannot use existing fuelling infrastructure, creating a competitive disadvantage against ICE-powered vehicles. Carbon fibre can dramatically reduce vehicle weight, but it cannot be used in traditional tooling, and recycling and cost issues also need to be resolved. (Ref: **CO_0019**)*




Source: Repowering transport (Ref: **CO_0019**)

**Figure 1-76 The "S Curve" Technology Deployment Challenge**

*Advanced driving devices*

- *"Eco-driving is gaining widespread recognition as a low cost method of reducing vehicle fuel consumption without the need for vehicle technology improvements." (Ref: **CO_0247**)*

*Traction technologies*

- *"Scientific advances will not reach the industrial/commercial scale at the pace expected. Consequently, the penetration of electric/hybrid and fuel-cell driven cars will be slow." (Ref: **CO_0077**)*
- *"In particular, costs, parallel development of electric-drive systems, onboard fuel storage and refuelling infrastructure challenges are likely to impede hydrogen fuel cells from becoming a competitive propulsion system in the near term and perhaps for another decade or more. Moreover, industry has no clear development path and seems to be moving in several different directions. Urban transit buses are serving as an important testing ground for fuel-cell buses." (Ref: **CO_0272**)*
- *"Battery electric vehicles have a potentially greater energy savings potential, but battery technology and cost must improve substantially to provide the performance and range demanded by consumers." (Ref: **CO_0049**)*
- *"(...) for heavier vehicles such as long-haul trucks, planes and ships, for example, the energy density and range limitations of batteries are likely to prevent significant market penetration until additional advances are made in lightweight, energy-dense battery (or other energy storage) technology." (Ref: **CO_0246**)*
- *"Major breakthroughs in battery technology, hydrogen storage concepts and fuel-cell technology (methanol/ethanol fuel types possible) will lead to faster penetration of electric/hybrid and fuel-cell." (Ref: **CO_0077**)*

*Traffic management systems*

- *"Current wireless applications for transport include travel and communication applications through third and fourth generation cell phones, GPS navigation systems, on-board safety equipment and electronic tolling systems. The next generation of technologies now being developed will bring together the advances in automotive engineering and IT on the one hand* *with the availability of high capacity wireless linking to and from moving vehicles." (Ref: **CO_0284**)*

- *"The new high capacity wireless solutions potentially hold a wide range of (...) benefits, for instance in road safety, traffic and demand management." (Ref: **CO_0284**)*
- *"Wireless technology is progressively being integrated into vehicles and transport infrastructure. The essence of the wireless revolution is the fitting of transmitter/receiver units to vehicles and widespread coverage of infrastructure to enable two-way communication between a vehicle and its infrastructure or between a number of vehicles." (Ref: **CO_0284**)*
- *"Improved micro-simulation tools have been developed to support the assessment of road traffic schemes and the optimisation of urban traffic control in real time. (...). In the future, the use of distributed computing is expected to speed up the simulations further, making them a useful tool across realistic road networks." (Ref: **CO_0289**)*

#### Information systems

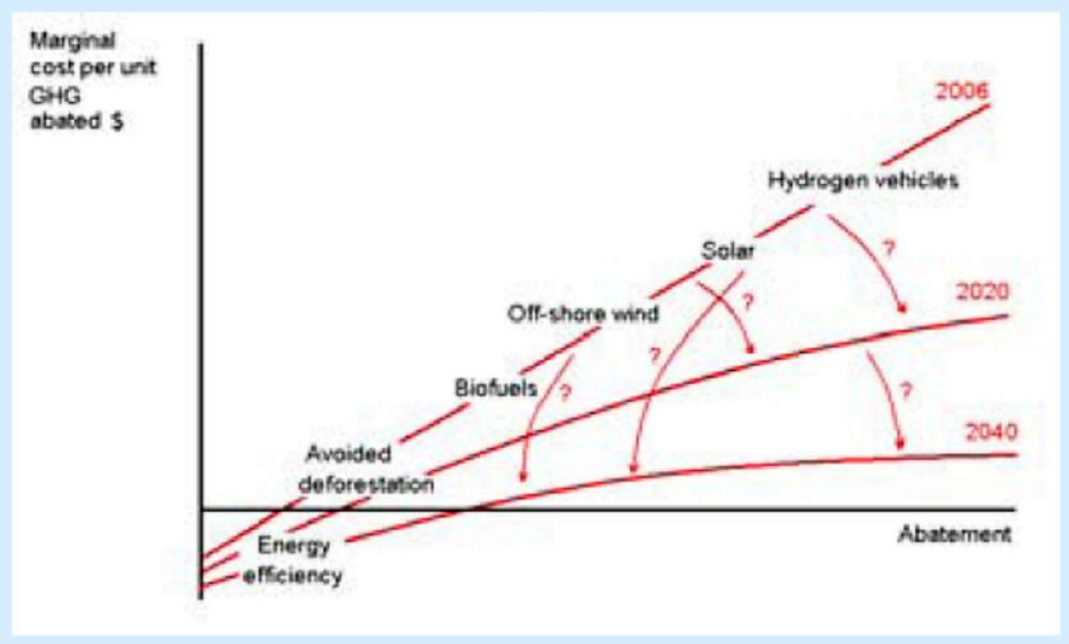
- *"Information & Communication Technology (ICT) is in many reports regarded as a very important technology enabler, both regarding safety and efficiency e.g. logistic applications and sustainable management systems." (Ref: **CO_0058**)*
- *"Technology is expected to contribute a great deal to the improvement of the safety record of road transport." (Ref: **CO_0077**)*
- *"A wider deployment of Intelligent Transport Systems that can detect incidents, support traffic supervision, and provide information to road users in real time will considerably improve traffic safety." (Ref: **CO_0077**)*
- *"Intelligent Transport Systems (ITS) represent the integration of information and communications technology with transport infrastructure, vehicles and users. The objective of ITS is to increase the efficiency and effectiveness of transport networks, improving safety and reducing environmental impacts." (Ref: **CO_0049**)*
- *"Another important aspect of technological development in the transport sector is that construction and operation of transportation systems is being transformed by computers, sensors, and communications technology, collectively called information technology (IT)." (Ref: **CO_5048**)*
- *"The evolution of mobile communication networks to 4G and beyond will deliver continuous connectivity to vehicles and travellers, giving access to on-line services via mobile Internet links." (Ref: **CO_0261**)*
- *"Wireless technologies will also enable automotive manufacturers and the ITS industry to provide a range of new products and services to road users." (Ref: **CO_0284**)*
- *"The idea of cooperative systems is to have vehicles connected via continuous wireless communication with the road infrastructure on motorways (and possibly other roads), and to "exchange data and information relevant for the specific road segment to increase overall road safety and enable cooperative traffic management. The basic innovation of cooperative systems is that intelligent transport tools, both in infrastructure and on vehicles, are active and "cooperate" in order to perform a common service. Consequently, in cooperative systems, communication can be Vehicle to Vehicle (V2V) or Vehicle to Infrastructure (V2I). (a) Vehicle to Vehicle communication: can be defined as the cooperative exchange of data between vehicles through wireless technology in a range that varies between a few meters to a few hundred meters, with the aim of improving road safety, mobility, efficiency and improving the use of road capacity. b) Vehicle to Infrastructure communication: can be defined as wireless cooperative interaction, between vehicles and infrastructure, based on systems that can improve safety and performance on roads." (Ref: **CO_0281**)*

#### Booking and payment system

- *"Regardless, other than flat fare, all other fare structures require a more sophisticated fare collection technology. However, fare collection technologies' costs have lowered in recent years." (Ref: **CO_0163**)*

*Pollution abatement and monitoring*

- *"For any single technology, marginal costs are likely to increase with the extent of abatement in the short term, as the types of land, labour and capital most suitable for the specific technology become scarcer. The rate of increase is likely to differ across regions, according to the constraints faced locally." (Ref: **CO_2024**)*




Source: STERN REVIEW: The Economics of Climate Change (Ref: **CO_2024**)

**Figure 1-77 Illustrative marginal abatement option cost curve**

- *"Policy should therefore ensure that abatement efforts at the margin also intensify over time. But policy-makers should also spur on the development of technology that can drive down the average costs of abatement." (Ref: **CO_2024**)*

*Energy efficiency*

- *"Technological solutions are aimed at reducing the negative impact per car and per kilometre. Examples include increasing the energy efficiency of cars and developing new forms of road surface to reduce the level of traffic noise. Such solutions do not appear to sufficiently reduce the problems of car use, such as to make it compatible with sustainability (e.g., OECD,1996)." (Ref: **CO_0042**)*
- *"The developments in the energy sector over the next 30 years depend crucially on the role of some key technologies and fuels on both the demand and the supply side." (Ref: **CO_2019**)*
- *"Technical progress generally leads to improved energy efficiency in technology such as lights, vehicles, refrigerators, and manufacturing processes." (Ref: **CO_0105**)*
- *"Improving vehicle fuel economy and average fleet fuel economy is influenced by both technical advanced and consumer choices. On the technical front, factors include vehicle size, vehicle weight and power train characteristics (e.g. engine displacement, transmission type, fuel type, engine aspiration type and engine power)." (Ref: **CO_0185**)*
- *"The brake system must be able to recuperate energy. By pure friction braking, normally a high amount of energy is dissipated into heat and cannot be used within the vehicle anymore. By an intelligent solution part of this energy can be recycled, using the electric motor(s) as generator(s). By these means, a longitudinal motion control for optimized energy consumption in an electric vehicle is feasible." (Ref: **CO_0058**)*

## Interactions with the Social Domain

### *Population aging*

- *"Demography used to be amongst the easiest part of the future to understand. We now know it is just as unpredictable as everything else. There are two key drivers, life expectancy and fertility decline. The amazing story on life expectancy is the leap that we've experienced. This is due to technologies as well as ideas – public health ideas like understanding that smoking causes cancer and that wearing seatbelts is safer." (Ref: **CO_0284**)*

### *Income structure and distribution*

- *"(...) it can be argued that ICT has a leverage effect on existing types of social inequality." (Ref: **CO_2018**)*
- *"Many will have doubts about the assertion that a technology so appropriate to distribute unprecedented amounts of free information and understandable knowledge among the mass of the population would contribute to rising social inequality. Yet this can be shown and explained, provided that one considers ICT as a technology that is able to reinforce the position of some people in societal competition and weaken that of others. So this concerns relative inequality and much less absolute inequality: the complete inclusion or exclusion of access to computers and the Internet." (Ref: **CO_2018**)ù*
- *"Considering physical new media access income still plays a role caused by the regular expenses for purchase of new hardware and software and usage costs that have to be made." (Ref: **CO_2018**)*

### *Gender roles*

- *"(...) improvements in ICT technology have allowed women (and men) around the world to access markets in growing numbers by lowering information barriers and reducing the transaction costs associated with market work. Because time and mobility constraints are more severe for women than men, women stand to benefit more from these developments." (Ref: **CO_0161**)*

### *Urbanisation*

- *"<The convergence between cities and other areas will grow as we start to spend time in 'virtual cities'>. Guy Summers, R&D Collaboration Manager, Vodafone." (Ref: **CO_5018**)*
- *"Employees may use teleworking to move further from their worksite, for example, choosing a home or job in a rural area or another city because they know that they only need to commute two or three days a week. This may increase urban sprawl." (Ref: **CO_5047**)*

### *Change of lifestyle and values*

- *"(...) the impact of technology on society and, conversely, the way technological development is driven by societal changes, are highly relevant themes within the European decision-making context." (Ref: **CO_2015**)*
- *"Telework refers to the use of electronic communication to substitutes for physical travel, including commuting, business activities and errands such as shopping and banking." (Ref: **CO_5047**)*
- *"The number of commuters and the associated distances travelled will fall sharply as people will tend to live closer to their jobs and/or make greater use of information technology." (Ref: **CO_0077**)*
- *"Many jobs and errands involve information-related goods suitable for telework, but the actual portion of trips reduced by telework tends to be small. Many trips require access to special materials and equipment, or face-to-face meetings, even if their primary good is information that can be transmitted electronically." (Ref: **CO_5047**)*
- *"(...) there is a resistance to change, and vested interest in existing systems and practices. Individuals and companies are often unwilling to pay for innovations that will bring forward improvements, in some instances because the benefits are widely shared, but the costs must be borne by individuals and firms. There is also a more emotional adherence to the status quo in some instances. For example, drivers do not want to see limitations on their control of vehicles, despite that fact that driver error is a major cause of crashes." (Ref: **CO_0293**)*

- *"More significant changes in consumer behaviours will be needed to accelerate the transition to advanced technology vehicles." (Ref: **CO_0154**)*
- *"By 2030, urban mobility will have changed due to socio-demographic evolution (ageing and immigration), urbanization, the increase of energy costs, the implementation of environmental regulations, and the further diffusion of sophisticated Information and Communication Technology (ICT) applications in virtually all aspects of life." (Ref: **CO_0077**)*
- *"People lifestyle and behaviour (...) tends towards individualism with an emphasis on consumerism, self-interest and a positive view of technology." (Ref: **CO_5048**)*
- *"A few areas of instrumental consumption have seen a massive shift to online transaction, which to some extent has replaced brick-and-mortar retailing. Examples include consumer financial services, travel services, recorded music, and computer software. (...) In consumer behaviour there is a shift towards consumption at home ("domestication") and the integration of consumption in other everyday activities. The supply of local, personalised products and services reflects the demand for such products and services by consumers, who increasingly value niche-products and markets." (Ref: **CO_2018**)*
- *"Innovations always rely on acceptance and a spirit of enterprise." (Ref: **CO_0284**)*
- *"Innovation is not only about technology. It has also a soft side. Caring for one's passengers, clients, employees and their needs helps in identifying innovative solutions and new business opportunities. Service orientation is a must." (Ref: **CO_0284**)*

### Interactions with the Economy Domain

*GDP Trends*

- *"(...) a key driver of (...) growth has definitely been innovation." (Ref: **CO_0155**)*
- *"(...) innovation leads to permanent increases in per capita GDP." (Ref: **CO_0156**)*
- *"The positive relationship between countries' own R&D and productivity growth has been also confirmed by studies using international panel data." (Ref: **CO_0156**)*
- *"For most of the period between 2000 and 2009, the share of R&D expenditure in GDP remained fairly stable for the EU as a whole at between 1.8 and 1.9 %. In 2008 and 2009 R&D expenditure improved slightly." (Ref: **CO_0197**)*
- *"The economic downturn will delay the development of necessary technology." (Ref: **CO_0077**)*
- *"Public and private bodies will only take measures to adapt infrastructure if absolutely necessary. The pace of introduction of new and intelligent technologies for the protection of vulnerable road users will slow down." (Ref: **CO_0077**)*
- *"The long-term outlook for economic growth in any economy is dependent, to a degree, on technological progress. When advances in technology are linked to investment, it is the quality of such an investment that drives growth." (Ref: **CO_0178**)*
- *"(the) ...rates of productivity growth and technology growth are interrelated. In other words, in scenarios of high macroeconomic productivity growth as reflected in per capita incomes (...), the productivity of resource use (e.g., energy, agricultural land) and rates of technological innovation are also high." (Ref: **CO_0003**)*
- *"Innovation is a key driver of economic growth and increasing welfare (...)." (Ref: **CO_0274**)*
- *"Investing in the right technologies, research and business practices will support global trade and competitiveness. The use of innovative products, services and processes can help make businesses more efficient and industries more resilient, even in tough economic times." (Ref: **CO_0284**)*
- *"(Information) technology will be more successful than expected at breaking the historical correlation between energy consumption and GDP." (Ref: **CO_0077**)*
- *"The most important factor behind the wealth of nations is technical progress." (Ref: **CO_0299**)*

### Employment

- *"Although science and technology developments have an impact on the labour market, they cannot be regarded solely as drivers: in the labour market system we find a process of co-evolution and thus clear cause and effect is not present." (Ref: **CO_2030**)*
- *"As the implementation of ICT has generally been accompanied by a restructuration of organizational processes, the division of labour has been affected by ICTs (= applications of ICT) (...)." (Ref: **CO_2018**)*
- *"Since labour productivity is assumed to continue to grow following past trends, there is an implicit assumption that new technologies will continue to be developed." (Ref: **CO_5009**)*
- *"It is obvious that in the ICT branch, a lot of new jobs have been created. However, e.g. within automation projects, there are also examples of job losses as results of ICT implementation." (Ref: **CO_2018**)*
- *"Competition and innovation have positively impacted on the transport labour market. However, transport workers in some sectors may be displaced from their jobs as a result of the adjustment to a radically different economic and energy context. It is important to ensure that such change is well anticipated and managed, so that changing conditions will also be a source of new jobs and that transport workers can participate in, and respond to, the process." (Ref: **CO_0015**)*

### Market regulations

- *"(...) there is no clear connection between pricing mechanisms and the supply of infrastructure, which can lead to misaligned incentives and rent-seeking behavior. Within the contracting process for services and infrastructure there is often a focus on lowest costs, as opposed to performance, which does not induce innovation either." (Ref: **CO_0293**)*

### Foreign trade, globalisation

- *"Because of advances in communications and transport technology, the notion of markets is more global." (Ref: **CO_5028**)*
- *"Efforts to accelerate basic technological development cycles are driven by better access to information and increasing scientific cooperation, building upon continued economic growth and trade." (Ref: **CO_0274**)*

### Energy availability and prices

- *"Technology development is likely to concentrate on increasing efficiency to compensate for higher fuel prices." (Ref: **CO_2057**)*
- *"<By 2040, the grid will be different: we will be burning electrons rather than hydrocarbons. Those electrons will be greener, so there will be a lot more renewable energy generation> Gordon Feller, Director of Urban Innovations at Cisco Systems." (Ref: **CO_5018**)*

## Interactions with the Environment Domain

### Climate change impacts

- *"Innovation (...) can contribute directly and indirectly to damaging or improving the environment." (Ref: **CO_0274**)*
- *"Innovation can also play a key role in achieving goals relating to sustainability (...). For example, efforts are increasingly focused on improving efficiency, safety and security, as well as on reducing environmental impacts." (Ref: **CO_0284**)*
- *"Vehicle technology has performed a key role in reducing environmental impacts from transport in the last decades, particularly in road transport." (Ref: **CO_5030**)*
- *"Technology also has a vital role to play in adaptation. (...)." (Ref: **CO_2024**)*
- *"[Technology] will greatly improve human abilities to understand and monitor environmental change and develop problem-solving strategies." (Ref: **CO_0274**)*
- *"Improvements to design, materials and construction techniques can improve the resilience of infrastructure and urban development. Scientific and technological progress that improves the quality of climate predictions and weather forecasts will enable more effective adaptive responses to climate change." (Ref: **CO_2024**)*

- *"A step change is needed in the pace and scale of low-carbon energy technology development and deployment across all sectors. Global climate change goals cannot be achieved without all technologies in the low-carbon portfolio making a full contribution." (Ref: **CO_0154**)*
- *"While new technologies are an indispensable part of any strategy to address problems of global environmental change, previous experiences with technological fixes show the possibility of simply shifting the source of the problem and creating new problems along the way. However, the legal requirement to apply the precautionary principle in the EU helps manage potentially harmful technologies and stimulate smarter, less threatening innovations." (Ref: **CO_0274**)*
- *"(...) technology does not, by itself, reduce environmental impacts." (Ref: **CO_5009**)*

*GHG mitigation*

- *"The new high capacity wireless solutions potentially hold a wide range of societal (...) benefits, for instance (...) pollutant and greenhouse gas emissions reduction." (Ref: **CO_0284**)*
- *"Medium term mitigation potential for $CO_2$ emissions from the aviation sector can come from improved fuel efficiency, which can be achieved through a variety of means, including technology, operations and air traffic management." (Ref: **CO_0146**)*
- *"Opportunities for realising GHG reductions in the building sector exist worldwide. However, multiple barriers make it difficult to realise this potential. These barriers include availability of technology, financing, poverty, higher costs of reliable information, limitations inherent in building designs and an appropriate portfolio of policies and programs." (Ref: **CO_0146**)*
- *"(...) technology (is) an important driver (...). Rates of technological change are critical across all sectors, as well as for both demand and supply aspects that together determine future GHG emission levels. (Ref: **CO_0003**)*
- *"Policy to reduce emissions should be based on three essential elements: carbon pricing, technology policy, and removal of barriers to behavioural change." (Ref: **CO_2024**)*

*Noise abatement and emission standards*

- *"Since January 2002 a noise reduction bonus is encouraging infrastructure users to employ low-noise rolling stock in Switzerland. To qualify for the bonus, advanced brake technology must be used (composite blocks, disc brakes or comparable)." (Ref: **CO_0151**)*
- *"In the case of speed humps, they also transmit frequent and sometimes severe shocks through the road surface, causing long-term damage to the infrastructure and nearby buildings." (Ref: **CO_0274**)*

*Pollution levels and emissions standards*

- *"How can sustainable mobility then be achieved? The answer lies in the further development and mass application of safe and clean technologies. The introduction of the three-way catalyst has thus far contributed most to reducing air pollution from cars. All sorts of safety techniques – both on vehicles and roads – have effectively reduced fatalities and injuries. New technologies will be developed and some are waiting for mass introduction. However, making transport much safer and cleaner cannot be left to market forces. Strong policies are required, of which setting and enforcing strict standards and a variety of financial incentives are the most important. These new technologies will impose additional costs to travelling. These costs need to be accepted as the price for making mobility sustainable." (Ref: **CO_2046**)*
- *"The mitigating effects of new technologies tend to be overshadowed by the continuing growth of car use. Whereas new technologies are capable of substantially reducing various emissions, other sustainability problems such as urban sprawl and accessibility are rooted in a wider complex of causes for which new technology, per se, is not a solution. For example, energy-efficient cars may help control environmental problems, but will hardly solve accessibility problems." (Ref: **CO_0042**)*

*Energy availability, production and consumption*

- *"The second driving force for discontinuity in energy patterns is technology. A technology that offers superior or new qualities, even at higher costs, can dramatically change lifestyles and related energy use." (Ref: **CO_5048**)*

- *"Transportation patterns and technology choices also require a balanced approach that recognises both the human and technological dimensions of energy consumption." (Ref: **CO_0154**)*

*Scarce resources of raw materials*

- *"Development of new technology is a driver for a more sustainable exploitation of the world's resources." (Ref: **CO_5048**)*
- *"Europe relies heavily on the rest of the world for non-renewables, and increasingly some of these non-renewables — such as fossil fuels or rare earth metals used in information technology products — are becoming difficult to source cheaply, if at all, often for geo-political as much as supply reasons. Such trends make Europe vulnerable to external supply shocks that may result from an over-reliance on non-renewables." (Ref: **CO_0141**)*
- *"Encouraging and supporting R&D and innovation for substitutes, better recycling techniques and sustainable production (material efficiency) are all of key importance in tackling the relative shortage of raw materials in the EU manufacturing sector." (Ref: **CO_0239**)*
- *"The pace of technological innovation needed to sustain economic growth under higher resource prices and possible larger disruptions is uncertain, as is the stability of financial markets." (Ref: **CO_0274**)*

## Impacts on Mobility and Transport

*The bi-directional relation between technology and transport*

- *"Technological innovation will be a major contributor to the solution of the transport challenges. New technologies will provide new and more comfortable services to passengers, increase safety and security and reduce the environmental impacts." (Ref: **CO_0015**)*
- *"Transport demand can be considered driven by social relations and economic activities, as well as by technology, but transport also drives activities and technologies." (Ref: **CO_5048**)*

*Increasing demand for fast mode of transport*

- *"(...) the main driver of the growth in passenger travel is the increase in average speed. (...) this shift to faster transport modes in its turn is caused by different forces. The first is technological improvements" (Ref: **CO_2046**)*
- *"Historically, innovation in transport has been about getting from A to B faster (...)." (Ref: **CO_0284**)*
- *"Each travel mode has become faster, cheaper and more comfortable by innovations such as the internal combustion engine, airplanes and building motorway networks. Note, however, that since the first flight with an aircraft in the beginning of the 20th century, no major technical breakthroughs have occurred in the transport field. Trains, cars, planes and related infrastructures are not new technologies. It is true, however, that these "old" technologies have been improved tremendously by e.g. mass-production, new materials and lately by the break-through of new information and communications technology and applications." (Ref: **CO_2046**)*
- *"But (...) speed will not play the same role tomorrow as it did yesterday. Average transportation speed is now close to the maximum and will be very difficult to increase. Also, there appear to be little gains from further improving speed while the cost of energy is rising." (Ref: **CO_0284**)*

*Mileage per capita*

- *"During the Twentieth Century, technological innovations significantly improved motor vehicle performance (power, speed, safety and reliability) which increased vehicle travel. Automobiles are now relatively safe, reliable, and can exceed legal speed limits. In recent decades most vehicle innovations have improved convenience and comfort (navigation systems, quieter vehicles, better sound systems, and more cupholders). Many newer technological improvements improve alternative modes or allow more efficient road and parking pricing, which are likely to reduce vehicle travel. Table below categorizes technologies according to their vehicle travel impacts. More new technologies are likely to reduce than increase vehicle travel." (Ref: **CO_5047**)*

| Increases Motorized Travel | Mixed Mobility Impacts | Reduces Motorized Travel |
|---|---|---|
| Increased fuel efficiency and cheaper alternative fuels.<br>Increased vehicle comfort.<br>Automated driving. | Electronic vehicle navigation<br>Improved traffic signal control. | Telework (electronic communication that substitutes for physical travel).<br>Improved road and parking pricing.<br>Improved transit user information.<br>Transit service improvements.<br>Improved rideshare matching.<br>Improved delivery services.<br>Improved carsharing services. |

Source: The Future Isn't What It Used To Be. Changing Trends And Their Implications For Transport Planning (Ref: **CO_5047**)

**Figure 1-78 Travel impacts of new transport technologies**

- *"The Twentieth Century was a period of declining vehicle costs. The Twenty First century will be a period of declining communication and computing costs, which improves mobility substitutes and management strategies. This may reduce vehicle travel." (Ref: **CO_5047**)*
- *"Transportation needs can (...) be reduced by increasing 'virtual' accessibility through information technology (teleworking,e-government, e-health, etc.). Evidence on the effect of these practices is still limited, but it seems they have a significant and yet unexploited potential for replacing travel" (Ref: **CO_0015**)*
- *"The use of information and communications technology to reduce transport demand can be particularly cost effective and can have large environmental benefits. Teleconferencing can reduce transport demand and enable companies to control travel costs if air travel becomes more expensive, helping to maintain economic competitiveness." (Ref: **CO_5030**)*
- *"On the other hand, greater ease of contact might encourage people to live further from their workplace and firms to disperse their activities. The net result could be fewer, but longer, journeys related to work. In any event, teleworking has the great advantage of providing flexibility in the choice of when to travel, therefore significantly reducing congestion." (Ref: **CO_0015**)*
- *"Although it tends to reduce peak-period trips, telework does not necessarily reduce total vehicle mileage unless implemented with other travel reduction strategies, for the following reasons: teleworkers often make additional errand trips that would otherwise be made during commutes, and vehicles not used for commuting may be driven by other household members." (Ref: **CO_5047**)*
- *"Improved telecommunications may increase long-distance connections, increasing travel. For example, people may make new friends through the Internet and travel more to visit them." (Ref: **CO_5047**)*

#### *Increasing demand for logistics services*

- *"Access to a growing variety of on-line information and e-commerce outlets will also increase the demand for home supply of goods and services. Urban logistics strategies will thus need to focus on efficiency gains – again with greater integration of deliveries and optimised use of the infrastructure." (Ref: **CO_0260**)*

#### *Sustainable mobility*

- *"The threat of increasingly unsustainable transportation systems in the large cities of the world comes from the interaction between growing demand for transportation services and the environmental impact of transportation. Demand tends to grow at a geometric rate, while the environmental capacity (at given technologies) to handle such growth is fixed. Technology offers enormous possibilities for change in the longer run, but unless harnessed to the goal of sustainability, may aggravate some problems (such as traffic congestion) while in the process of fixing others (reducing emissions per road vehicle kilometre)." (Ref: **CO_0272**)*
- *"(...) (an) important (...) driving force(s) to achieve a sustainable future transportation solution (is):*

  → *Technology development" (Ref: **CO_0058**)*
- *"Only with discovery, promotion and development of new energy resources, matched to innovation and improvements in current technologies, catalysed by optimally formulated policies*

*can we hope to ensure a more sustainable transport future for current and future generations." (Ref: **CO_0159**)*

- *"Demography or urbanization trends have small impacts as well, as their effects on transport can only be seen on the very long term. Other factors, such as improvement of technology or changes in infrastructure stock have much more accelerated effects." (Ref: **CO_5048**)*

#### Public transport

- *"Social media can improve the image of public transport companies and it is a very effective tool that public transport companies should be using already. (...) Social media offers an opportunity to open a dialogue with the customer, allowing interaction and providing opportunities to augment traditional web and wider marketing activities. This is very useful given the very frequent interaction public transport companies have with their customer base (almost daily)." (Ref: **CO_0290**)*
- *"Social media is also impacting how people complain about services. Previously this was quite individual with the wider public only becoming aware if the 'mainstream' media became involved. Now, an increasing number will complain through social media channels, often as they are experiencing the service failure. If ignored, these complaints can spread and be shared rapidly but, by addressing such complaints through social media dialogue, public transport companies can often effectively manage and respond to these complaints and enhance reputation in a very visible way." (Ref: **CO_0290**)*
- *"The mobile nature of social media in particular makes it a very natural 'fit' for public transport, both as a source of significant competitive advantage and as a highly effective tool to grow patronage, keep our customers informed, listen to them and enhance customer service, satisfaction and reputation." (Ref: **CO_0290**)*

#### Increasing road safety

- *"Across Europe, researchers are busy developing new and exciting systems that have the potential to advance road safety in myriad ways. Yet these technologies will only deliver real progress on road safety if they are made available in vehicles and on our roads. Research must therefore be accompanied by user tests and cost-benefit analyses to help regulatory authorities and consumer testing organisations prioritise different options for action." (Ref: **CO_0266**)*

#### The emerging need to tackle with new problems

- *"Some key transport innovations – containerisation, high-speed rail, low-cost air travel, etc. – have led to great increases in the amounts and speeds of both passenger and goods transport, with benefits to consumers and business. The transport sector has traditionally revealed itself to be adept at increasing speed and traffic volumes. But these improvements have often come at excessive costs, in terms of increased energy use, GHGs and congestion, as well as costs related to public spending. Furthermore, there are areas where transport has notably failed to make important improvements, including managing road space, improving the productivity of public transport, and increasing overall system efficiency, such as the integration of land-use and transport planning. Many fundamental challenges associated with transport remain, such as pollution, safety and congestion. (...) future innovation in transport will need to change to focus less on speed and volume and more on addressing the new challenges noted earlier, and that this change in focus will require clear policy signals" (Ref: **CO_0293**)*
- *"Therefore, a completely new issue emerges (...). The new challenge is to unleash the potential to improve the time we spend in the transport system. (...) a future focus of innovation will be to reduce the time spent in idle, for instance in congestion. Some innovations in this area will be useful from a collective point of view, though to some extent inconvenient for individuals – electronic speed control or road charging, for instance." (Ref: **CO_0284**)*

### 1.5.3 The Vehicle Technology Factor

#### *1.5.3.1 New Vehicles Design*

**Driver description**

- *"The need for innovation exists both within entire transport systems (of a country or city) as well as within individual modes or forms of transport. In the former case, innovation should result in giving the user a new generation service; in the latter, successful innovation is new generation means of transport, infrastructure, new traffic control methods, new ways of improving safety or reducing environmental and social impact." (Ref: **CO_5065**)*
- *"The pace of technological change in railway rolling stock is fairly slow because railway rolling stock have long lives. Locomotives are typically rebuilt many times. The relatively slow turnover of both locomotives and freight cars has slowed the penetration of energy-efficient technologies into the railroad system. Nevertheless, the key aspects of technological change in railway equipment can be predicted. They involve suspension and drive, power and energy, communications and information, track, and track environment." (Ref: **CO_0272**)*
- *"Rail transport is not very susceptible to disruptive technologies. Such is the nature of the rail track that it can hardly be changed, and replacing it with something else would simply mean the end of this transport mode. Innovative processes concerning rail infrastructure are targeted at greater possibility of incorporating it in various spatial dimensions. These processes have resulted in the emergence of not only flat surface rail tracks, but also of elevated and underground rail structures, as well as cable and magnetic cushion rail. In terms of rail systems, there are two major, seemingly opposing innovative tendencies: on the one hand, to lower unit costs by developing heavy train technologies, on the other, attempts are made to increase spatial accessibility of the rail services by using light rail units requiring tracks that are cheaper to build and operate." (Ref: **CO_5065**)*
- *"After three years of research, a team from Newcastle University in the UK, working in collaboration with Bombardier Transportation and Portuguese manufacturing firm AP&M, succeeded in producing a prototype lightweight train cab which reduces the weight of the traditional cab by a remarkable 40%. The breakthrough technology behind the new cab takes the form of a 'sandwich' construction, in which an aluminium honeycomb structure and a polymer foam core are enclosed in outer layers of special glass-reinforced plastic. Crucially, the inherent strength of the new construction eliminates the need for steel elements. This reduces not only the weight, but also the number of separate parts required. In addition to the 40% weight reduction, the new cab reduces the number of separate component parts by up to 75%. And this in turn reduces overall costs by up to 20%, as assembly and outfitting are far simpler than before" (Ref: **CO_0258**)*
- *"Aviation is the transport mode in which technological development has its definite logic and clear-cut stages of development." (Ref: **CO_5065**)*
- *"Modern innovative processes in civil aviation include: concepts of new generation planes, new generation navigational equipment of existing aircraft, air transport systems based on IT and satellite technologies, new generation airports and airfields. Major innovative tendencies in this mode of transport are as follows: concepts and prototypes of variable wing geometry, vertical takeoff aircraft (...); new generation cargo airships (Airship, Dirigeable); designs of low-noise, low-CO2 eco-friendly planes, like the hydrogen powered Cryoplane; new generation flying wing planes (with no traditional fuselage); very large passenger airliners (like the Airbus 380, the prototype of a onethousand- seat Boeing 797 Blended Wing, an experimental craft developed by Boeing and NASA X-48B) to limit the number of takeoffs and landings and thus reduce congestion; new generation airports (including Smart Automated Airports, Highway in the Sky, Off-Shore Air Stations); merger of huge airports with cities and transforming them into logistics centres (Aéropolis); technologies of safe, automated air traffic management (ATS)." (Ref: **CO_5065**)*
- *"Traffic overload is the problem of large airports and their expansion is limited for spatial and environmental reasons. If airports are to operate more efficiently, innovative concepts of their location must be worked out as well as greater harmony in the make-up of individual modules of an air terminal, fast and reliable transfer of passengers between the terminal and the city and new technologies of passenger and baggage handling. Meeting the demands of the constantly*

*growing air traffic is not possible through traditional investment projects, but only through seeking innovative solutions, of which the most promising are the concepts of: offshore airports; common-use self-service kiosks, Self-service baggage check, high-capacity flow-through elevators (...)."(Ref: **CO_5065**)*

- *"Cars will change too." (Ref: **CO_5018**)*
- *"New-generation vehicles, alternative fuels, smart systems of traffic control and new technologies of construction and maintenance of transport infrastructure have become a necessity." (Ref: **CO_5065**)*
- *"The scope of the changes ranges over every aspect of the car's design, ranging from engines, motor parts, transmission, ignition systems, exhaust controls, vehicle bodies, suspensions, brakes, wheels, vibration dampeners, tires, filters, coolants, external coatings, windscreens and windows, seats, dashboard and instrumentation, on-board diagnostics, enhanced electronics for driver comfort and entertainment, and automated vehicle control systems. At the same time, the design and manufacture of automobiles will be revolutionized by the application of advanced virtual reality design technologies." (Ref: **CO_0272**)*
- *"Technologies include direct injection systems, other engine and drive-train improvements, lightweight materials, and better aerodynamics. Although stock turnover considerations mean that the full effect of these improvements would not be realized until 2020-2025, they could still reduce the average fuel use per kilometer for the entire stock of cars by 10-15% over the next ten years in IEA countries." (Ref: **CO_0272**)*
- *"In order to enable better future mobility services, researchers and start-ups are intensively exploring new vehicle designs." (Ref: **CO_0005**)*
- *"Innovative trends in road transport can be divided into inventions in the field of new generation vehicles and innovations in new generation road infrastructure. The underlying motive of innovation is to replace the stock of currently operated vehicles with ones that will be environmentally clean, more functional, safer and requiring less space." (Ref: **CO_5065**)*
- *"In order to guarantee sustainable transport in the future, taking into account the urban space occupation, energy consumption and emissions, it is necessary to develop new concepts for individual transport." (Ref: **CO_0260**)*
- *"(...) leading companies are incorporating ICT into vehicles, and over the next thirty years this trend is likely to become much more mainstream." (Ref: **CO_5018**)*
- *"Nissan has designed a collision-free, zero carbon robot concept car. The design is biomimetic – the Eporo travels in a group of like-vehicles, mimicking the behavioural patterns of a school of fish in avoiding obstacles without colliding with each other. The technologies developed for Eporo are not just useful for collision avoidance but also aim to improve the migration efficiency of a group of vehicles and contribute to an environmentally friendly and traffic jam-free driving environment." (Ref: **CO_5018**)*


Source: Megacities on the Move (Ref: **CO_5018**)

**Figure 1-79 Nissan Eporo Robot Car**

- *"A stackable, electric two-seater car designed to be used as part of a mobility on-demand system – similar to a bike-hire scheme such as Vélib, where stacks of vehicles are available for instant short-term hire at key transport hubs such as train stations and multiple other points around the city. Three or four CityCars can fit in a standard parking space. Future iterations could be integrated with the urban energy supply system – stacks of parked cars act as batteries that could 'smooth' electricity demand in a city with lots of microgeneration such as solar roofs or small-scale wind turbines." http://cities.media.mit.edu/ (Go to Mobilitysection, then select CityCar) (Ref: **CO_5018**)*

Source: Megacities on the Move (Ref: **CO_5018**)

**Figure 1-80 MIT City Car System**

- *"This is a folding electric scooter designed for cities where scooters are a popular form of transport (such as many developing world cities). "RoboScooters serve as approximate functional equivalents of 50cc gasoline powered $ scooters. They are, however, clean, silent, and occupy less parking space. They are also much simpler – consisting of $about 150 parts, compared to the 1,000 to 1,500 of an equivalent gasoline-powered scooter – which simplifies supply chains and assembly processes, reduces vehicle costs,and simplifies maintenance." http://cities.media.mit.edu/ (Go to Mobilitysection, then select Roboscooter). (Ref: **CO_5018**)*

Source: Megacities on the Move (Ref: **CO_5018**)

**Figure 1-81 MIT Roboscooter Concept**

- *"But there is also a future for small cars. We designed the first prototype of a new electric car we called the Dock-Dock. We want to introduce around 1000 Dock- Docks in Curitiba, operating in dedicated lanes they will share with cyclists and connect to the public transport system. You cannot have a big car in the city, that is not smart. In the city you do not need a car that drives 100 km/h. The Dock-Dock travels at 25 km/h. There is no risk; it can share space with bikes and with the pedestrians. With the Dock-Dock you do not need to use a car that was made for the road in the city." (Ref: **CO_5019**)*


Source: Transport for Society, Highlights 2011 Annual Summit (Ref: **CO_5019**)

**Figure 1-82 J. Lerner with a prototype of his Dock-Dock city car and a standard sedan**

- *"Electric vehicles are no longer a technology of the future: they are a technology for today and the long anticipated Renault Z.E. range of electric vehicles has arrived!" (Ref: **http://www.ze-tour.co.uk/**)*

Source: http://www.renault.fr/gamme-renault/vehicules-electriques/twizy/twizy/ze-car/a-chacun-son-twizy/

**Figure 1-83 Renault Twizy**

- *"A barrier to innovation in transport, however, is the conservative attitudes of the users of traditional means of transport, the fear of automatically controlled vehicles and distrust of vehicles propelled by hydrogen or electricity." (Ref:* ***CO_5065****)*

## Interactions within the Technology Domain

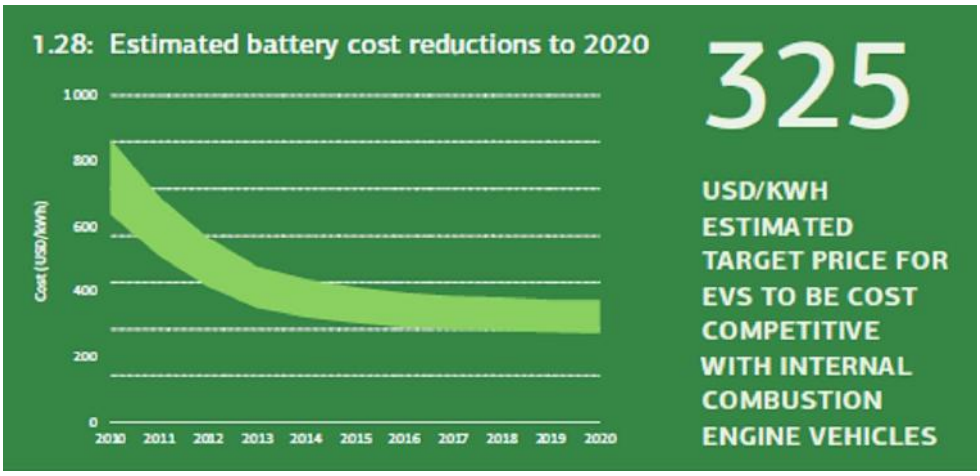
### *Traction technologies*

- *"Research on new technologies and engines is ongoing in almost all sectors. Current research on vehicle technology includes optimal structural solutions, as well as new design concepts for cars, ships, aircraft and locomotives, to increase Energy efficiency and thus reduce CO2 emissions." (Ref:* ***CO_0234****)*
- *"(...) road transport is a primary target for research on alternative fuels. Biofuels are already on the market, either as admix or as self-contained fuel. Pilot projects are being carried out on other alternative fuels and propulsion systems, such as electricity." (Ref:* ***CO_0234****)*
- *"Biofuels are one of the main alternative fuels that can offer very low net-GHG performance. In contrast to BEV[59]s or vehicles running on hydrogen, biofuels have been produced commercially in both the United States and Brazil for several decades. The sector grew the fastest in the past ten years." (Ref:* ***CO_0185****)*
- *"Railways are highly energy efficient compared to other transport modes. This is mainly because of low rolling and air resistance of locomotives, railcars and wagons running on dedicated tracks, and in a controlled, regulated driving pattern. Energy consumption in the railway system is determined by the highly interrelated subsystems of rolling stock, infrastructure, signalling systems and circulation schemes." (Ref:* ***CO_0234****)*
- *"For inland waterways and small boats, hydrogen is a promising alternative, while LPG[60] and LNG[61] show potential for short sea shipping vessels, and LNG and nuclear power for maritime shipping." (Ref:* ***CO_0234****)*
- *"While aviation will continue to rely on liquid kerosene, promising sustainable alternatives to fossil kerosene are synthetic biomass-derived fuels and second generation biofuels. As a result of extensive research, biofuels were approved for use in 2011 and demonstration and commercial flights are now being carried out using add-on biofuels." (Ref:* ***CO_0234****)*

[59] Battery Electric Vehicles.
[60] Liquefied Petroleum Gas.
[61] Liquefied Natural Gas.

*Material technology*

- *"For electricity to play a significant role in transport, [vehicle] purchase prices will have to come down. This can be achieved, through lower battery costs." (Ref: **CO_0284**)*
- *"Battery costs are often cited as the biggest hurdle to EV competitiveness with standard gasoline cars. Estimating battery costs is difficult, and hard to separate from prices, which can reflect marketing strategies as well as actual production cost." (Ref: **CO_0185**)*




Source: Estimated battery cost reductions to 2020 (Ref: **CO_0185**)

**Figure 1-84 Vehicle fuel economy, enacted and proposed standards**

- *"Energy labels will also be introduced for tyres." (Ref: **CO_0269**)*

*Information systems*

- *"All measures which generally enhance the quality of public transport in a city in general support the success of new public transport information systems. For example, the introduction of new vehicles will create a synergy effect between new information systems and a general improvement of the public transport system." (Ref: **CO_0286**)*

*Pollution abatement and monitoring*

- *"The technical $CO_2$ reduction potential of gear shift indicators is estimated at 6% in case of 100% utilization rate. However, it must be recognised that the real reductions will be lower than this, depending on the degree to which drivers respond to the indicator." (Ref: **CO_0250**)*
- *"(...) providing the driver real time information about fuel consumption, energy-use efficiency and appropriate gear selection together with additional upcoming preview information from enhanced map data including road slope, curvature and road attributes such as speed limits and stop signs." (Ref: **CO_0250**)*

*Energy efficiency*

- *"Advanced aerodynamic styling. Enhanced streamlining, using sophisticated body design and reduced frontal areas, aimed at reduce the vehicle's drag coefficient, can offer improvements in energy efficiency of about 2%." (Ref: **CO_0272**)*
- *"The global aircraft fleet has improved its fuel efficiency by 1.5% per year on average between 1960 and 2008 (weighting for aircraft shares in total travel volume) Looking forward, there are opportunities for improvement of the technological efficiency of aircraft currently in use but most of these have already been exploited following recent fuel price spikes.(...) Most of the technical efficiency improvements that are likely in the mid-term will come from new aircraft models incorporating new engine technology, wing configuration and weight-saving from the use of composites. IATA estimates that the optimised deployment of these technologies could reduce fuel burn per passenger kilometre by approximately 25-35% for new aircraft designs around 2020-2025. Beyond that, efficiency improvements are expected to stem from two major changes in technology: open rotor engines for short- to medium-haul aircraft and blended wing bodies. The first application of open rotor engines is not expected before 2025 and blended wing aircraft*

*(where the fuselage and wings merge into each other) are only expected to be a commercial prospect after 2030-2040." (Ref:* ***CO_0160****)*

## Interactions with the Social Domain

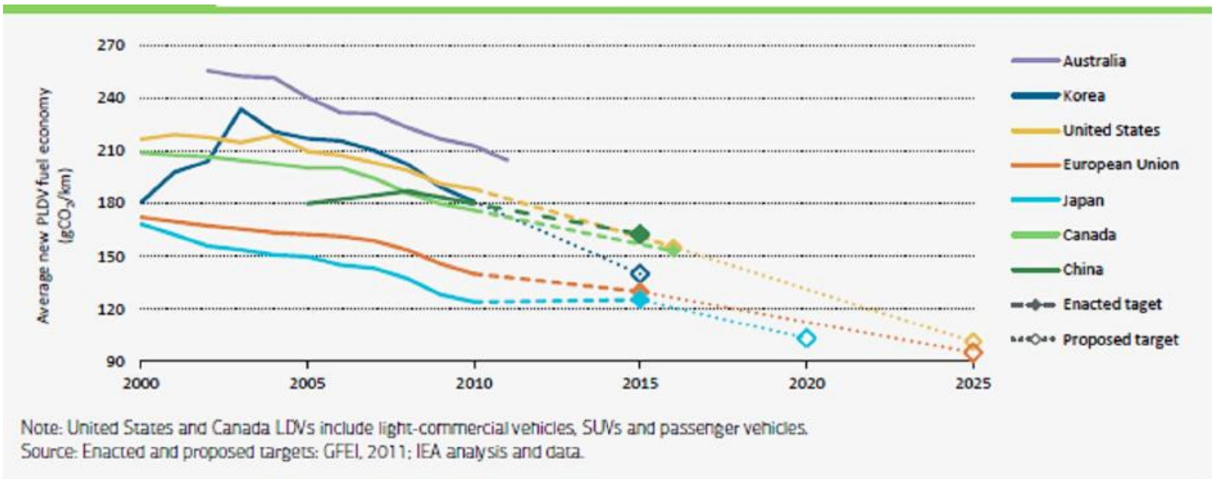
### *Households structure and distribution*

- *"Passenger mobility will thus react to growth of GDP per capita and to transport speed changes. As transport modes have become faster in cities, people have moved farther away from downtown locations (e.g. TGV[62] commuters)." (Ref:* ***CO_5048****)*

## Interactions with the Economy Domain

### *Regional differences in economics*

- *"New, more robust vehicle efficiency standards have indeed improved average fuel economy of fleets in a number of countries (...). In OECD countries, the market share of large sport utility vehicles (SUVs) decreased, while the number of smaller vehicles increased in some countries." (Ref:* ***CO_0185****)*




Source: Tracking clean energy progress (Ref: **CO_0185**)

**Figure 1-85 Vehicle fuel economy, enacted and proposed standards**

### *Availability of public and private resources and investments in the transport sector*

- *"Most studies show that fuel savings from these improvements (more efficient combustion, such as variable valve systems, gasoline direct injection, cylinder deactivation, more efficient transmissions such as 5- and 6-speed automatic, automated manual and continuously variable, and overall vehicle advances, such as aerodynamics and light-weighting) more than outweigh the increased vehicle cost, often by a large amount." (Ref:* ***CO_0148****)*
- *"To alleviate road congestion while maintaining a separation from general traffic, future PRT[63] networks covering whole city areas can be envisaged as running entirely or partly on underground or elevated track ways, which are not massive structures and would require relatively modest infrastructural investment." (Ref:* ***CO_0260****)*

### *Foreign trade, globalisation*

- *"Ultra-compact city cars are by now a familiar sight on the streets of Europe. While most employ conventional ICEs, manufacturers around the world are joining the race to introduce hybrid and electric versions or by using alternative fuels." (Ref:* ***CO_0260****)*

## Interactions with the Environment Domain

### *GHG mitigation*

- *"New cars are becoming more and more efficient, but this trend is counterbalanced with more miles driven and more vehicles on the road." (Ref:* ***CO_0091****)*

[62] Train à Grande Vitesse (High Speed Train)
[63] Personal Rapid Transit

- *"Transport technology innovations might include further changes in vehicle design, propulsion systems and energy sources to address congestion, carbon emissions and safety." (Ref: **CO_5018**)*
- *"Incremental improvements include more efficient combustion, such as variable valve systems, gasoline direct injection, cylinder deactivation, more efficient transmissions such as 5- and 6-speed automatic, automated manual and continuously variable, and overall vehicle advances, such as aerodynamics and light-weighting. Greenhouse gas emissions rates can be reduced by 20-30 per cent with these technologies in new vehicles." (Ref: **CO_0148**)*

*Noise levels and emissions standards*

- *"While type-approval noise limits for road vehicles, including their tyres, have been tightened over the years, the overall exposure to noise generated by road vehicles has not improved due to increasing traffic volumes." (Ref: **CO_0089**)*

*Pollution levels and emissions standards*

- *"A future large scale uptake of electric vehicles could lead to significant benefits arising from the displacement of harmful air pollutants from urban to rural areas (where fossil-fuelled power stations are typically situated) where population exposure is lower." (Ref: **CO_0134**)*

*Energy availability and production*

- *"Electricity sourced from non-combustion renewable sources would lead to further benefits. However the size of any benefits will depend upon the particular grid mix properties and on the type of conventional vehicles that have been substituted by electric vehicles. Assuming more stringent power plant emission regulations in the future, the benefit of electric vehicle operation with regard to air quality improvement could further increase" (Ref: **CO_0134**)*

*Scarce resources of fossil fuels*

- *"Road vehicles, ships and aeroplanes alike have so far been propelled by combustion engines alone; it is only rail transport that has used stationary electric power supply to a greater extent. This could have been tolerated until the threat of global oil depletion emerged. The proven deposits of crude oil (feasible for extraction) globally amount to 160-181 bn tonnes, while average global output stands at 3.5 bn tonnes annually. This means oil will run out in a matter of 46 to 52 years. The economy (transport inclusive) must gradually make a shift to renewable energy sources (RES) like biomass, hydropower, wind, solar, geothermal, tidal power and others." (Ref: **CO_5065**)*

### Impacts on Mobility and Transport

*New vehicles and their impact on future land use and travel habits*

- *"Some new modes could develop during the next century, such as Personal Rapid Transit (PRT), Magnetic Levitation (Maglev) trains, flying cars, Segways, and their variants. There may also be new transport services, such as commercial space travel and more underwater tunnels replacing ferry travel. Their overall impacts are likely to be modest since they only serve a small portion of trips. For example, even if Maglev technology is perfected, it is only suitable for medium-distance (30-300 mile) trips on heavy traffic corridors. It may increase long-distance commuting in a few areas but have little effect on other travel. Only if Maglev systems stimulate transit oriented development (compact communities designed around transit stations) is overall travel likely to change, and this will result from land use changes, not the technology itself. Similarly, Segways are unlikely to affect overall travel unless implemented with urban design and traffic management changes to favor local, slower-speed modes over automobile traffic." (Ref: **CO_5047**)*

*Mileage per capita*

- *"Travel speed affects per capita mileage. People tend to devote an average of about 1.2 hours per day to travel. Higher speeds allow more mileage within this time budget." (Ref: **CO_5047**)*

### 1.5.3.2 Advanced Driving Devices

**Driver description**

- *"Advanced Driver Assistance Systems represent a wide range of systems designed to help the driver, making the driving process safer and more efficient. When designed with a safe Human-Machine Interface (HMI) they should improve car safety and road safety in general. Examples of such systems include: adaptive cruise control; adaptive light control; automatic parking; blind spot detection; collision avoidance system (pre-crash system); driver drowsiness detection; intelligent speed adaptation or intelligent speed advice; in-vehicle navigation systems (typically GPS and TMC for providing upto- date traffic information); lane change assistance; lane departure warning systems; night vision; pedestrian protection systems; traffic sign recognition, etc." (Ref: **CO_0281**)*
- *"Other examples of driving support functions available on the market or at an advanced stage of development are: Night vision: infra-red cameras enable the driver to have better perception in conditions of low visibility, such as at night and in fog; Blind spot detection: rear-view mirrors are affected by the blind angle a side area the driver cannot see unless they turn their head. A camera and an electronic image processing unit could serve as a vital warning system to alert rivers to a vehicle overtaking them; parking manoeuvre support: parking sensors are already widespread on many vehicles. Furthermore, some vehicles have recently been equipped with a function that detects the space between two vehicles and - if sufficient – aids manoeuvring by guiding the steering wheel." (Ref: **CO_0281**)*
- *"A more advanced method of delivering feedback and support is the head-up display (HUD). This is a transparent display that presents critical and relevant information to the driver without requiring him/her to look away from the road. A HUD can be used on forward displays, such as a car windshield, or in rear view/wing mirrors." (Ref: **CO_0081**)*

Source: The application of in-vehicle systems for elderly drivers. European Transport Research (Ref: **CO_0081**)

**Figure 1-86 Head-up displays**

- *"E-Call is an automated emergency call system. An e-Call can either be generated manually by vehicle occupants or automatically through activation via in-vehicle sensors in the event of a crash. E-Call directly establishes a voice connection with the relevant emergency Public Service Answering Point (PSAP), and sends crucial information such as time and location of the accident as well as a description of the vehicle involved." (Ref: **CO_5019**)*
- *"Emergency Braking Systems detect the danger of an imminent rear-collision, warn the driver of a potential crash and assist in the braking process – automatically activating the brakes if there is no reaction from the driver." (Ref: **CO_5019**)*
- *"A final stage of ADAS[64] development could result in for example fully automated driving. Although such a concept is not plausible to become reality on a large scale in the near future, its potentials are sufficient great to conduct much research on automated driving." (Ref: **CO_5012**)*
- *"In the search for innovative forms of transportation, an EU-funded project (SARTRE[65]) has found a way for people to drive their cars without actually having to drive them. Known as "road*

[64] Advanced Driver Assistance Systems

*trains," a truck driven by a specially trained driver leads a procession of cars or other trucks that automatically follow steering and braking instructions being transmitted wirelessly from the escort vehicle. With their hands and feet completely free, drivers can read, eat, talk on the phone, catch up on work, write letters or watch television, if they so wish. If the lead vehicle has to turn, speed up, slow down or even brake suddenly, the action is sent instantaneously to the following vehicles, which copy the actions automatically and safely – without the need for the driver to do anything. The following cars constantly measure the lead vehicle's location, speed and direction, and immediately adjust to any changes – no matter how slight. (...).With such complicated technology, a number of challenges – technical and otherwise – have to be worked out. Still unresolved are questions about how the vehicles would respond if the lead truck had an accident, the ideal distance between vehicles, and whether dedicated routes would be established, like traditional public transportation. An EU-wide legal framework will have to be developed to allow road trains to operate throughout Europe." (Ref: **CO_0258**)*

- *"Intelligent driver aids for speed control, collision avoidance and parking assistance will also progressively filter down to even the lower priced models, contributing to a safer, more relaxed driving experience." (Ref: **CO_0260**)*

## Interactions within the Technology Domain

### *Traffic management systems*

- *"SARTRE has brought together leading-edge researchers from four countries, creating meaningful synergies that have already led to spin-off technologies in the rapidly growing field of intelligent transport." (Ref: **CO_0258**)*

### *Information systems*

- *"Encouraging greater harmonisation regarding in-vehicle devices and applications will promote ITS uptake and can enhance road safety." (Ref: **CO_0280**)*
- *"Intellidrive[66] is a US initiative to develop transport connectivity. It aims to enable networked wireless real-time communications between vehicles, infrastructure, and drivers' and passengers' personal devices. At the individual level this improves safety via crash prevention and provides rich real-time information about routes, traffic and optimum drive speeds. At the system level, real-time information from thousands of vehicles will enable transportation managers to optimise the system for efficiency by adjusting signalling, lane availability, etc." (Ref: **CO_5018**)*

### *Energy efficiency*

- *"Fitting real-time information systems such as fuel economy computers in cars is also highly cost-effective, and provides an important reminder to drivers of the value of eco-driving on a daily basis." (Ref: **CO_0154**)*

## Interactions with the Social Domain

### *Population aging*

- *"Driver support systems have the potential to address either directly or indirectly the specific declines in perceptual, cognitive and physical performance by enabling a reduction in driver workload. Nevertheless, it is important to allow elderly drivers to select when and how much support they wish to receive, thereby increasing user acceptance and subsequent willingness—and capability—to improve their driving performance and road safety. A summary of these driver support systems with the potential assistance to elderly drivers is shown below." (Ref: **CO_0081**)*

**Table 1-2 Driver support systems for elderly drivers**

[65] Safe Road Trains for the Environment
[66] http://www.intellidriveusa.org/

| Driver support systems | Assistance to elderly drivers |
|---|---|
| ***Adaptive Light Control (ALC)/Adaptive Front Lighting System (AFS)*** *Using lighting technology, sensor networks (and satellite navigation systems in the future), ALC/AFS can adjust the direction, width and depth of the headlamps' light automatically in reaction to the surroundings, type of road, steering wheel angle, speed and movement of the vehicle.* | *Increase visibility at night time and bad weather; offer a better view of the road ahead, including other vehicles and obstacles in the distance.* |
| ***Lane Departure Warning (LDW)*** *LDW is a forward-looking and vision-based system using algorithms to interpret video images to estimate the direction and lateral position and velocity of the vehicle and lane width and road curvature.* | *Alert the driver to drive within the lane when deviation occurs.* |
| ***Intersection Assistant*** *Intersection assistant monitors the traffic from the right, road signs and the traffic signals at the intersections. Via a wireless communication link, it provides the driver with the status of the traffic lights and a suggested speed to allow him/her to pass the intersections safely.* | *Alert the driver to stop for the traffic from the right or offer speed suggestions according to the road signs/traffic signals, and then warn the driver if he/she performs inappropriately.* |
| ***Lane Change Assistance (LCA) or Blind Spot Detection (BSD)*** *LCA or BSD continuously monitors the rear blind spots on both sides of the vehicle.* | *Warn the driver visually/audibly to avoid overtaking in critical situations.* |
| ***Obstacle and Collision Warning (OCW)*** *Using radar sensors or video image processing or a combination of them, OCW monitors the area in front of the vehicle. OCW is proactive in terms of providing full braking force, arming airbags or tightening the seatbelt when needed.* | *Warn the driver when vehicles, cyclists, pedestrians or other obstacles on the road ahead are detected; prepare the vehicle for an imminent collision proactively to avoid the collision and/or mitigate the severity.* |
| ***Intelligent Speed Adaptation (ISA)*** *Using satellite navigation technology, sensor technology, a road side beacon system and a central control system, ISA constantly monitors vehicles and the local speed limit on a road. ISA can be configured in two ways: advisory ISA and voluntary ISA.* | *Help the driver maintain a safe speed by alerting the driver (advisory ISA) or decelerating automatically in cooperation with traffic management systems (voluntary ISA) when the speed limit for a given road is exceeded.* |
| ***Electronic Brake Assist System (EBS)*** *EBS can activate the maximum braking power immediately and is triggered when the driver performs fast and hard braking.* | *Take over the activity from the driver to avoid an accident or decrease vehicle speed at the moment of collision in order to reduce its seriousness.* |
| ***Adaptive Cruise Control System(ACC)*** *Using a long range radar sensor, a signal processor and longitudinal control of the vehicle, ACC constantly monitors the speed of the vehicle and the distance to the vehicle ahead. It will slow down the vehicle when needed and accelerate automatically to the pre-selected speed whilst maintaining the correct distance to the vehicle ahead without requiring any action from the driver.* | *Take over the activity from the driver to keep a safe distance from the vehicle ahead and avoid collision. The driver can override the system at any time.* |

Source: The application of in-vehicle systems for elderly drivers. European Transport Research (Ref: **CO_0081**)

***Planning***

- *"Fully Automated Driving is only applied successfully in small public transport concepts. Expected is that within 5 to 10 years, Fully Automated Driving will be possible for freight transport and larger public transport systems." (Ref: **CO_5012**)*

### Interactions with the Economy Domain

*Availability of public and private resources and investments in the transport sector*

- *“< SARTRE’s underlying technology can be integrated into vehicles within a few years in a cost-effective manner >, said Eric Chan, chief engineer of Ricardo, a UK-based transportation technology company that is leading the project. < And there is no need to change the road infrastructure, which would allow SARTRE vehicles to use existing highways >.” (Ref: **CO_0258**)*

### Interactions with the Environment Domain

*GHG mitigation*

- *“With the vehicles drafting a few metres behind each other, SARTRE – short for “Safe Road Trains for the Environment” – can cut fuel consumption by up to 20%.” (Ref: **CO_0258**)*

### Impacts on Mobility and Transport

*Increasing transport safety*

- *“Increasingly, however, further advances in road safety are made possible by purely electronic devices that are integrated into vehicles. Many of these are not intended to reduce the consequences of an impact in case of a crash, but to help to prevent an accident in the first place by aiding drivers, and even taking over for them, in potentially dangerous situations – hence not only protecting the lives and health of passengers and other persons in a highly efficient way, but also preventing damage.” (Ref: **CO_5019**)*
- *“Because the sensor-based system reacts faster than people – who are the cause of 87% of traffic accidents – SARTRE[67] provides safety benefits.” (Ref: **CO_0258**)*
- *“Driver assistance systems are approaching market entry in a number of applications. However it is not clear how they will impact on road transport, in particular on safety.” (Ref: **CO_0289**)*

*but...*

- *“Implementing Automated Fully Driving in road traffic requires much more technological development regarding safety and new legislation by governments.” (Ref: **CO_5012**)*

*New vehicles mixing up with old ones*

- *“Advances in control and guidance systems, sensor technology and interactive vehicle-to-vehicle and vehicle-to-infrastructure communications, many of which are at or near market readiness, will make the concept of driverless automated vehicles sharing public highways with conventional forms of transport a realistic possibility.” (Ref: **CO_0260**)*

*Decreasing congestion*

- *“And SARTRE can improve how roads are utilised, since vehicles can travel very close together or drive long distances at night when roads are used less.” (Ref: **CO_0258**)*

*Raising in mileage per capita*

- *“Fully Automated Driving has the highest potential to increase what we called attractiveness of a transportation system.” (Ref: **CO_5012**)*

[67] www.sartre-project.eu

#### 1.5.3.3 Traction Technologies

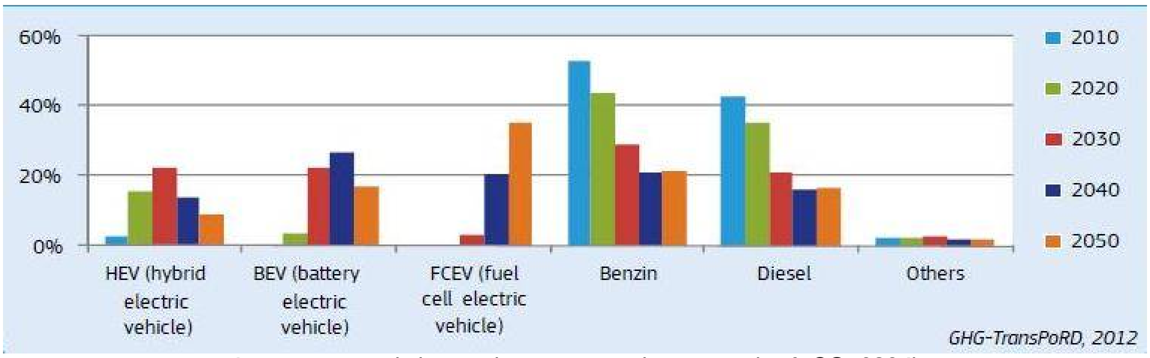
**Driver description**

- *"There is not much interest today in conceptual work aimed at replacing vehicles rolling on wheels with ones using a different motion technology (sliding, hovering). The technological breakthrough that will occur in this transport sector within the next twenty years will mean the replacement (nearly completely) of motor vehicles powered by combustion engines with electric ones." (Ref: **CO_5065**)*
- *"A wide range of innovations in motor vehicles and their equipment deal mainly with new types of propulsion and alternative fuels." (Ref: **CO_5065**)*
- *"The Green Cars Initiative[68] supports development of technologies, systems and services to reduce environmental pollution and the use of fossil fuels in road transport. This public private partnership with public financial support for R&D is developing leading edge technologies mainly in electrification of road transport. The research also covers alternative fuels, internal combustion engines, co-modality logistics and long distance freight." (Ref: **CO_0237**)*
- *"Projections for the penetration of alternative powertrain technologies over the next decades suggest that a large proportion of new light-duty vehicles will continue to use an internal combustion engine equipped with advanced concepts and technologies. ERTRAC's Strategic Research Agenda 2010 (ERTRAC (2010a)) indicated that more than half of new light-duty vehicles in 2050 will still be powered by an advanced ICE[69]. A substantial fraction of these can be expected to be vehicles with an ICE as the sole source of propulsion while, in others, ICEs will increasingly be integrated with electric motors and batteries in a range of hybrid powertrains as described above." (Ref: **CO_0294**)*
- *"Today's ICEs have reached a very high level of maturity but they still offer significant potential for further improvement and these refinements should be exploited in future research activities." (Ref: **CO_0294**)*
- *"While the energy and fuel supply is expected to diversify in the future, advanced ICEs and powertrains will continue to play a major role for both light- and heavy-duty applications. The improvement potential for fuel consumption of advanced ICEs is still significant and continued improvements in regulated emissions performance and low overall cost are still feasible. For these reasons, advanced ICEs and powertrains will be important for meeting future consumer and regulatory demands over the near- and medium-term and they will be the pace setter technology for alternatives like hybrid and battery electric vehicles." (Ref: **CO_0294**)*
- *"New drive technologies are a key strategic challenge for the automotive industry. The race for alternatives to the traditional combustion engine is under way, but it remains unclear which alternative technology promises to become the eventual winner, or even whether a specific technology will manage to make a real breakthrough in the market." (Ref: **CO_0005**)*
- *"The most likely to make a technological breakthrough in road transport is the concept of electric car (...)."(Ref: **CO_5065**)*
- *"The electrification of road transport is of specific importance in the context of growing urbanization in Europe, and considering the high potential of electrified mobility for climate protection, resources management, and air quality. The electrification includes the development of full electric vehicles (FEVs) specifically designed for use in the urban environment (typical daily range of 50km), as well as plug-in hybrids (PHEVs) and vehicles equipped with a range extender, capable of longer trips within and between cities." (Ref: **CO_5033**)*
- *"The most widespread type of electrified vehicle at present is the hybrid, employing one or more battery-powered electric motors, supplemented by a small conventional ICE to deliver higher total power and torque, and to extend the drivable range beyond that of the batteries alone. An extension of this concept, the 'plug-in hybrid', adds the ability to recharge the batteries by connection to any convenient mains supply." (Ref: **CO_0260**)*
- *"In EVs and hybrids (...) energy is stored in the batteries or a bank of capacitors for later use. Another energy storage method is by a rotating flywheel, as used in the mechanical KERS*

[68] The Green Cars Initiative is one of three public private partnerships launched in November 2008 under the European Recovery Plan to alleviate the consequences of the economic crises.
[69] Internal Combustion Engines

*(kinetic energy recovery systems), which briefly made its appearance in some Formula 1 racing cars during the 2009 season. Some EV and hybrid prototypes are equipped with electric double-layer capacitors ('supercapacitors') – which are devices able to store and release large amounts of energy extremely rapidly. They are thus very effective for capturing the energy released during events such as braking, and using it during the next acceleration. If batteries were subjected to such rapid charge/discharge cycles, they would suffer damage and a reduction in lifetime. Supercapacitors, by contrast, can withstand hundreds of thousands of discharges as should easily be capable of surviving the full working life of a vehicle." (Ref: **CO_0260**)*

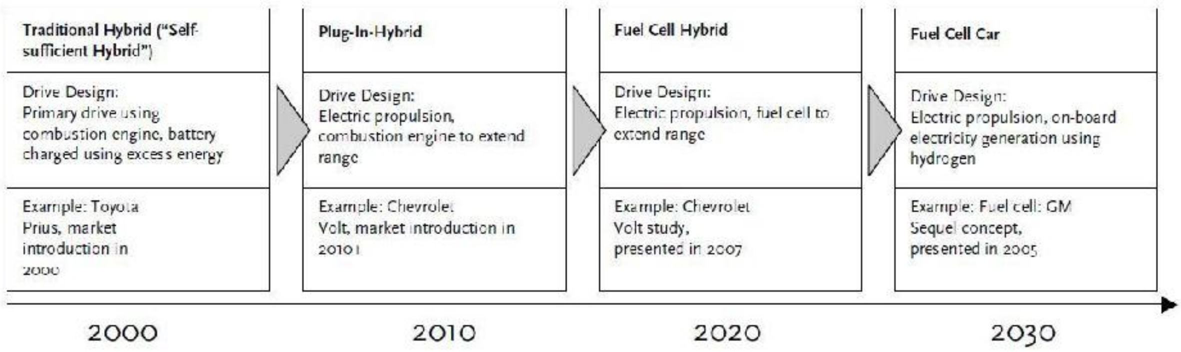
- *"Hybrid electric vehicles combine two power sources with at least one powering an electric motor. The range of alternative power sources includes batteries, flywheels, ultracapacitors, and heat engines. Hybrid systems come in a variety of configurations." (Ref: **CO_0272**)*
- *"Hybrid electric vehicles have three significant advantages over conventional vehicles: regeneration of energy during deceleration, automatic engine shutdown when the vehicle stops, and optimisation of engine drive to allow the electric motor to be used wherever possible. Their disadvantage is that they are heavier than conventionalmodels because of the need to accommodate a relatively large battery pack, an electric motor and an inverter in addition to a conventional engine. This increases their manufacturing costs and reduces their potential efficiency in terms of emissions reduction (IEA 2004). Nevertheless, fuel-economy ratings suggest fuel economy for hybrids as being 25% or better than for conventional vehicles, although recent research conducted in the United States suggests smaller gains in fuel economy." (Ref: **CO_0272**)*
- *"Policies and strategies for CO2 emission reduction have set targets for 2020 to increase the share of bio-fuels and of alternative hydrocarbon fuels. Targets have also been set for the development of hydrogen and fuel cell technology as economic, safe and reliable alternatives to fossil fuel. Research indicates promising applications for electric vehicles for short distances, hydrogen and methane for medium distances, and bio-fuels/synthetic fuels, LNG (Liquefied Natural Gas) and LPG for long distances to reduce CO2 emissions from road transport. New concepts for freight transport based on electricity may change the logistics chain. The expected market penetration of alternative fuels and propulsion systems in road transport is presented in Figure below." (Ref: **CO_0234**)*




Source: Towards low carbon transport in Europe (Ref: **CO_0234**)

**Figure 1-87 Market penetration of fuel and propulsion systems**

- *"During the coming decades, widely varying technologies will likely coexist, including alternative fuels such as second-generation biofuels or gas-to-liquid diesel, but also other innovations such as homogenous compression ignition." (Ref: **CO_0005**)*




Source: The Future of Mobility (Ref: **CO_0005**)

**Figure 1-88 Roadmap from combustion to fuel cell**

- *"Currently, there is mainly one long-term alternative propulsion system under development: electrification of the power train in different stages by using fuel cells or batteries." (Ref: **CO_0017**)*
- *"In case electrification would not be deployed on a large-scale, biofuels and other alternative fuels would need to play a greater role to achieve the same level of emissions reduction in the transport sector. For bio-fuels this could lead, directly or indirectly, to a decrease of the net greenhouse gas benefits and increased pressure on bio-diversity, water management and the environment in general." (Ref: **CO_0194**)*
- *"First-generation bio-fuels from food crops are unsustainable and are unlikely to have a significant long-term future. However, second-generation biofuels from waste are in development, such as cellulosic ethanol. This can be distilled from plant waste headed for landfill such as corn stalks, timber chippings, even low-grade paper. It is estimated that cellulosic ethanol from these sources could provide a third of the USA's transport fuel requirements; there is also potential for effective deployment in the developing world, where most plant waste is currently burned." (Ref: **CO_5018**)*
- *"This reinforces the need to advance in 2nd and 3rd generation biofuels and to proceed with the ongoing work on indirect land use change and sustainability." (Ref: **CO_0194**)*
- *"Some emerging and novel technologies for producing ethanol or diesel from ligno-cellulosic feed-stocks look more promising. In some cases they can reduce emissions by more than 100% when co-products are used to produce heat and power, replacing fossil fuels for example. However, estimates for these processes are theoretical or based on pilot plants and the uncertainties are higher, since such plants are not yet operating at a commercial scale." (Ref: **CO_5032**)*
- *"Sustainable biofuels could be used as an alternative fuel especially in aviation and heavy duty trucks, with strong growth in these sectors after 2030." (Ref: **CO_0194**)*
- *"Several processes are under development that aim to produce fuels with properties very similar to diesel and kerosene. These fuels will be blendable with fossil fuels in any proportion, can use the same infrastructure and should be fully compatible with engines in heavy duty vehicles. Advanced biodiesel and bio-kerosene will become increasingly important (...) since demand for low-carbon fuels with high energy density is expected to increase significantly in the long term. Advanced biodiesel includes: hydrotreated vegetable oil (HVO) is produced by hydrogenating vegetable oils or animal fats (...); biomass-to-liquids (BtL) diesel, also referred to as Fischer-Tropsch diesel, is produced by a two-step process in which biomass is converted to a syngas rich in hydrogen and carbon monoxide. After cleaning, the syngas is catalytically converted through Fischer-Tropsch (FT) synthesis into a broad range hydrocarbon liquids, including synthetic diesel and bio-kerosene." (Ref: **CO_5032**)*
- *"Various alternatives may replace petroleum as the primary vehicle fuel, but virtually all currently being developed will be more expensive than what petroleum cost in the past, and most impose their own problems. From a motorists' perspective the primary change will be a gradual increase in costs over the century, regardless of which fuel is used." (Ref: **CO_5047**)*

- *"EIA projections show advanced technology vehicles accounting for 19 percent of light-duty sales in 2025. Alcohol flexible-fuel vehicles are expected to comprise about 8 percent of new sales, hybrids about 6 percent and turbo direct diesel vehicles about 4 percent. Travel in hybrids also is expected to grow significantly from 2003 to 2025, but would still represent less than 5 percent of total light-duty miles in 2025. Hydrogen is a potentially viable alternative to petroleum fuels in the long term." (Ref: **CO_4012**)*

## Interactions within the Technology Domain

### *Material technology*

- *"Powering a car with batteries is basically a question of numbers. The more you have, the further you can expect it to go. However, larger batteries do not necessarily bring more mileage. Their sheer weight and size can cancel out power gains and limit performance; a battery in a 1200 kg Tesla Roadster weighs in at a hefty 450 kg. This is encouraging the automotive industry to look for other ways to reduce weight and improve performance." (Ref: **CO_0258**)*
- *"To make purely electric vehicles (EV) more widely usable, research is urgently searching for ways to increase battery capacity, while also reducing their considerable weight and bulk." (Ref: **CO_0260**)*
- *"Reducing weight is a key factor in determining the final performance of any electric vehicle," (Ref: **CO_0258**)*

### *Pollution abatement and monitoring*

- *"Measures that address air pollution abatement on vehicles also have the potential to lead to slightly higher $CO_2$ emissions in some forms of engine technology and exhaust treatment systems." (Ref: **CO_0134**)*
- *"Emissions of both primary PM2.5 and PM10, and precursors of secondary PM, are expected to decrease as vehicle technologies are further improved and stationary fuel combustion emissions are controlled through abatement measures or the use of low-S fuels such as natural gas." (Ref: **CO_0134**)*

### *Energy Efficiency*

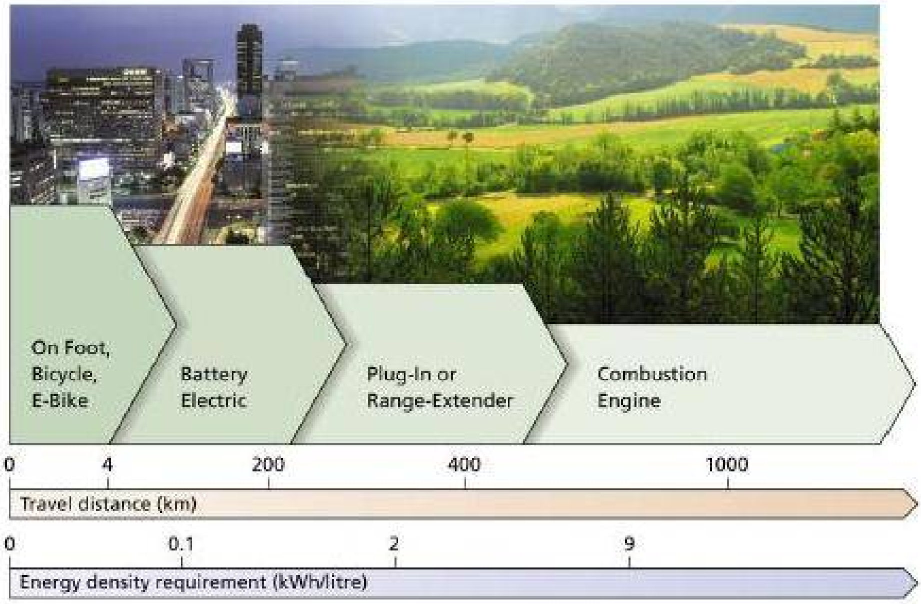
- *"The most exciting area so far as potential for the increased energy efficiency of vehicles is concerned is engine technology." (Ref: **CO_0272**)*
- *"Substantial improvements in fuel economy and GHG emission performance are achievable today just through greater utilization of existing technology. Using a fuel mix of electricity, biofuels, and hydrogen could significantly reduce the number of gasoline-powered passenger vehicles on the road by 2050. Technological advances in other vehicles including trucks, buses, and airplanes could improve the efficiency of those modes substantially." (Ref: **CO_4013**)*
- *"Furthermore, the efficiency of engines, both electric and diesel, is expected to be improved, resulting in an overall decrease in energy consumption in the rail sector (even though the sector is expected to increase its production up to 2030 and most likely beyond)." (Ref: **CO_5048**)*
- *"Substantial near-term improvements in the fuel economy of new light-duty vehicles can be achieved using available, cost-effective technologies. By 2015, new car fuel consumption can be reduced by up to 25% at low cost by fully exploiting available technologies. In some cases these have negative costs to consumers because the time–discounted vale of fuel savings is greater than the cost of the technologies." (Ref: **CO_0272**)*
- *"Buses, with their frequent stops and starts, are particularly suited to energy recovery. Flywheel KERS that can be installed in standard buses have been shown to offer more than 30 % percent fuel saving over a London test cycle." (Ref: **CO_0260**)*

## Interactions with the Social Domain

### *Urbanisation*

- *"Although advanced ICEs are expected to dominate road transport for several decades, especially in long-distance transport modes, the global competition for affordable energy and resources will lead to increasing diversification of energy sources, fuel types, and vehicles. This diversification will be greatest in urban environments where the transport and distance* *requirements are more compatible with diversified energy types and new energy distribution infrastructures." (Ref:* ***CO_0294****)*

- *"Each new technology has advantages and disadvantages. Some are better for urban driving and others for long-distance driving. For example, a hybrid petrol vehicle is a very good performer (low CO2 emissions) in urban driving through the frequent involvement of the electric motor and the regeneration of braking energy back to the batteries. However, in highway driving where the electric motor has only a secondary role to play and braking is infrequent, a small diesel vehicle may actually be a better performer due to the higher efficiency of the diesel engine over the petrol engine in the hybrid vehicle." (Ref:* ***CO_5030****)*
- *"Trials with various forms of supercapacitor-assisted buses have also been underway for several years. The short distances between stops on urban routes even makes it feasible to operate without need for a battery. The supercapacitor can be recharged at regular intervals, collecting sufficient energy when the bus is stationary for 20-30 seconds – i.e. the normal passenger unloading/loading times – to proceed for a further one or two stops. This has been done using so-called 'electric umbrellas' that rise from the vehicle roof to contact charging points similar to the overhead systems of tramways and light railways. A full recharge, taking perhaps 10 minutes, can be carried out when the vehicle reaches its terminal destination." (Ref:* ***CO_0260****)*
- *"Taking a system approach to the Road Transport System, the development of a diversity of powertrains is needed to meet the mobility demands of passengers and freight for both urban and long distance transport." (Ref:* ***CO_5033****)*




Source: European Green Cars Initiative PPP. Multi-annual roadmap and long-term strategy (Ref: **CO_5033**)

**Figure 1 78 Mobility solutions for both urban and long-distance travel**

*Planning*

- *"It was concluded that 40 miles of charge depleting range is necessary for an average PHEV if no infrastructure is available outside of the owner's primary residence. If public charging infrastructure is available, allowing PHEV (Plug-in Hybrid Electric Vehicle) charging outside of the owner's primary residence, the charge depleting range can be lowered to 13 miles. It is, therefore, considered important to evaluate charging infrastructure in both residential and commercial settings because the availability of a rich charging infrastructure can reduce the onboard energy storage requirement (i.e., battery size) for PHEVs." (Ref:* ***CO_5059****)*
- *"Better Place[70] – battery subscription has been set up to counter the two main obstacles to mass adoption of electric vehicles (i.e. cars that solely use batteries, as opposed to hybrids). Better Place stations allow you to switch a used battery in your car for a fully charged one in a few minutes, avoiding the need for hours of recharging during a long journey. Better Place also*

[70] http://www.betterplace.com/

*allows you to subscribe to a battery service. This means that drivers don't have to pay to own the battery – which is usually the most expensive component of a fully electric vehicle. Better Place is due to launch commercially in 2011 in Denmark and Israel, in partnership with Renault which has designed a switchable-battery electric." (Ref:* ***CO_5018****)*

*Change of lifestyle and values*

- *"For EVs to be attractive, quick charging mechanisms are needed, such as overnight charging with standard electrical supply." (Ref:* ***CO_0284****)*

*Health*

- *"(...) a future large scale uptake of electric vehicles could lead to significant benefits arising from the displacement of harmful air pollutants from urban to rural areas (where fossil-fuelled power stations are typically situated) where population exposure is lower." (Ref:* ***CO_0134****)*

**Interactions with the Economy Domain**

*GDP trends*

- *"New technologies such as electric cars and e-bikes also give rise to new opportunities for value creation." (Ref:* ***CO_5019****)*

*Regional differences in economics*

- *"The potential for electric vehicles (EVs) differs among countries. New Zealand strives for 90 % EVs in 2025. In India, on the other hand, constraints on electricity production prevent widespread use of EVs. And in China, power production will rely on coal for the next 20 years at least. The potential for electric cars in those large economies thus seems limited, at least in as far as they are seen as means to cutting transport emissions." (Ref:* ***CO_0284****)*
- *"In addition, biofuels can support economic development by creating new sources of income in rural areas." (Ref:* ***CO_5032****)*

*Availability of public and private resources and investments in the transport sector*

- *"Alternative fuels and propulsion systems are based on extensive research to enable a shift from fossil fuel dependence to decarbonised transport. While research has led to a range of promising fuels and technologies to meet emission reduction targets, market uptake will require further R&I[71] investment and other policy interventions to bring emission reduction closer to 2050 targets." (Ref:* ***CO_0234****)*
- *"There are impediments to innovation and to the dissemination of innovation in the transport sector, which reside in factors of funding, governance, acceptability, and regulation. To begin with, R&D costs are great, and are often difficult to justify in transport, given low profit margins and the long life spans of assets, which mean that returns on investment take a long time to manifest themselves." (Ref:* ***CO_0293****)*
- *"Should either electric or fuel-cell driven cars be introduced on a major scale, a radically new infrastructure will be necessary – in the case of the electric car, several hundred million Euros will be needed to prepare a country of the size of Israel. Investment cost for the United States were estimated by the Climate Group to be in the range of 100 billion USD." (Ref:* ***CO_0005****)*
- *"New technologies such as electric cars and e-bikes also give rise to new opportunities for value creation. Facilitating infrastructure such as public recharging stations will be required, and cities will have to engage with the private sector to develop new and innovative solutions. Neil Walker of Bombardier Transportation cited the example of his company's PrimoveCity inductive charging solution as an innovation that liberates electric vehicles from the weight and cost-constraints imposed by high-range batteries. Implementing such a system on a city-scale will require fundamental changes to how urban roads are financed and managed." (Ref:* ***CO_5019****)*

*Foreign trade, globalisation*

- *"(...) global competition for the electric vehicle market will be intense. The speed with which car manufacturers and their suppliers are able to develop these new vehicles and bring them to market is likely to be a decisive factor." (Ref:* ***CO_0258****)*

[71] Research and Innovation

### *Energy availability and prices*

- *"If we calculate 'Tank-to-Wheel', that is to say only on the vehicle, an electric vehicle consumes around three times less final energy (= petrol, diesel or electricity) than a fossil fuel vehicle with the same weight and the same performance (excluding driving range). However, energy is required to produce fossil fuel and electricity, as well as to distribute them. If we include this energy, then fossil fuel vehicles consume 'Well-to-Wheel' 20 to 80% more primary energy than electric vehicles of the same weight and performance, excluding driving range (20% = diesel-lead comparison, 80% = petrol-lithium comparison)." (Ref: **CO_5044**)*
- *"Production and use of biofuels can also provide benefits such as increased energy security, by reducing dependency on oil imports, and reducing oil price volatility." (Ref: **CO_5032**)*
- *"Not least, prices for traditional fuels need to be high – historically, they have not been at a high enough level to induce a shift towards EVs." (Ref: **CO_0284**)*

### *Fiscal policy*

- *"A potential future barrier to alternative fuel consumption in transport (mainly electricity and biofuels) is the revenue which arises from current fuel-related taxes (applied to petrol and diesel). The likely progressive electrification of transport and the increasing use of alternative fuels will call for a reinforcement of fuel taxes towards fair energy-carbon taxes. The subject is being considered in the recent proposal to revise the Energy Taxation Directive (EC, 2011g), that aims to restructure the way energy products are taxed and takes into account both CO2 emissions and energy content. The objective is to remove artificial barriers to energy transition such as fuel subsidies and the substantial revenue from taxation on fossil fuels that some Member States obtain." (Ref: **CO_5030**)*

## Interactions with the Environment Domain

### *GHG mitigation*

- *"The upshot is that reducing CO2-emissions appears to be first and foremost a technological challenge. Prioritising technological change to alter transport's energy base may be the best bet to cutting carbon, in the sense of being most likely to succeed and in doing so at reasonable cost." (Ref: **CO_0160**)*
- *"Whilst some of the life-cycle GHG reductions are expected to be made in upstream emissions from conventional fuels (e.g. reduced flaring and venting at oil production sites), it is currently anticipated that a significant part of the reductions will be achieved through the increased use of biofuels." (Ref: **CO_5030**)*
- *"But even if these technologies (fuel cell or batteries) have a higher efficiencies than internal combustion engines, it has to be kept in mind that their overall efficiency and greenhouse gas balance depend significantly on the source of the energy carrier." (Ref: **CO_0017**)*
- *"When biofuel production involves a change in land use then there may be additional emission impacts – positive or negative – that must be taken into account in calculating the GHG balance. The land-use change can be: direct, as when biofuels feedstocks are grown on land that was previously forest; indirect, when biofuel production displaces the production of other commodities, which are then produced on land converted elsewhere (perhaps in another region or country)." (Ref: **CO_5032**)*
- *"Changes in light-duty vehicle technologies have not significantly impacted CO2 emissions. For the most part, these technologies have been used to improve vehicle power, safety, and driving performance, rather than to increase vehicle fuel economy." (Ref: **CO_4012**)*
- *"Alternative fuels do not necessarily emit less greenhouse gases than gasoline when used to power a vehicle. Most alternative fuels do contain less carbon per unit of energy than gasoline, but do not necessarily emit less total emissions well to wheel – including emissions from the extraction of the alternative fuel or feedstock, energy used in its production, distribution and storage, and its use in vehicles – in a life cycle analysis of fuel." (Ref: **CO_0272**)*
- *"A few alternative fuels promise substantial reductions of greenhouse gases on a full fuel-cycle basis everywhere. These include ethanol and methanol under certain circumstances, namely when these alcohols are derived from cellulosic (woody) feedstock using advanced, low-energy production processes." (Ref: **CO_0272**)*

- *"Short-term savings in well-to-wheel emissions can be gained through: the use of turbo-injection diesel engines running on low sulphur fuel (25%); the use of natural gas (LPG, CNG or LNG) as a fuel (around 20% for CNG); cellulosic alcohols (ethanol and methanol) and biodiesel promise larger reductions (50% or more); and hydrogen, although the net reduction of emissions depends on how the hydrogen is obtained – on current technologies it has substantially higher emissions, but it could be considerably lower with new, advanced technologies." (Ref: **CO_0272**)*
- *"Much greater GHG reductions are possible with electric drive propulsion technologies. These include the increasingly popular hybrid gasoline-electric vehicles, plug-in hybrids which use both electricity and petroleum fuels, battery electric vehicles and hydrogen powered fuel cell vehicles. Such technologies can double vehicle fuel efficiency. The life cycle GHG emissions, considering the potential to use low carbon electricity and hydrogen, can be reduced by at least 80 per cent." (Ref: **CO_0148**)*
- *"Large potential GHG benefits can be achieved by powering vehicles with hydrogen (and fuel cells) and electricity, with plug-in hybrids and battery electrics. Electric drive vehicles, powered by low carbon versions of these fuels made with biomass, wind, nuclear energy, or with fossil energy coupled with carbon capture and storage, could yield much greater GHG reductions than with vehicle efficiency improvements alone." (Ref: **CO_0148**)*
- *"The role of bioenergy systems in reducing GHG emissions needs to be evaluated by comparison with the energy systems they replace using life-cycle assessment (LCA) methodology." (Ref: **CO_5032**)*
- *"Not all vehicle technology and fuel options can be applied to each of the transportation subsectors because of specific requirements for characteristics such as power, weight, or vehicle range. Biofuels appear to be most applicable across all transportation subsectors as a "drop-in" fuel replacement for petroleum-based fuels. However, because they can only be made from biomass, they are likely to be limited by biomass resource availability and may also be limited by land-use change impacts, which may reduce or negate their GHG benefits. Hydrogen and electricity can be made from a wide range of domestic resources, and resource constraints are unlikely to be major impediments to their adoption; however, they may be limited in their applicability to some transportation subsectors (especially aviation, marine, and off-road)." (Ref: **CO_5046**)*
- *"While low- and near-zero-carbon vehicles and fuels can go a long way to achieving GHG/energy reduction goals, other strategies will also be needed, especially in the near to midterm, before major technological improvements can be made." (Ref: **CO_0149**)*

***Noise levels and emissions standards***

- *"The gradual phasing out of 'conventionally-fuelled' vehicles from the urban environment is a major contribution to significant reduction of oil dependence, greenhouse gas emissions and local air and noise pollution." (Ref: **CO_0021**)*
- *"One of the positive consequences of introducing virtually silent electric road vehicles will be to make cities much quieter than they are today." (Ref: **CO_0260**)*

***Energy availability, production and consumption***

- *"It is (...) expected that different types of energy source could coexist in the future, depending on factors such as journey distance and payload – e.g. electricity for short trips and stop/start deliveries, combined electricity/hydrocarbons or hydrogen for medium distances, and hydrocarbons alone or hydrogen for longer runs." (Ref: **CO_0260**)*
- *"The environmental track record for both hybrid cars and pure electric cars strongly depends on the way the electricity used is generated – if gasoline is merely replaced by coal converted into electricity in conventional power plants, it would be unjustifiable to speak of decarbonisation." (Ref: **CO_0005**)*
- *"(...) it is widely recognised that electric cars will only make a significant difference if they are accompanied by a move towards smart grids and cleaner electricity generation (...). "(Ref: **CO_0258**)*

*Scarce resources of fossil fuels*

- *"Electric mobility combines environmental sensitivity with achieving and expanding technological leadership in the automotive sector. And it contributes to reducing our dependence on finite fossil fuels." (Ref: **CO_0284**)*
- *"In sum, there is considerable scope for increasing the use of electricity as an energy source in transport. But whether electricity will replace fossil fuels as the main energy source in road transport is not at all obvious." (Ref: **CO_0284**)*

*Scarce resources of raw materials*

- *"(...) deployment of 'green' vehicles reduces the use of fossil fuels but increases the demand for electricity and certain raw materials, some of which are subject to supply restrictions and concentrated in a few geographical areas (e.g. rare earth elements for electronic components and fuel cells, lithium for batteries)." (Ref: **CO_0195**)*

### Impacts on Mobility and Transport

*Towards a more sustainable mobility*

- *"The use of hydrogen-fuelled transport will depend on the successful development of an affordable and widespread refuelling infrastructure. Currently, only a few expensive hydrogen refuelling stations exist worldwide, and refuelling station costs need to be reduced to make them commercially viable." (Ref: **CO_0018**)*
- *"Much effort is also being put into the development of charging infrastructures, which in the future will comprise interacting power, communications and software layers." (Ref: **CO_0260**)*
- *"Several recharging scenarios can be envisaged: charge at home – resulting in limited range, but little investment; charge when the car is at standstill – needing a great deal of ICT to locate filling sites, identify the supplier and manage payment (with significant data security implications); fast charging – which would have major impact on the grid and demand high infrastructural investment; and exchange of pre-charged batteries – demanding service stations with standardised pre-charged spares." (Ref: **CO_0260**)*
- *"The use of electric, hydrogen and hybrid technologies would not only reduce air emissions, but also noise, allowing a greater portion of freight transport within the urban areas to take place at night time. This would ease the problem of road congestion during morning and afternoon peak hours." (Ref: **CO_0021**)*

*Increasing concerns about road safety*

- *"(...) electric vehicles are likely to become an increasingly common sight on Europe's roads in the not-too-distant future. Yet these novel cars pose novel challenges for road safety. The large battery pack in particular could represent a threat to the safety of both passengers and the emergency services in the aftermath of an accident. There are also questions regarding the crashworthiness of electric cars, which are generally smaller and lighter than conventional cars. The near-silent nature of electric vehicles represents an additional risk for road safety. Inside the vehicle, inexperienced drivers may not realise how fast they are travelling, while outside, cyclists and pedestrians may simply fail to hear them coming." (Ref: **CO_0266**)*

#### 1.5.3.4 Material Technology

**Driver description**

- *"Materials and design are key technologies in the automotive industry." (Ref: **CO_0058**)*
- *"Over the coming decades motor vehicles will embody completely new engine technologies, material technologies, and electrical/ignition systems." (Ref: **CO_0272**)*
- *"Nanotechnologies are especially relevant because with decreasing size the properties of materials change. (...) Examples include nanotechnologies for energy conversion and storage (for example dye-based solar power cells); replacement of toxic materials; new, lighter materials; and environmental remediation technologies (UBA, 2010)." (Ref: **CO_0274**)*
- *"Besides the advancement in steel body design (short and medium-term), construction methods with fibre- reinforced high performance plastics and multi material design will be able to play an important role in a long term." (Ref: **CO_0058**)*
- *"Light composite structures can be even stronger than steel, although the assessment of the robustness of composites to accidental impacts is more difficult than for traditional metals. The manufacturing technology for strong, lightweight composite materials is still accomplished largely by hand and costs are prohibitive." (Ref: **CO_0272**)*
- *"The choice for light weight materials depends besides the mechanical properties on expected production volume, markets (material availability), vehicle use, customers and performance-cost-balance." (Ref: **CO_0058**)*
- *"Much research needs to be done on the feasibility of automated manufacturing processes for new materials. Nevertheless, materials technology and its application to transportation in terms of motor body construction and for components is a key area for research in both the United States and Japan." (Ref: **CO_0272**)*
- *"The main areas of technological innovation in the aerospace sector are aerodynamics, materials, engines, avionics and electronics, design and manufacturing technologies, maintenance and repair, and safety." (Ref: **CO_0272**)*
- *"The use of advanced materials such as carbon fibre composites can dramatically reduce aircraft weight. These composites can be used throughout the aircraft, from the airframe to the brakes and can generate weight savings as high as 20%." (Ref: **CO_0019**)*
- *"Several key technologies are expected to transform shipbuilding in the future – advanced materials, embedded information and communications technologies, advanced hydrodynamic design, engine technologies derived from the experience gained in the aerospace industry, and new technologies that assist maintenance and repair." (Ref: **CO_0272**)*
- *"There is much greater potential for mass reduction in passenger trains than in freight trains since the weight of passengers is very low compared to the weight of the train. New materials and new designs such as wide or double-decker trains have the potential to reduce mass-per-seat by more than 35%." (Ref: **CO_0019**)*
- *"Europe has about 5.5 million km of roads and most (90%) are made of asphalt. We all know a bad road when we drive on one so this is why billions of euros are spent each year digging them up and replacing them. Both industry and governments recognise the potential environmental costs of road building. (...). It is often simply cheaper to extract new aggregate and bituminous binders than recycle it. (...). According to the Re-Road[72] project it should be possible to increase the use of recycled asphalt to as much as 99%. (...) The major concern of the project however, is to look for ways to reduce consumption of natural aggregates and decrease amounts of waste produced when roads are rebuilt." (Ref: **CO_0019**)*

**Interactions within the Technology Domain**

***Traction technologies***

- *"The challenges in lightweight design for innovative vehicle concepts are amplified by the ongoing electrification of the drivetrain. For electric vehicles, due to the weight and volume of the batteries on the one hand, and the substitution of mechanical drive train components through*

[72] www.re-road.fehrl.org

*electric motor specific elements on the other hand, the boundary conditions for lightweight architecture have completely changed and the importance of lightweight materials and design will increase.” (Ref:* ***CO_0058****)*

- *“The IEA is sponsoring research on the development of revolutionary materials (structural ceramics and ceramic matrix composites) for operation at higher temperatures and pressure. Hard, wear-resistant, durable and insulating ceramic coatings are an expanding technology for improving the durability, reliability, and efficiency of diesel and turbine engines for automotive and industrial power.” (Ref:* ***CO_0272****)*
- *“Fuel cell durability is a critical element in the life-cycle cost of fuel cell application. In mobile applications a life of 3000-5000 hours for cars and up to 20,000 hours for buses is required.(...) Fundamental fuel cell design changes, such as different membrane materials and new high-temperature catalyst materials, may increase durability.” (Ref:* ***CO_0272****)*
- *“Carbon composites are already used in products such as sports equipment, aircraft and some high-performance sports cars to provide strength and reduce weight in the products. They tend not to be employed in mass-produced vehicles yet because of current high costs. According to Emile Greenhalgh of Imperial College, London and the project’s coordinator, this could change if the composites can also be used to provide power to the vehicle. < “It could mean that we can get rid of the batteries altogether and power an electric car just from its body work >, he says.” The technology relies on carbon composites acting as super-capacitors to deliver power. The strength of the material and the fact that it can be moulded into any shape could make it ideal for car body parts. Both batteries and super-capacitors store energy. However, that is just about where the similarity ends. Batteries store energy chemically which is then converted to electrical energy. This is a relatively slow process but it means lots of power can be delivered over a sustained period. Super-capacitors meanwhile store electrical charge in a layer of ions absorbed on a carbon sur face. As there is no chemical reaction, charging can be very quick and recent developments mean that charge can be delivered quickly and stored for much longer. (Ref:* ***CO_0258****)*

#### Energy efficiency

- *“By 2015, new car fuel consumption can be reduced by up to 25% at low cost by fully exploiting available technologies.” (Ref:* ***CO_0272****)*
- *“The utilisation of new vehicle body materials, such as carbon-fibre or other composite materials, and also lighter metal alloys should increase energy efficiency by reducing mass, and at the same time have a lower energy-content in their production. The extensive use of aluminium and other light-weight materials in suspension and other components (such as brake fittings, sway bars, and wheels) can also improve energy efficiency.” (Ref:* ***CO_0272****)*
- *“(...) new materials technology offers the scope for increased energy efficiencies in transportation. The use of lightweight metal alloys and composite materials was pioneered by the aerospace industry and is now being taken up by motor vehicles and other transport equipment. Further development is occurring in lightweight metal alloys, while composites are undergoing development both in terms of materials design and in manufacturing technology. Other areas of technological development include structural ceramics, ceramic matrix composites, ceramic coatings, surface engineering to improve resistance to wear and contact damage, and protective coating systems. Synergies in materials technology can be obtained because of its use across such sectors as transport equipment, other manufactured equipment and structural engineering.” (Ref:* ***CO_0272****)*
- *“Expected fuel savings from the increased use of fuel efficient tyres which will be achieved by the combination of tyre rolling resistance limits (Regulation (EC) No 661/2009) and the labelling scheme (Regulation (EC) No 1222/2009) are estimated at between 2.4 and 6.6 Mtoe (million tonnes of oil equivalent) in 2020 depending on the speed of market transformation. The* $CO_2$ *savings from all vehicle types are expected to range from 1.5 to 4 million tonnes per year.” (Ref:* ***CO_0250****)*

### Interactions with the Social Domain

No particularly relevant interrelationships have been found.

## Interactions with the Economy Domain

### *Regional differences in economics*

- *"(...), crucial mineral sources for new technologies tend to be very unevenly distributed over the globe. For example, more than half of the world's stock of lithium, a metal at present essential for hybrid and full‐electrical cars, is believed to be located in Bolivia, with huge economic potential." (Ref: **CO_0274**)*

## Interactions with the Environment Domain

### *GHG mitigation*

- *"In order to reduce carbon emission of the vehicles and therefore to achieve the stringent emission targets (...), car manufacturers are intensifying their efforts to decrease car weight. This trend requires the development of new lightweight material concepts and architectures." (Ref: **CO_0058**)*
- *"A realistic long-term objective would be to cap the level of GHG emissions arising for air transport. The prospects for reduced emissions-intensities in air transport are quite good, building on the experience of recent decades. Innovation rates in aerospace are high, and continuing improvements in aero-engine and lightweight materials technologies should facilitate continuing reductions in emissions intensities." (Ref: **CO_0272**)*

### *Noise level and emissions standards*

- *"The limits in the EU Tyre/road directive need to be tightened if new technology is to be promoted." (Ref: **CO_0151**)*

### *Pollution levels and emissions standards*

- *"Yet scientific committees in Europe and elsewhere, for example the US National Research Council, have expressed major concerns about the environmental and health issues arising from new technologies (SCENIHR, 2009). For instance, the rapid transformation that nanoparticles could undergo when released into the natural environment may render traditional approaches to describing air or water quality inadequate (RCEP, 2008). Currently, there is an increasing gap between the need for and the availability of relevant data and testing methods to understand, for example, the toxicology and exposure paths of novel materials in the environment (McGarvin, 2010)." (Ref: **CO_0274**)*

### *Energy availability, production and consumption*

- *"The materials used in an average vehicle – glass, steel, aluminium and plastics – are highly energy-intensive. Moreover, traditional materials technology in vehicles is well short of optimal for recurrent vehicle energy consumption." (Ref: **CO_0272**)*

## Impacts on Mobility and Transport

New materials will impact transport sector in terms of lighter vehicles that in principle may provide an increase in speed, allowing people to move even faster that today. But they have also importance in terms of the possibility to introduce innovative solutions as far as engine and traction are regarded, reducing noise emissions (vehicles will be quiter) and pollutants as well.

### 1.5.4 The ICT and Telematics Factor

- *"Intelligent Transport Systems and Services (ITS) refers to the integration of information and communication technologies with transport infrastructure to improve economic performance, safety, mobility and environmental sustainability for the benefit of all European citizens." (Ref: **CO_0261**)*
- *"Intelligent Transport Systems (ITS) comprise several combinations of communication, computer and control technology developed and applied in the domain of transport to improve system performance, transport safety, efficiency, productivity, and level of service, environmental impacts, energy consumption, and mobility. ITS, sometimes also known as Transport Telematics Applications, can play particularly vital roles in ensuring mobility for all and meeting demand in increasingly competitive markets. The need for such solutions stems from existing traffic and transport problems including congestion, accidents, lack of user information, lack of communications and decision-support for operators, etc. These Information and Communications Technologies (ICT) provide the means to improve service quality, safety and management of transport systems, allowing existing infrastructure capacity to be used more efficiently and safely." (Ref: **CO_0255**)*
- *"ITS applications in road transport include electronic tolling, dynamic traffic management with variable speed limits, parking guidance and reservation, navigation devices and driver assistance systems like electronic stability control and lane departure warning systems." (Ref: **CO_0280**)*

#### *1.5.4.1 Traffic Management Systems*

**Driver description**

- *"Traffic management is the planning, monitoring and control or influencing of traffic. It aims to: maximise the effectiveness of the use of existing infrastructure; to ensure reliable and safe operation of transport; to address environmental goals; and ensure fair allocation of infrastructure space (road space, rail slots, etc.) among competing users." (Ref: **CO_0288**)*
- *"Traffic management has long existed in one form or another, from the early days of railway signalling or traffic lights on city streets, but the development and implementation of sophisticated integrated applications based on Intelligent Transport Systems (ITS) has grown apace in recent years, as a result of successful research and technological advances. This has been pushed by realisation of the need to manage transport networks more effectively in order to maximise the use of existing infrastructure, provide a reliable service to the end user and increase safety, while reducing negative environmental effects." (Ref: **CO_0288**)*
- *"Addressing traffic congestion was one of the initial motivations to look at intelligent transport systems solutions for a better utilisation of transport capacity through the exchange of realtime information on infrastructure and traffic conditions." (Ref: **CO_0261**)*
- *"A number of major policy challenges underline the need for intelligent infrastructure to improve the transportation system: pollution, congestion, road safety, to name but a few." (Ref: **CO_0284**)*
- *"Management of traffic in the aviation and waterborne sectors follows very different principles and organisational and operational characteristics to land transport. (...). Air Traffic Management, for example, is strongly controlled by both EU and international norms and procedures" (Ref: **CO_0288**)*
- *"EU initiatives and EU-funded projects have developed smart mobility systems, including the air traffic management system of the future (SESAR), the European rail traffic management system (ERTMS) and rail information systems, maritime surveillance systems (SafeSeaNet), and River Information Services (RIS). ITS applications in transport demand management (road charging, access management, eco-driving support and multi-modality) can also substantially reduce CO2 emissions." (Ref: **CO_0234**)*
- *"The main difference is therefore that routing for rail traffic is highly prescriptive whereas for road users it is primarily informative." (Ref: **CO_0288**)*
- *"The SESAR system is the EU's response to the problem of Air Traffic Control in international corridors. The European Council identified the project in 2005 as one of the "projects of common*

*interest" for infrastructure to be implemented. SESAR is the technological element of the Single European Sky, adopted in March 2004, which lays down a clear organisation and establishes cross-border blocks of airspace. With these blocks, routes and airspace structures are no longer defined in accordance with borders but in accordance with the operational reality of traffic." (Ref:* ***CO_0255****)*

- *"(...) the predicted growth in air traffic calls for more efficient use of existing capacity in the air transport system. This is a key goal of the planned European ATM*[73] *system. The development of ATM now requires a robust validation process, and this has been the focus of substantial research." (Ref:* ***CO_0289****)*
- *"Traditional vessel traffic services (VTS) for both maritime and inland navigation have focused on traffic management, with an emphasis on safe navigation. More recently, vessel traffic management and information services (VTMIS) and river information services (RIS) have been developed as the ITS concepts for efficient and safe navigation at a European level." (Ref:* ***CO_0289****)*
- *"Traffic management involves the allocation of infrastructure (road space or train slots on a railway network) according to strategic operational and policy goals. These include efficiency, safety, environmental, economic and equity objectives." (Ref:* ***CO_0288****)*
- *"Progress in information technology has led to systems that can rationalise long-distance passenger journeys within the EU, enabling passengers to plan door-to-door multimodal journeys with the aid of integrated e-timetables and e-tickets." (Ref:* ***CO_0234****)*
- *"The role of technology in mobility has had three well-defined phases: a strategic phase initially (infrastructure provisioning) focused on functional and physical aspects, followed by a tactical phase from the industrial revolution, focusing on mechanisms, engines and energy, and the latest operational phase with ICt and other management tools applied to mobility. The ethics of these phases are also different: public service, productivity and market." (Ref:* ***CO_5005****)*
- *"Intelligent Transportation Systems (ITS) apply computers and electronic communication to improve transport services. So far, ITS successes consist primarily of driver information and navigation services, transit user information, transit priority systems, and better road and parking pricing, which tend to reduce rather than increase motor vehicle travel." (Ref:* ***CO_5047****)*
- *"ITS applications for traffic management and control include rerouting using VMS, Variable Speed Limits (VSL) with automated enforcement, lane control, dynamic use of the hard shoulder on motorways or access control measures such as ramp metering, as well as specific measures for freight such as information on Heavy Goods Vehicle (HGV) parking and "stacking" of lorries in the case of disruption. Cooperative systems, whether vehicle-to-vehicle (V2V) or vehicle-to infrastructure (V2I,) will play an increased role in traffic management and control in the future; coordination across countries and regions, as well as with vehicle and equipment manufacturers, is required in order for systems to succeed in meeting traffic management objectives." (Ref:* ***CO_0288****)*
- *"The rapid fall in the cost of telecommunications and the evolution of IT systems is making congestion charging a lot more feasible than in the past." (Ref:* ***CO_0017****)*
- *"'Soft infrastructures' — such as intelligent transport systems for road (ITS and traffic management systems for rail (ERTMS*[74]*) and aviation (the single European sky's SESAR*[75]*, backed by Galileo — can optimise the use of the network and improve safety; innovative vehicle techno logy can lower emissions, reduce oil dependency and increase comfort." (Ref:* ***CO_0015****)*
- *"ITS applications in road transport include electronic tolling, dynamic traffic management with variable speed limits, parking guidance and reservation, navigation devices and driver-assistance systems like electronic stability control and lane departure warning systems. Thanks to ITS: transporters benefit from integrated ITS systems such as navigation, digital tachographs, fleet and freight management and electronic toll payment; toll payments are fully automated, eliminating the need to stop at the toll gate; a vehicle involved in an accident sends its precise location, obtained by satellite positioning via a communications network, to an emergency centre." (Ref:* ***CO_0015****)*

[73] Air Traffic Management
[74] European Rail Traffic Management System
[75] Single European Sky A(ir) T(raffic) M(anagement) Research

- *"Results could also be affected by the introduction of intelligent transportation systems (ITS), such as timed-entry freeways and on-board traffic directors that could reduce congestion and increase the mean speed of automobiles by up to 15% (e.g. Diebold Institute for Public Policy Studies, 1995). Consequently the share of automobiles would rise as this mode could, with ITS, better satisfy the demand for higher speed transport. (…) n NAM, for example, ITS would increase the 2050 automobile traffic share from 28 to 32%. However, as high-speed modes are still one order of magnitude swifter, the decline of automobiles would be delayed by only approximately 4 years."* (Ref: ***CO_0001***)
- *"Intelligent Transport Systems (ITS) are a key tool for traffic management (...) especially for interurban networks such as the TERN[76], where congestion is less recurrent (as in urban areas) and can be caused by seasonal traffic peaks, incidents, closures, roadworks, weather, etc, and where in many cases diversionary routes, traffic demand and capacity management solutions exist."* (Ref: ***CO_0254***)
- *"Interurban traffic management includes traffic control centres, tactical management (such as lane control, variable speed limits, hard shoulder running and automatic incident detection), as well as strategic management (longer distance diversions or re-routing, data exchange and common approaches such as traffic management plans involving neighbouring road authorities, etc)."* (Ref: ***CO_0254***)
- *"Although many traffic management and control techniques used on interurban networks are valid, with some traffic management plans near key conurbations integrating the interface to urban networks, urban traffic management principally involves traffic signal management and co-ordination, priority and improvements to public transport and a more comprehensive mobility management approach, given in particular that a much greater proportion of trips in urban areas are regular journeys (e.g. commuting)."* (Ref: ***CO_0254***)
- *"It is increasingly evident that technological improvements involving individual vehicles or infrastructure components and sub-systems are insufficient. Solutions must be found at the level of the interactions between the various constituents of transport systems, including users, and their optimal combination."* (Ref: ***CO_0261***)
- *"Integration is needed at three levels: between vehicles, infrastructures and users – against an appropriate background of legislation to promote deployment across Europe; between different transport modes, permitting efficient and cost-effective door-to-door trips for both passengers and freight; and multi-criteria optimisation, taking into account performance indicators related to safety, congestion, environmental impact, cost and comfort."* (Ref: ***CO_0261***)
- *"(...) ITS will play a prominent part in securing the future of sustainable mobility against a background of mounting economic, environmental and societal pressures."* (Ref: ***CO_0261***)

### Interactions within the Technology Domain

#### *Technology development in general and innovation diffusion*

- *"Key examples of systems for road traffic management that are developing rapidly include Hard Shoulder Running (HSR), Section (or Average) Speed Enforcement and floating vehicle traffic information systems, which are now available commercially in many countries. Many of these systems are restricted in their effectiveness and transferability, however, by a lack of timely and accurate information or the ability to exercise suitable control over traffic. To that end there is a need for an increasing research focus on issues such as distributed sensing or "data nets" potentially using data fusion, or developing low cost sensor equipment." (Ref: **CO_0288**)*

#### *Advanced Driving Devices*

- *"Although ITS research initially focused on automated driving, which probably would increase vehicle travel, implementation of this strategy has been slow. It seems unlikely that driverless cars will become widely available during the foreseeable future." (Ref: **CO_5047**)*
- *"Deployment of large scale intelligent and interoperable technologies is critical in optimising use of infrastructure capacity." (Ref: **CO_0234**)*

[76] Trans-European Road Network

*Information systems*

- *"(...) transition towards more intelligent infrastructure needs to be managed well. There is a danger in introducing new technology if there is insufficient design and planning. (...) rushing to implement new solutions has repeatedly led to sub-optimal solutions that are not integrated with other parts of the system. This can result in unnecessary barriers for subsequent, more optimised solutions for the overall transport development." (Ref:* ***CO_0284****)*
- *"Future innovations in intelligent infrastructure will come less from information is transformed and distributed. (...) The challenge will be in integrating, processing and disseminating this information in a way that benefits the user. So not only the systems need to be interoperable, but also the information will have to be made compatible through standards or by creating additional layers to interconnect different data. And in the foreseeable era of information overflow, care needs to be taken in ensuring the reliability of data provided." (Ref:* ***CO_0284****)*
- *"Increasingly, it is seen that traffic management can be implemented at a microscopic level (e.g.i2010) through the use of Cooperative Vehicle Highway Systems (CVHS). Information from vehicles could be used individually to provide accurate network conditions and aid in the detection and early warning of accidents and the selection of appropriate management strategies, with these implemented by giving early warning of network or road conditions ahead, so that vehicles will be able to communicate with each other and modify speed, headway and route in order to optimise conditions." (Ref:* ***CO_0288****)*

*Pollution abatement and monitoring*

- *The clear solution is for government to begin addressing the problem of transportation pollution by monitoring gas levels where they are being created, and using ITS as a way to inform and manage the problem. (Ref:* ***CO_0278****)*

## Interactions with the Social Domain

*Urbanisation*

- *"Intelligent Transportation Systems (ITS) are increasingly being deployed in urban areas as part of the response to the transport issues faced by authorities." (Ref:* ***CO_0260****)*
- *"The parts of the road network which require traffic management the most are urban areas, where most congestion occurs, and on the Trans-European Road Network (TERN, or road TEN-T), which serves as the core motorway and high-quality road network linking the different regions and Member States of the EU, and which carries the great majority of regional and long-distance traffic." (Ref:* ***CO_0254****)*
- *"Provision of adequate data for traffic management is particularly important in the urban context where the needs of passenger cars and freight are increasingly in conflict with those of public transport, and priority systems are required, such as Automatic Vehicle Identification and Location (AVI/AVL) and Automatic Number-plate Recognition (ANPR), in order to ensure full use can be made of traffic management and enforcement strategies. Indeed existing Automatic Incident Detection (AID) measures can be supplemented by, for example, "probe" (or "floating") vehicle systems." (Ref:* ***CO_0288****)*

*Planning*

- *"With an increasing number of traffic management and control techniques and products available, the place of traffic management within sustainable mobility itself is of vital importance. Indeed its use as a transport planning tool is now of increasing importance." (Ref:* ***CO_0288****)*

*Change of lifestyle and values*

- *"The core of the opportunities of ICT according to many analyses and documents is that the technology works 24 hours a day and seven days in a week, and that this goes world-wide. The popular view is that ICT annihilates the significance of space and time and that this is a new phenomenon." (Ref:* ***CO_2018****)*

## Interactions with the Economy Domain

*Regional differences in economics*

- *"Intelligent Transport Systems are reasonably common in developed countries but still rare on the roads of emerging economies. This represents an unfavourable trend in relation to the* *smoothing of regional differences in the development of an international transport system." (Ref: **CO_0281**)*

*Availability of public and private resources and investments in the transport sector*

- *"Cost-effective use of public money is an issue clearly addressed by urban and interurban traffic management. Increasing the punctuality of public transport and the reliability of networks depends on providing an improved service level with the same system cost." (Ref: **CO_0288**)*
- *"ITS systems have considerable benefits in improving traffic flows, increasing safety and improving services to road users, for relatively little costs compared to the cost of building new infrastructure." (Ref: **CO_0254**)*
- *"Even with relatively small investments, the integration of existing technologies could create new services bringing more reliable, real-time traffic information and better routing. This would make more effective use of the available infrastructure and avoid delays caused by traffic jams, as well as reducing the need for new investments in additional roads." (Ref: **CO_0261**)*
- *"Intelligent mobility solutions and transport demand management based on smart charging will alleviate congestion, but new or improved infrastructure will also be needed." (Ref: **CO_0255**)*

*Market regulations*

- *"For rail, rules for market opening, network capacity allocation and pricing also constitute policy-level strategic management." (Ref: **CO_0288**)*
- *"Traffic management has some political implications, such as perceived discrimination against certain users, and public and political outreach is important in explaining the overarching benefits of management strategies adopted and gaining public acceptance. At operator level, there can also be conflicts, for example, if traffic is diverted from a motorway operated by one authority to a network operated by another or if a political decision is made to allow more intercity passenger trains to use a rail network at the expense of freight or regional passenger services. Thus, for all modes, but especially road, institutional issues are often more of a barrier than technical ones." (Ref: **CO_0288**)*

*Fiscal policy*

- *"Policy actions that would accelerate the market take-up of ITS include pricing reform, financial incentives in the early stages of ITS markets' development, dissemination, pilot projects, and measures to stimulate co-operation between operators." (Ref: **CO_0289**)*

## Interactions with the Environment Domain

*GHG mitigation*

- *"Intelligent Transport Systems using Information and Communication Technologies contribute to greater efficiency of all transport modes, resulting in the reduction of CO2 emissions." (Ref: **CO_0234**)*
- *"In particular, they [ITS] help in lessening environmental impact: reduced congestion, a more efficient transport network together with better-informed travellers and more sustainable transport choices can help tackle climate change and reduce air pollution." (Ref: **CO_0281**)*
- *"At the September 2009 ITS World Congress in Stockholm, András Siegler, Director of Transport for the European Commission's DG Research, estimated that widespread introduction of Intelligent systems and services could reduce congestion by up to 15 %, CO2 emissions by 20 %, and road fatalities by up to 15 %."(Ref: **CO_0261**)*
- *"Continuing progress in ICT and sensing devices will open the door to even more radical advances. And, while environmental benefit may not be the prime purpose of many ITS developments, more efficient road usage automatically leads to energy savings and reduced emissions." (Ref: **CO_0261**)*
- *"More efficient journey planning will reduce travel times and eliminate unnecessary journeys, lowering CO2 emissions." (Ref: **CO_0234**)*
- *"Furthermore, consolidation of large freight volumes for long-distance transport by rail and water can reduce the number and length of truck journeys, reducing CO2 emissions." (Ref: **CO_0234**)*

- *"Electricity use is already growing more quickly relative to other energy carriers as a result of the improvements and increasing numbers of electrical appliances and information technology and the Internet." (Ref: **CO_1009**)*

*Noise levels and emissions standards*

- *"In freight transport, information technology and transport management tools are used to optimise schedules and traffic flows (e-freight), which contribute to reduced congestion, travel time and CO2 emissions." (Ref: **CO_0234**)*

*Pollution levels and emissions standards*

- *"Traffic management systems are a key tool in controlling congestion and pollution." (Ref: **CO_0288**)*

Impacts on Mobility and Transport

*Impacts are difficult to assess*

- *"The use of information and communication technology (ICT) is deemed to have a considerable influence on the demand for transportation, even if the assessment of the right direction is not easy to grasp." (Ref: **CO_0034**)*

*Facilitating the implementation of pricing and charging schemes*

- *"Intelligent Transport Systems and Information and Communication Technologies are also important in supporting efficient use of transport infrastructure by facilitating road charging and access management schemes." (Ref: **CO_0234**)*

*Improving efficiency and attractiveness of public transport*

- *"For public transport – whether by road or rail – the scope includes fleet management and timetabling, matching services and vehicles to meet demand and providing socially essential services while also fitting in with (or finding ways to improve) constraints caused by network capacity, driver shift patterns and technical aspects." (Ref: **CO_0288**)*
- *"New innovative solutions are needed to reach the objective of sustainable mobility while reducing energy consumption and air pollution. In urban areas, for instance, public transport priority strategies can significantly reduce travel time and have been shown to encourage modal shift in favour of public transport, although buses or trams need to run at sufficient frequency to justify the business case for priority measures." (Ref: **CO_0288**)*

*New transport services and facilities*

- *"The increasing pervasiveness of information and communication technologies (ICT) in all aspects of daily life is a powerful driver of change. New services and business models are facilitating journey sharing, shared ownership of vehicles and other collective services," (Ref: **CO_0260**)*

*Intermodality*

- *"ITS can be applied to all types of transport infrastructure (highways, streets, bridges, tunnels, railways, port and airport infrastructure), as well as vehicles across all transport modes, for both passenger and freight transport. It is also a potential tool to help link different modes (promoting co-modality and intermodality) as well as the services of different operators or infrastructure providers within a single mode." (Ref: **CO_0255**)*

*Increase in interoperability and standardisation of data*

- *"For road transport, tactical traffic management involves monitoring the actual traffic situation in real-time (including volumes, speeds, incidents, etc.) and then controlling or influencing the flow using that information in order to reduce congestion, ideal with incidents and improve network efficiency, safety and environmental performance, or achieve other objectives. On a broader scale, strategic traffic management involves managing whole networks at a macro level (overall operational policy), as well as integrating or linking different networks." (Ref: **CO_0288**)*
- *"Because transport is inherently transnational in nature, research efforts to solve its problems must also transcend the scope and scale of purely national efforts. The resultant innovations should be applicable across the whole of Europe, and even beyond. Geographical continuity,*

*standardisation and interoperability of services are essential, in order to avoid the emergence of a patchwork of ITS applications and services." (Ref: **CO_0261**)*

*Increasing interoperability in railways network*

- *"The development and deployment of ERTMS (European Rail Traffic Management System), which encompasses ETCS (European Train Control System) and GSM-R (Global System for Mobile communications - Railway) to unify signalling and speed control in Europe, forms a major part of the EU's railway policy." (Ref: **CO_0254**)*
- *"(...) today, although railway tracks crisscross the world, European trains are stubbornly limited in their range. Cross-border rail traffic is hindered by discrepancies between the national networks, with factors such as power supply, signalling, operational procedures and even track gauge varying from country to country. It means that with rare exceptions – for example, the Eurostar and Thalys trains – it is almost impossible for passengers to take the same train across national borders. A €30.4 million project called MODTRAIN[77] has helped develop standardised, interoperable components for tomorrow's trains." (Ref: **CO_0258**)*

*Improvements in air mode*

- *"The air transport sector is the mode where transport management is most advanced, with Air Traffic Control (ATC), airport management and on-board systems being essential to efficient and safe operation. The most important EU policy, as proposed in the 2001 White Paper and adopted in 2004 under Regulation 550/2004, is the Single European Sky legislation (CEC 2007a)." (Ref: **CO_0254**)*
- *"In 2007, the EU established a joint undertaking to develop SESAR, the new generation of European ATM. This is the technological element to the Single European Sky. (...) Finally, a roadmap towards the implementation of the Single European Sky II (SES II) was adopted in a high level conference in Madrid in February 2010" (Ref: **CO_0254**)*

*Improvements in shipping*

- *"One of the EU's major policies in maritime transport is to promote Short Sea Shipping between Member States, both in terms of increasing the efficiency of multimodal journeys with a sea element and in terms of promoting coastal shipping as a way of transferring freight away from busy land corridors (for example direct sea links between Spain and Italy to reduce road transit traffic through southern France). The Motorways of the Sea concept is a key initiative in this regard, aimed at further facilitating the start-up of innovative integrated inter-modal transport solutions, simplifying administrative requirements and supporting initiatives in the field of the "greening" of transport." (Ref: **CO_0254**)*

[77] www.modtrain.com

### 1.5.4.2 Information Systems

**Driver description**

- *"The key innovation that has changed transport over the last two decades is the way information has become available in real time for transport users. This revolution will continue and lead to profound changes." (Ref: **CO_0284**)*
- *"The technologies for real-time multi-mode travel planning, parking reservation, toll and fare payment and multi-mode navigation exist today. The rise of the "internet of things" is well underway and will include intercommunicating cars, parking spaces, buses, tramways, metros, streets, shared bicycles or other vehicles and service providers." (Ref: **CO_0284**)*
- *"In recent years there has been a significant increase in sales of in-car electronics devices, especially of portable navigation devices. Conservative estimates suggest that the market penetration in the EU of dynamic traffic information and navigation services, as a percentage of all road vehicles, will rise from 1.5 % in 2005 to some 9 % in 2010 and 43 % in 2020." (Ref: **CO_0280**)*
- *"When collecting data by video cameras it has to be ensured that legal framework conditions allow the levying of fines based on these data." (Ref: **CO_0280**)*
- *"It is advantageous to use consistent methodologies and standards for the data collection and the data exchange format." (Ref: **CO_0280**)*
- *"The development of the information and communication sector has raised high expectations in terms of the efficiency and effectiveness of doing business. ICT developments will affect the transport sector both in a direct and an indirect way. Direct impacts relate to safety and the efficient use of capacity through, for instance, the instalment of traffic management systems. Indirect effects relate to new modes of doing business (e-commerce) and new methods of work (teleworking) and are potentially more fundamental in the long-term. However the extent to which these technological changes will also result in measurable impacts within the foreseeable future largely depends on the pace of diffusion of relevant technologies, the legislative / regulatory framework within transport as well as commercial and labour market policy." (Ref: **CO_2041**)*
- *"Services for drivers and travellers (...) cover information on traffic roads, traffic links, information presented to drivers via information tables at highways and parking lots, dynamic traffic information provided via radio, TV or Internet, information sent to vehicle drivers via RDS and GPS, mobile operator services." (Ref: **CO_0039**)*
- *"Increasing capacity and flexibility of ICTs together with decreasing investment and operation costs makes possible real development of cooperative systems. If traffic means communicate with one another and/or with infrastructure, quality of information related to vehicle position, velocity, weather conditions etc. increases. ICTs are considerably connected to many kinds of mobility, especially those related to traffic means." (Ref: **CO_0039**)*
- *"The potential benefits of route guidance, especially in terms of travel time variability, increase with the sophistication of the methods used to estimate the travel time information. However, these benefits are not without a cost. In particular, the cost of providing en-route information may be higher compared to pretrip information. In the most comprehensive form en-route information provision requires two-way communication between the traffic control center and an in-vehicle unit, and the capability to track the location of the vehicle. More limited communication can also be used, but would also result in more limited access to new information in terms of spatial and temporal availability as well as the level of detail." (Ref: **CO_5039**)*
- *"Intelligent digital maps are a basic requirement for a whole range of ITS tools. The problem has been that the road data needed to produce them is not always available, accurate or reliable, with a lack of rules for timely updates. This hinders Europe-wide interoperability and the development of advanced — including safety-related — ITS technologies. The challenge is to ensure easy access to the digital road databases maintained by thousands of European road authorities in a standardised, non-discriminatory and transparent way." (Ref: **CO_5049**)*
- *"In February 2006 (...) the Commission launched the "Intelligent Car Initiative", to remove bottlenecks in rolling out intelligent systems and to speed the development of smarter, safer and cleaner transport for Europe. The Intelligent Car Initiative will accelerate the deployment of*

*intelligent vehicle systems in European and international markets, using a mix of policy, research and communications instruments to: ensure interoperability across different EU countries and harmonise technical solutions through a comprehensive European approach; support ICT-based research and development in the area of transport and facilitate the take-up and use of research results; raise awareness of the potential benefits of ICT-based solutions among consumers and decision-makers." (Ref: **CO_0255**)*

- *"Variable Message Signs (VMS) are electronic traffic signs that allow the TCC[78] to distribute information concerning particular events in a timely fashion. Such signs can warn of traffic congestion, accidents and incidents, roadworks or speed limits on a specific highway segment." (Ref: **CO_0281**)*
- *"There is still a need to provide information through other media when existing or potential customers do not have access to mobile phones or smartphones." (Ref: **CO_0287**)*

## Interactions within the Technology Domain

### *New vehicle design*

- *"According to some estimates, 90% of all automotive innovations stem from the electronics sector (not counting drive designs). It has to emphasised that in the future, cars will be increasingly software-based. IT is essential when it comes to driver assistance systems ranging from night vision to automated parking and collision warning systems; it delivers new software and protocols for car-to-car communication and new traffic control systems; it promises to integrate the multitude of controlling systems using an IP-based on-board network; and it enables new services, e.g. solving issues by remote maintenance." (Ref: **CO_0005**)*
- *"Conversion to electronic steering modelled on airplanes ("X by wire") also promises considerable reductions in weight." (Ref: **CO_0005**)*

### *Advance driving devices*

- *"A new generation of control technology is already changing long established practices in railway operations. Combining electronic interlocking with advanced computerised control systems provides the basis for automation of traffic management on the railway. An extension of such technology facilitates multi-media communication of traffic information to customers. Ultimately, such systems would combine operational control including the monitoring and correction of real-time performance, such as energy use, and the allocation of resources in terms of vehicles, infrastructure and staff. These systems would embrace on-board signalling and train control with automatic vehicle identification and continuous track-to-train communication. The final logical step would be the automation of train driving and driverless trains as used in some forms of urban transit." Ref: **CO_0272**)*
- *"In the longer term, vehicles will talk to each other and to infrastructure." (Ref: **CO_0015**)*

### *Traffic management system*

- *"Cities (...) are already deploying (...) technologies to provide travellers with ubiquitous information about travel options. These same systems can be used to manage traffic on both road and public transport networks." (Ref: **CO_0284**)*
- *"Putting information available on an open platform accessible to everyone is likely to help accelerate innovation in intelligent infrastructure." (Ref: **CO_0284**)*
- *"Besides passenger information, these systems [public transport information] can also be used for successful fleet management." (Ref: **CO_0286**)*
- *"ERTRAC[79] predicts that, as well as receiving mobility information from various service providers, the on-line urban consumer will actively and passively reciprocate with feedback that will enable services to be aligned ever more closely with evolving patterns of use. It is estimated that making the most of the opportunities presented by multimodal systems could bring a 20 % to 30 % gain in usable road capacity." (Ref: **CO_0260**)*

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[78] Traffic Control Centre
[79] European Road Transport Research Advisory Council

### Booking and Payment systems

- *"Mobile technologies could be exploited in the development of payment systems to generate new methods of payment and service packages combining public transport tickets and other services of interest to customers." (Ref: **CO_0004**)*
- *"Multimodal traffic and travel information services will grow in quality and quantity – with mobile handsets becoming increasingly powerful personal mobility terminals. Travel guidance, on-line booking and payment facilities will be combined with location-based Web 2.0 applications to facilitate ride-sharing, data collection and information exchange via mushrooming social networking websites." (Ref: **CO_0261**)*

### Monitoring

- *"Intelligent Transport Systems provide technology that permits users to address security concerns through the use of GPS (or other positioning technology), wired and wireless communications and improved sensors and information systems. Intelligent Transport Systems can monitor the contents and locations of containers, monitor the cargo and routes taken by trucks, track the location and status of public transport vehicles, and generally support, simplify, and increase the visibility of transport logistics. This is an area in which increased security can facilitate efficiency and productivity by standardising and integrating processes for managing the transport of people and cargoes." (Ref: **CO_0281**)*

### Energy efficiency

- *"Intelligent Transport Systems will help to reduce the wasted time and energy by optimising trips, reducing congestion, improving vehicle and driver performance and fostering better the management of the transportation system as a whole. The optimisation of the transport system will result in energy savings (...)." (Ref: **CO_0281**)*

## Interactions with the Social Domain

- *"(...) the social impact of ICT has no revolutionary but an evolutionary nature. From a technical point of view ICT may be revolutionary, but her societal impact is not of that nature. This does not rule out that ICT contributes to important societal transformations. With ten contemporary trends it was observed that they are reinforced by ICT. Without ICT they would also have occurred, though to a lesser extent. This would have led to major problems in a number of societal domains such as a congestion of social and economic exchange and all kinds of organizational processes." (Ref: **CO_2018**)*

### Population ageing

- *"Mobility is of key importance to people with special needs, including the elderly, the poor, people with disabilities and people who live in remote areas. (...) Intelligent Transport Systems include many methods for enhancing the mobility of people and freight in all transportation modes." (Ref: **CO_0281**)*
- *"When establishing an information system for public transport, people with reduced mobility can benefit especially from this as the services usually offer special services for them (e.g. voice information from speakers outside of the vehicles)." (Ref: **CO_0286**)*
- *"The term telecare is generally used to refer to remote social care and support for independent living for older people, with the focus more on social as opposed to medical needs. Three 'generations' of telecare can be distinguished - first generation telecare (often called 'social alarms'), involving systems that enable older people to easily call for help in case of emergency; second generation telecare, involving additional home environment sensors that enable alerts to be triggered automatically; and third generation telecare, involving more extensive monitoring of activity and lifestyle. A core emphasis of telecare is on safety and security, in the context of a more general aim to enable older people to remain living independently in their own homes for as long as possible." (Ref: **CO_2018**)*

### Migration flows

- *"Use and employment of communication media take a central function within the migration process. The manner of communication and access to information do not only influence the movement itself, but they also shape the formation of ethnic communities at the destination." (Ref: **CO_2018**)*

- *"It could be assumed that the Internet offers young immigrants the possibility to overcome the physical distance between home and destination country, by allowing them to maintain the same sets of relationships as prior to the movement – with the only difference that social interaction would now mainly or exclusively taking place in the virtual domain." (Ref: **CO_2018**)*

*Car ownership*

- *"Whip car is the world's first peer-to-peer car rental service. Car owners can rent out their own cars when they aren't using them. Users can search for and hire cars in their neighbourhoods. This is a distributed and flexible system that uses existing cars, mediated by a trusted website with a ratings system, and requires no additional physical infrastructure. http://www.whipcar.com/" (Ref: **CO_5018**)*

*Urbanisation*

- *"(...) information systems could lead to a pattern of distributed human settlements as a superior way of organisation, giving rise to a landscape of scattered new homogeneous motorized neighbourhoods, in which charges would be paid, as needed, to keep down congestion and CO2 emissions." (Ref: **CO_5048**)*
- *"ITS applications can play an important role in transport, especially in more urban areas." (Ref: **CO_0281**)*
- *"Yet seamless inter-modal mobility services cannot be deployed everywhere, they require relatively dense urban areas for commercial viability." (Ref: **CO_0284**)*

*Planning*

- *"ICT will provide a huge amount of real-time information from low-cost, reliable sensors (cameras, parking spot detector, traffic loop detector, GPS and Galileo, Bluetooth in cellular phones, etc.) but 'intelligence' (scientifically sound research and innovation) should still be developed in order to obtain intelligent transport systems (ITS)." (Ref: **CO_5005**)*

*Change of lifestyle and values*

- *"Evidently, ICT very much enables to conduct a life with so much complexity and choice." (Ref: **CO_2018**)*
- *"It has often been observed that ICTs enable work to be brought to the worker (telework) instead of transporting workers to work (commuting)." (Ref: **CO_2018**)*
- *"(...) the new media enable an individualized existence and lifestyle. Simultaneously, these media maintain the possibility to keep in touch with employers and colleagues at work being on the road or working at home. These days appointments for our overfull calendars of leisure spending can only be realized with the aid of cars and modern communication means such as mobile phones, PDA's and e-mail." (Ref: **CO_2018**)*
- *"Research on new areas such as human behaviour is therefore critical to successful ITS implementation." (Ref: **CO_0284**)*

*Education*

- *"Most research of digital media access, that often deals with the so-called digital divide shows that there is a strong correlation between access and personal or positional characteristics of people (Norris, 2001; Mossberger et al., 2003 and van Dijk, 2005). Primarily education, age and societal position appear to be important. Considering physical new media access income still plays a role caused by the regular expenses for purchase of new hardware and software and usage costs that have to be made. People that need ICT for their work or education have a much higher chance of having physical access." (Ref: **CO_2018**)*
- *"At present, citizens do not make the most effective use of all the available transport modes – either because they are unaware of them, or because they face difficulties in obtaining information in an appropriate form to permit interconnected travel." (Ref: **CO_0260**)*
- *"Some users are not skilled on the use of mobile devices." (Ref: **CO_0287**)*
- *"Many travellers still do not have access to the internet or cell phones. Others face real cognitive difficulties in assimilating map and trip guidance information. Others still have physical disabilities which make it difficult for them to use multiple travel modes. Innovation must ensure*

*that these impediments do not render travel information or options inaccessible." (Ref: **CO_0284**)*

- *"Communication with the public is necessary to overcome negative reactions and to counteract the possible refusal of the measures caused by the fear of loss of privacy." (Ref: **CO_0255**)*
- *"General information, education and marketing campaigns for clean public transport can also be used to raise awareness concerning the new information services among the residents." (Ref: **CO_0286**)*

#### Health

- *"The availability of new communication systems and organisational means will enhance the abilities of road operators and the emergency services. Intelligent Transport Systems will be able to pinpoint an accident, help determine the extent of injuries sustained, direct emergency vehicles to the accident site more quickly and find the best route to hospitals, allowing the flow of traffic to return to normal conditions more quickly." (Ref: **CO_0281**)*

### Interactions with the Economy Domain

#### Employment

- *"It is also possible to provide links with employers' intranet sites to give tailored travel information including real-time passenger information." (Ref: **CO_0286**)*

#### Regional differences in economics

- *"In many cases, it is more economical for developing countries to import technology from developed countries than to develop the technology domestically. However, there are some cases in which the demand for IT-related equipment, including ITS equipment, can help foster new domestic industries for manufacturing this equipment. This works best in developing countries that already have at least some base IT industry in place. In addition, ITS equipment and systems require maintenance and renovation throughout their life cycle, some of which can often be provided by domestic resources. This can also help build the IT base in developing countries. Plans for developing these industries can be made during the introduction of ITS." (Ref: **CO_0281**)*

#### Availability of public and private resources and investments in the transport sector

- *"Many stand to gain from efforts at European level to promote ITS, including transport users, the logistics and transport industry, industry involved in ITS and — thanks to a cleaner, more efficient and safer and more secure transport system — society at large." (Ref: **CO_0280**)*
- *"Individuals can benefit from less congestion and reduced travel times effected by the improved traffic management. Fewer people are injured in traffic accidents, reducing personal harm and associated costs." (Ref: **CO_0279**)*
- *"More specifically, studies have shown that the use of ICT could enable the number of accidents in the European Union (EU) to be reduced considerably. For example, 1.500 accidents a year could be avoided if 0.6% of vehicles were equipped with systems helping them to stay in lane or to overtake." (Ref: **CO_0255**)*
- *"Goods delivery companies introduce ITS often because they especially benefit from the combination of GPS-techniques with existing logistics programmes. The use of logistics software can significantly increase the efficiency of delivery trips." (Ref: **CO_0279**)*
- *"Public transport companies and public transport authorities achieve a better image when providing real-time information and when using innovative information systems in their communication with the users, resulting in higher customer satisfaction. The possibility of higher income might be a long-term benefit when the measures result in higher demand for public transport." (Ref: **CO_0286**)*
- *"As (...) ITS technologies are taken up faster and are more widely used, economies of scale are likely to bring down their cost to the benefit of both citizens and professionals." (Ref: **CO_0280**)*

#### Market regulations

- *"(...) the potential for intelligent transport systems can only be fully realised in Europe if we move from a limited and fragmented approach to a coordinated one." (Ref: **CO_0284**)*

- *"The greatest barrier to the development of seamless passenger services is the slow pace of innovation in regulatory structures and transport operators. Greater acceptance of new concepts and adapting regulation to rapidly changing business models are necessary and political leadership and buy-in from key operators is essential." (Ref: **CO_0284**)*
- *"Reaping the benefits of technological advances will require changing how we do things, e.g. by sharing data and infrastructure, or accepting different regulatory models and different attitudes to risk acceptance. For example, private sector telecom and navigation companies collect a huge amount of real time data from their customers which can be used by government agencies for improving traffic information and management services." (Ref: **CO_0284**)*

*Foreign trade, globalisation*

- *"That ICT supports globalization, is a statement almost everybody takes for granted, Globalization is no new phenomenon either. It has occurred in many waves since the Western colonization of the world (Bayly, 2004). Each time progress in information and communication technologies offers a strong support." (Ref: **CO_2018**)*
- *"Information is the key to a globalised, outsourced economy, and the entire supply chain depends on effective management of the information flow." (Ref: **CO_0284**)*

**Interactions with the Environment Domain**

*GHG mitigation*

- *"Information and communication technologies can be used to improve mobility and reduce transport GHG emissions. Incremental enhancements include: automating urban traffic signals to streamline traffic and reduce stop and go conditions; implementing integrated smart cards to facilitate multimodal travel and increase transit use; provide real time traffic data to traffic managers and vehicle users to improve efficiency. More substantial changes are possible by creating entirely new modes of travel, such as smart car sharing that allows convenient short term rentals, smart paratransit that provides door to door service without advanced reservations, and dynamic ride sharing that facilitates organised ride sharing." (Ref: **CO_0148**)*

*Pollution levels and emission standards*

- *"Real-time traffic information for drivers helps fighting congestion, reducing bottlenecks and pollution." (Ref: **CO_0280**)*

**Impacts on Mobility and Transport**

*Increasing in travels' distance*

- *"In general, the technological opportunities provided by the development if ICT can influence transport demand in several directions, depending on the directions that society take. Assuming the continuation in the long term scenario of the trend emerging over the past years, e.g. reducing but stable economic growth, sustained international trade, urbanization, etc, a summary of the ICT impacts, separately on passenger and freight transport demand, can be summarised as follows. For passenger transport: (…) reduction in travel frequency; but perhaps longer distance travel (when individuals move further from work, due the globalisation trends) and also substitution of work travel with other travel (with time saved by not travelling to work), due to widespread diffusion of flexible and remote working technologies, (…) but may add to journey distance, due to real-time route guidance and hazard warning." (Ref: **CO_0034**)*

*Increasing transport demand...*

- *"Increasing mobility is a deeply rooted trend in modern society. By itself it has no relationship at all with ICT. Instead it has many social causes (Mokhtarian et al., 2004). On the field of demographics we are able to observe the shrinking household and the rise of the number of people living alone that drive people outdoors for social life and assistance. In the economy the geographical scale of labour processes is expanding and labour participation of women and housewives is rising. The growth of income and car ownership enable unimpeded travelling for work, study and leisure time. In a cultural respect spending leisure time outdoors is intensified and varied. ICT strongly supports all these trends." (Ref: **CO_2018**)*
- *"The primary effect of ICT in transport consists in enabling development of more intelligent vehicles, more sophisticated telematic services and improvement of ITSs to be applied in traffic control and road infrastructure. Telematics and innovative logistics based on ICTs are able to*

*increase traffic flows by preventing congestions, even in the existing infrastructure" (Ref:* ***CO_0039****)*

- *"In general, the technological opportunities provided by the development if ICT can influence transport demand in several directions, depending on the directions that society take. Assuming the continuation in the long term scenario of the trend emerging over the past years, e.g. reducing but stable economic growth, sustained international trade, urbanization, etc, a summary of the ICT impacts, separately on passenger and freight transport demand, can be summarised as follows. For passenger transport: more long-distance travel for business meetings and services by air due to the new opportunities favoured by new technologies (transport cost reductions)." (Ref:* ***CO_0034****)*

***even if…***

- *"(…) ICT (…) reduces the need for individuals to travel for many transactions, but may also lead to new journeys to replace the ones that would have been necessary in the absence of the e-activity or to completely new demand resulting from social networking." (Ref:* ***CO_0034****)*

***...the limit could be humans***

- *"(...) the trend of increasing mobility will only be reinforced more by ICT in the future. Until this trend also reaches its limits. Mobility will collide with the physical limitations of humans to be on the road all of the time, the material restrictions of rising transport costs and the limits of ecological non-sustainability." (Ref:* ***CO_2018****)*

***Improving air transport and maritime efficiency***

- *"There is a lot of old technology behind air traffic management. The link between air space and ground control is particularly weak, still reliant on analogue voice radio. The suite of technologies needed is available now. These include transmitting detailed flight plan revisions to pilots in real time to avoid storms and aircraft location technology so planes can interact and fly closely spaced on very precise routes. Managing the transition process is more complicated than developing the technologies. Some delay results from ensuring systems are forward and backward compatible, necessary because of the great range of plane generations in the skies. Some lag is due to attitudes that fail to embrace technology, for example the need to move away from a sector-by-sector air space control system. (...) Gate-to-gate management will become increasingly important. Three quarters of the delays are on the ground or a result of delays to earlier legs of a plane's rotation. Getting ground side transport information integrated into system could make a big difference. It is clear that innovation in air traffic management will be able to successfully cope with the massive increase in demand for air travel. Managing delays on the ground, in airports, is a tougher challenge, and financial sustainability is the toughest challenge of all for the sector." (Ref:* ***CO_0284****)*
- *"Flagship[80], an EU-funded consortium of more than 40 European maritime organisations,(...) has been able to come up with a number of cross-border innovations. One example of such cross-border innovation, developed by researchers, that could generate considerable savings is an automated computerised system to help ship operators fill in forms that they need to send to port authorities.(...) If every European ship used automated form filling, this could lead to a total time cost saving in the region of €8.94 million per year (..). In a nutshell, the beauty of the real-time scheduling system for containers is that it can help companies ensure, for example, that trucks do not drive to or around ports empty. (...). But it is not just companies that can benefit in terms of savings. The wider public can benefit too because the system will mean lower emissions of CO2. "The direct public benefit is a reduction in congestion with 10% fewer truck movements now for the same volume of goods and a 10% reduction in CO2 emissions"" (Ref:* ***CO_0258****)*

***Increasing transport safety***

- *"Information can also be used to help drivers through co-operative safety systems that help them to avoid accidents by using data from other vehicles in the same area." (Ref:* ***CO_0284****)*
- *"The use of information and communication technologies (ICT) in building intelligent cars can contribute towards increasing road safety by these elements: making transport systems more efficient; using fuel more efficiently; helping drivers to prevent or avoid accidents; providing*

[80] www.flagship.be

*drivers with real-time information about the road network in order to avoid congestion; enabling drivers to optimise journeys." (Ref:* ***CO_0255****)*

- *"To meet the challenges of achieving virtually accident-free, clean and efficient mobility through ITS, it is crucial that all elements of transport systems are able to communicate and cooperate in exchanging real-time information. Bi-directional communication is needed from vehicle to vehicle (V2V) and vehicle to infrastructure (V2I). This requires the development of a communication architecture that provides a common frame for cooperative systems to work together. Examples of applications based on cooperative systems that are currently under development are: traffic control and management, intersection collision warning," (Ref:* ***CO_0261****)*
- *"Intelligent infrastructure technologies are therefore also needed to give drivers safety-related information on the broader road infrastructure and traffic situation." (Ref:* ***CO_0266****)*
- *"Indeed, ITS systems can save lives: it is estimated that two technologies alone — the electronic stability control driver assistance system and the pan-European in-vehicle emergency call system eCall — could save 6.500 lives per year in the EU when fully deployed. Driver assistance and other safety systems, navigation and tracking and tracing systems all have a role when it comes to promoting transport safety." (Ref:* ***CO_0280****)*
- *"An increasing amount of data is being presented to drivers. This is not always particularly useful, and sometimes may even be detrimental to safety. Research is looking at the needs of drivers in terms of content, presentation, availability, reliability, timing and hierarchy of the information provided." (Ref:* ***CO_0289****)*

#### More conscious mobility

- *"The way people move within the city context changes with the development of transportation systems, information and communication technologies." (Ref:* ***CO_2037****)*
- *"Traffic and travel information services allow Europeans to make well-informed decisions both before and during their journeys." (Ref:* ***CO_5049****)*
- *"Access will be made easier still with the advent of more comprehensive multi-modal timetables, and journey planners embracing options such as walking and cycling, all drawing on real-time travel and traffic information as necessary to ensure optimal accuracy." (Ref:* ***CO_0260****)*
- *"Informal, peer-to-peer and crowd-sourced car-sharing sites build on the same premise, as emerging internet services can multiply mobility options and further reduce car use without reducing access to cars or overall mobility." (Ref:* ***CO_5019****)*
- *"Mobile communications will also permit en-route customers to be updated via mobile phone or computer with information regarding delays, schedule changes and other critical matters." (Ref:* ***CO_0260****)*

#### Encouraging and improving inter-modality and co-modality

- *"Intelligent transport systems are also a key enabler of the integration of different transport modes to provide door-to-door transport services." (Ref:* ***CO_0289****)*
- *"(...) The most promising market segment for additional services is real-time travel-information, since far more people were interested in this service than en-route-information to the final destination (...). This makes sense, since "travel information (...) can minimize the inconvenience of using public transport by making it easier to plan and execute a journey," especially with multi-modal journeys." (Ref:* ***CO_5040****)*
- *"The availability of efficient information and the possibility of a smart road transport system allows for the promotion of a pro-active exchange of information and services with other modes of transport, promoting an integration of the capabilities of the different modes." (Ref:* ***CO_0281****)*
- *"(...) in many parts of Europe, ITS technologies are already being used to improve transport management operations and facilitate interchange between modes — notably between road and rail. This encourages co-modality." (Ref:* ***CO_0280****)*
- *"The potential of intelligent transport infrastructure depends on the capability to bring maximum benefits to the user. Many users require seamless and reliable transport from origin to destination, regardless of the mode. Users and freight operators can be assisted with dynamic route guidance to make a multi-modal trip, saving money and time." (Ref:* ***CO_0284****)*

- *"By providing integrated information, intermodality can also be supported." (Ref: **CO_0286**)*

*Improving efficiency and attractiveness of public transport*

- *"In general, the technological opportunities provided by the development if ICT can influence transport demand in several directions, depending on the directions that society take. Assuming the continuation in the long term scenario of the trend emerging over the past years, e.g. reducing but stable economic growth, sustained international trade, urbanization, etc, a summary of the ICT impacts, separately on passenger and freight transport demand, can be summarised as follows. For passenger transport: (…) modal shift in favour of public transport, due to new technologies (Integrated public transport planning information, e.g. real time information on bus schedules)." (Ref: **CO_0034**)*
- *"Advances in smart phone technology also facilitate the provision of real-time information on the availability of public transport services, provided that the technology is comprehensively deployed when developing the information system for all public transport." (Ref: **CO_0004**)*
- *"Receiving the right information at the right time and in the right place is critical for successful urban public transport, especially in a multimodal transport system. It is hard to imagine the existence of flexible and high-quality urban public transport without the deployment of ITS." (Ref: **CO_0281**)*
- *"By improving the information on the public transport system, public transport can develop as a real alternative to private car use." (Ref: **CO_0286**)*
- *"One key missing link is useable and transparent information on public transport routes, schedules, and especially, fares." (Ref: **CO_0284**)*

### 1.5.4.3 Booking and Payment Systems

**Driver description**

- *"(...) all transport modes should be interlinked, as part of one integrated system. (...) The current planning and ticketing systems are not really capable of addressing this concern." (Ref:* ***CO_0284****)*
- *"This group of solutions concerns the provision of integrated pricing and/or ticketing for the individual components of long distance journeys: pre-paid tickets or cards allowing unlimited local travel; simple tariff structure for local transport services; provision of integrated tickets for local journeys; competitive pricing of integrated tickets; integrated ticketing for air and rail & within mode; pre-booked ticket for parking and public transport; integrated ticketing for long-distance rail & local public transport; inclusion of local taxi journeys in rail or air tickets; smart cards; payment via mobile telephone text messages; virtual tickets on smart phones." (Ref:* ***CO_0283****)*
- *"Smartcard technology is being implemented around the world as a substitute for cash transactions in various capacities. When applied to public transport fare collection, smartcards eliminate the need for commuters to queue for tickets and reduce the burden on transport providers to process fare transactions." (Ref:* ***CO_0292****)*
- *"As well as providing more efficient transport services to commuters, smartcard ticketing systems enable service providers and transit authorities to collect comprehensive data on the travel behaviour of commuters. With this information at hand service providers are able to cater to the needs of commuters, and allocate resources more efficiently. In spite of these benefits, experience has shown smartcard ticketing systems are prone to early implementation problems, as commuters adapt to the new technology, and it is tailored to meet the needs of unique transport systems." (Ref:* ***CO_0292****)*
- *"Smartcards are typically the size of a credit card, and contain a microchip that stores and transmits data using radio frequency identification (RFID), enabling it to communicate with a device within ten centimetres of the card without physical contact. (...)There are two categories of smartcards that can be used for public transport ticketing – a single purpose transit pass and an electronic purse (e - purse) card with multiple applications beyond fare payment, such as small retail transactions and personal identification. Both involve a prepaid account managed by the card holder. Recent innovations in smartcard technology have concentrated on developing e - purse applications to enhance the appeal and accessibility of smartcard ticketing to infrequent commuters or tourists" (Ref:* ***CO_0292****)*
- *"The need to combat road traffic congestion and the desire to find new revenue sources for transport investments have stimulated the interest in schemes where charges for road use are introduced, such as parking fees and charges to allow vehicles to use certain roads." (Ref:* ***CO_0289****)*
- *"The various European electronic road toll systems introduced at local and national levels from the early 1990s onwards were, and generally still are, non-interoperable. They oblige drivers to affix several electronic tags inside their vehicle in order to take advantage of the various systems encountered on their itinerary." (Ref:* ***CO_0253****)*
- *"Directive 2004/52/EC and related Decision 2009/750/EC aim to achieve the interoperability of all the electronic road toll systems in the European Union in order to avoid the proliferation of incompatible systems." (Ref:* ***CO_0253****)*
- *"The directive therefore stipulates that a European Electronic Toll Service shall be set up, which covers all the road networks and tolled (infra)structures in the Union on which road-usage is declared electronically by means of a single on-board equipment, and defines the allowed technological solutions for carrying out electronic toll transactions, namely 5.8 GHz microwave and satellite positioning coupled with mobile communications." (Ref:* ***CO_0253****)*
- *"The European Electronic Toll Service (EETS) will ensure interoperability of tolling services on the entire European Union road network. EETS will enable road users to easily pay tolls throughout the whole EU with only one subscription contract with one service provider and a single on-board unit." (Ref:* ***CO_0253****)*

- *"(...) electronic fee collection is expected to be used by nearly half of all vehicles (about 46 %) by 2020, compared with 3.7 % in 2005." (Ref: **CO_0280**)*
- *"The traditional distinction between actors in the transport supply chain will progressively become blurred by a shift towards more integrated mobility solution providers. Future mobility integrators will act as 'one-stop shops', coordinating the functions of vehicle manufacturers, transport providers, service providers, technology providers and telecom operators. One European auto-maker, for example, has launched a scheme that enables holders of a special pre-paid chipcard to rent vehicles from its own range, including bicycles, scooters, cars and vans, stocked at the premises of its agency and dealership network. Subscribers can also use the card to hire accessories, or to pay for travel and accommodation via a common call centre." (Ref: **CO_0260**)*

## Interactions within the Technology Domain

### Technology development in general and innovation diffusion

- *"(...) the EETS[81] on-board equipment functionalities can be used by various other added-value telematic applications and services, such as eCall, real-time traffic and travel information. EETS will therefore contribute to further strengthening the competitiveness of the European information and communications technologies industry in this sector, already at the international forefront." (Ref: **CO_0253**)*
- *"Another aspect is to improve the quality of time spent waiting at security checks or for connections, for example by providing e-mail access." (Ref: **CO_0284**)*

### Information systems

- *"A challenge for researchers will be to develop the data exchange protocols and standards required to ensure the modal and geographical interoperability of such far-reaching ICT applications. However, the high take-up of smart devices such as the Apple iPhone is expected to provide ample scope for independent companies to build and launch their own personalised 'apps' to provide such services." (Ref: **CO_0260**)*
- *"Smart payments also can provide valuable data on behaviour and mobility patterns of users." (Ref: **CO_0285**)*
- *"As well as simplifying fare payments, the smartcard's capacity to track and record travel data has the potential to revolutionise public transport delivery. With virtual real - time information on the demand side of the transport market, service providers can optimise the supply of services and fare prices to ensure optimum asset utilisation." (Ref: **CO_0290**)*

### Energy efficiency

- *"If ticket vending machines are provided at bus stops or in vehicles the time for boarding diminishes and the reliability and efficiency of public transport services increases due to the fact that tickets are not bought from the driver." (Ref: **CO_0285**)*

## Interactions with the Social Domain

### Population ageing

- *"An important issue is also the availability of sales points for different user groups (e.g. elderly people or people with reduced mobility)." (Ref: **CO_0285**)*

### Urbanisation

- *"To enhance the use of public transport, cities should aim at making the ticketing system attractive and easy to understand for everyone." (Ref: **CO_0285**)*
- *"Public transport in rural areas suffers from low levels of patronage, and therefore has to be flexible to compete. Research highlighted the potential of using the Internet and mobile phones in the operation of both regular and on-demand services. Combining passenger and goods transport, for example by integrating the booking of passenger trips with the scheduling of goods deliveries, also looks promising." (Ref: **CO_0289**)*

[81] European Electronic Toll Service

*Planning*

- *"Implementing smartcard ticketing, on the other hand, presents an opportunity for governments to significantly influence the demand for public transport. With access to comprehensive travel data on the demand side, transport operators are able to develop and improve ticketing as a consumer product. This may include offering discounts on travel to and from certain areas at various times to stimulate the spread of demand across a network, maximising its revenue earning potential and encouraging increased patronage in off peak periods." (Ref: **CO_0290**)*

*Tourist flows*

- *"Continual innovation in smartcard ticketing systems will undoubtedly increase their appeal, as consumers opt for the convenience of using one card for multiple applications. One of the major beneficiaries of this technology will be international tourists who potentially could use one credit card on public transport services in different cities around the world." (Ref: **CO_0290**)*

*Change of lifestyle and values*

- *"(...) pricing technologies should be able to communicate service consumption to travellers on a regular and automated basis, as this will influence their travel behaviour." (Ref: **CO_0289**)*
- *"Smartcard technology demands an element of public compliance to ensure successful implementation. As such, smartcard ticketing systems are is prone to encountering early implementation problems as commuters are required to change their everyday behaviour in order for the system to succeed. For smartcard technology to work on transit modes such as bus and light rail, commuters must swipe on when boarding, and off when alighting the vehicle. This can cause problems if commuters forget to swipe off, and the potential arises for penalty fares to be issued in cases of genuine human error." (Ref: **CO_0290**)*

### Interactions with the Economy Domain

*Availability of public and private resources and investments in the transport sector*

- *"When using a smart card or mobile phone, public transport passengers can save money because the best price for the trips is calculated automatically (e.g. after a certain amount of trips passengers get a price reduction)." (Ref: **CO_0285**)*
- *"The development of integrated e - purse payments for public transport fares and small value purchases raises opportunities for new revenue streams for retailers, the financial sector and transport service providers. Employing the payment systems expertise of financial service providers delivers cost savings to all stakeholders, enabling transport agencies to focus more resources on service provision." (Ref: **CO_0290**)*

### Interactions with the Environment Domain

*Pollution levels and emissions standards*

- *"Electronic Toll Collection (ETC) systems have advantages for individual drivers as well as for the overall road system. The immediate advantage to the individual driver is that with ETC it is no longer necessary to stop at toll barriers - the toll can be paid while vehicles are still in motion. The indirect advantage is an overall decrease in delays at toll barriers for all vehicles, even those that are not using ETC devices. In this way overall pollution is reduced as a result of reducing the level of stop-and-go traffic." (Ref: **CO_0281**)*

### Impacts on Mobility and Transport

*Achieving a seamless transport system*

- *"(...), ticketing and payment portals (...) will enable people to move seamlessly and efficiently from door to door. With the help of technology, entire transactions can be electronically scheduled, managed and implemented at the click of a few buttons." (Ref: **CO_0260**)*
- *"The introduction of electronic ticketing has various advantages for travellers and transit companies. For travellers, there is no need to queue at ticket machines and ticket offices. Further, it involves payment via direct debit and online accounting on the traveller's personal page. For suppliers, it may reduce ticketing costs and opportunities for value added services are created. Moreover, the supplier will be able to monitor the actual traveller's behaviour more closely. In addition, electronic ticketing yields possibilities for more flexible fares, offering, for example, opportunities to transform a zone-based fare system into a distance-based one.*

*Another opportunity is the creation of flexible subscription rates, for example, intermediate rates between those for weekly-based and monthly-based season tickets." (Ref: **CO_5040**)*

- *"Smartcard ticketing systems enable commuters to carry one durable card for use on all transit modes. A single multi-purpose ticket makes using multiple transport modes much simpler and less time consuming. In turn, this facilitates the multimodal travel behaviour that is encouraged by operators and transport planners. In this regard, smartcard ticketing facilitates a genuinely seamless multimodal transport system." (Ref: **CO_0290**)*

#### Reducing congestion

- *"By limiting cash transactions at toll stations and eliminating cumbersome procedures for occasional users, EETS will facilitate daily operations for road users, improve traffic flow and reduce congestion." (Ref: **CO_0253**)*

#### Increasing the use of public transport

- *"The use of public transport is facilitated by personalised information systems, accessible vehicles and pedestrian access, affordable fares and a user-friendly payment system." (Ref: **CO_0004**)*
- *"E-ticketing may increase the convenience of public transport." (Ref: **CO_0034**)*
- *"The ease and convenience of purchase afforded by innovative ticketing systems in a city should attract more public transport passengers, resulting in less private cars entering the urban area and greater passenger satisfaction. The accessibility of public transport in general is enhanced with the introduction of a ticket valid for all services and vehicle types." (Ref: **CO_0285**)*
- *"Additionally, public transport operators can increase their effectiveness and reduce the overall operational costs by using the logistics and positioning tools, particularly benefiting from the diminished time needed for management. As a long-term benefit, an increase in the number of passengers can be expected due to the better service and reliability of public transport." (Ref: **CO_0279**)*

#### 1.5.4.4 Monitoring

**Driver description**

- *"In order to continuously monitor motorway conditions, road operators install detectors capable of collecting information on the operation's main points of interest: traffic, weather and environmental monitoring. The video monitoring system for road traffic is a network composed of remotely operated Closed Circuit Television (CCTV) cameras." (Ref: **CO_0281**)*
- *"Blind Spot Monitoring Systems detects other vehicles moving into the sensitive "blind spot" zone towards the back and sides of a car and alerts the driver of the potential danger." (Ref: **CO_5019**)*
- *"On-board diagnostic systems monitor all the emission controls on a vehicle and warn the driver, through instrument panel displays, of any faults that may occur. These systems have become mandatory for new passenger motor vehicles in the United States." (Ref: **CO_0272**)*
- *"Even greater opportunities for detecting malfunctioning vehicles is provided by the use of transponders to allow roadside units to monitor the condition of vehicles as they drive by. Within 20 years, these systems could be installed in sufficient numbers to render inspection and maintenance programs unnecessary." (Ref: **CO_0272**)*
- *"Increases in world trade flows mean that more and more ships are sailing on the high seas. As a result, ships are increasingly being monitored and controlled and the crew needs to send a growing number of reports and other data to various shore authorities." (Ref: **CO_0258**)*
- *"For huge cargo vessels that carry millions of litres of oil, thousands of shipping containers, or tens of thousands of tonnes of coal or steel, safety is paramount. These ships must comply with rising safety standards that require time-consuming inspections by surveyors, who in turn risk their own safety by climbing inside massive cargo areas and on scaffolding constructed around ships. To help save time and money, and improve the accuracy and quality of these important inspections, an EU-funded research project has developed a fleet of remote-controlled robots that crawl through cargo ships in search of cracks, corrosion and other defects. (...) The project, known as MINOAS [82](Marine INspection rObotic Assistant System), holds the potential to make ships safer while also extending their life at sea." (Ref: **CO_0258**)*

**Interactions within the Technology Domain**

***Advanced driving devices***

- *"Traditionally, road safety systems could be divided into passive systems (which protect road users in case of an accident), and active systems (which are designed to prevent an accident from happening in the first place). Today, however, the line between active and passive safety is increasingly blurred. New systems are being developed which use sensors such as radars, cameras, lidar, real-time video processing systems, ultrasound or infrared to detect potentially dangerous situations on the road. Based on what they see, the systems are able to take actions to avoid the crash. If a crash is unavoidable, the car can intervene to reduce the impacts of the crash on the car occupants by braking to reduce the car's speed, tightening seatbelts and deploying airbags." (Ref: **CO_0266**)*

***Traffic management systems***

- *"To optimise the traffic and passenger flows and to improve system management, integrated real-time information on the traffic situation in the urban area (e.g. concerning parking spaces, congestion, public transport) can be provided. To achieve these goals, as a first step systems are needed to collect data on the conditions of the transport network. Amongst others, data can be collected by: automated systems, such as automatic traffic count sites (e.g. automatic number plate recognition systems, congestion monitoring loop detectors in the surface of the roads); CCTV (Closed Circuit Television), which means the use of video cameras transmitting information to a set of monitors; using data from different sources and actors (police, medical emergency department, injuries, etc.) collected with a uniform methodology for measuring a coherent set of performance indicators to give a complete picture of road operating characteristics but also taking into account data security." (Ref: **CO_0279**)*

[82] www.minoasproject.eu

- *"(...) a TCC*[83] *can also benefit from a numerical count given by traffic detection systems made up of sensors. These sensors use various technologies inductive loops placed under the road surface, radar sensors, "cooperative" vehiclemounted units, etc.); and are designed to perform the real-time, precise monitoring of vehicles in terms of traffic volumes and types of vehicle in transit. Data is collected, registered and computed by local units that transmit the information to the TCC. In doing so, the TCC is able to perform realtime traffic management according to current traffic volumes." (Ref:* ***CO_0281****)*

*Energy efficiency*

- *"New technologies have an important role to play in enabling improvements in the maintenance of road vehicles. Better maintained vehicles will be able to operate close to their rated energy efficiency." (Ref:* ***CO_0272****)*

**Interactions with the Social Domain**

*Planning*

- *"Governments should adopt regular monitoring of the performance of the transport system as an integral part of the planning process, and they should use the resulting information to assess the effectiveness of the policies implemented and the nature of the problems still to be tackled. The data collected should reflect the policy objectives and desired outcomes, and they should be consistent with any targets set." (Ref:* ***CO_0054****).*

**Interactions with the Economy Domain**

No particularly relevant interrelationships have been found.

**Interactions with the Environment Domain**

No particularly relevant interrelationships have been found.

**Impacts on Mobility and Transport**

*Increasing transport safety*

- *"Automated speed cameras have proved their worth in many countries and need to be promoted to showcase their effectiveness." (Ref:* ***CO_5019****)*
- *"Now, thanks to advances in technology, researchers can monitor drivers in their natural environment, i.e. their own cars. These 'naturalistic driving' studies rely on miniature cameras and other tiny sensors to gather data on when and how hard drivers brake and accelerate, as well as where they are looking, for example. Small data storage devices retain the information, while developments in software make it easier for researchers to analyse the information. The benefits of these studies are immense. In naturalistic driving you can actually be there, so you can see what happened, what condition the driver was in 10 minutes before the accident, and what kind of manoeuvres he undertook to try to prevent the accident." (Ref:* ***CO_0266****)*
- *"Advanced vehicle safety features could be significantly improved by the development and integration of new sensor systems. Sensors provide information on what is going on in the immediate vicinity of the vehicle." (Ref:* ***CO_0266****)*

[83] Traffic Control Centres

### 1.5.5 The Pollution Factor

#### *1.5.5.1 Pollution Abatement and Monitoring*

**Driver description**

- *"Carbon sequestration involves removing GHG emissions from the atmosphere, either through enhancing natural 'carbon sinks' (e.g. conserving forested areas and enhancing river environments), the development of new carbon sinks (e.g. reforestation or afforestation) or through the capture and storage of GHGs being produced within the city (e.g. the capture of methane from landfill sites for energy generation)." (Ref:* ***CO_0147****)*
- *"The increased uptake of cleaner and more efficient energy technologies envisaged in the ACT and the BLUE scenarios will need to be driven by:*
  - → *Increased support for the research and development (R&D) of energy technologies that face technical challenges and need to reduce costs before they become commercially viable;*
  - → *Demonstration programmes for energy technologies that need to prove they can work on a commercial scale under relevant operating conditions;*
  - → *Deployment programmes for energy technologies that are not yet cost-competitive, but whose costs could be reduced through learning-by-doing. These programmes would be expected to be phased out as individual technologies become cost-competitive;*
  - → *$CO_2$ reduction incentives to encourage the adoption of low-carbon technologies. Such incentives could take the form of regulation, pricing incentives, tax breaks, voluntary programmes, subsidies or trading schemes. The ACT scenarios assume that policies and measures are put in place that would lead to the adoption of low-carbon technologies with a cost of up to USD 50/t $CO_2$ saved from 2030 in all countries, including developing countries. In the BLUE scenarios the level of incentive is assumed to continue to rise from 2030 onwards, reaching a level of USD 200/t CO2 saved in 2040 and beyond;*
  - → *Policy instruments to overcome other commercialisation barriers that are not primarily economic. These include enabling standards and other regulations, labelling schemes, information campaigns and energy auditing. These measures can play an important role in increasing the uptake of energy-efficient technologies in the building and transport sectors, as well as in non-energy intensive industry sectors where energy costs are low compared to other production costs." (Ref:* ***CO_0275****)*
- *"With regulation on CO2 emissions from cars and vans now agreed, a course towards a fleet of low emission vehicles has been set. The type-approval measurement procedure that forms the basis for the regulation does not, however, fully capture all energy-consuming technologies on a vehicle, and it will never be able to account for the influence of the driver and his or her driving style on fuel consumption. As a result, while there is correlation between the type-approval and in-use CO2 emissions, the magnitude of the reductions gauged from the type-approval conditions does not necessarily lead to an equal reduction of the in-use consumption." (Ref:* ***CO_5030****)*

**Interactions within the Technology Domain**

***Technology development in general and innovation diffusion***

- *"There are important opportunities for reducing $CO_2$ emissions through the use of CCS[84] in iron and cement manufacturing." (Ref:* ***CO_0275****)*
- *"Three main technology options exist for $CO_2$ capture: post-combustion, pre-combustion, and oxyfueling (or denitrogenation)". (Ref:* ***CO_0275****)*
- *"Advanced coal technologies (often confused with clean coal technologies) will play an important role in minimising the environmental impact of future coal use by reducing dust, sulphur oxides ($SO_x$) and oxides of nitrogen ($NO_x$) emissions. At the same time, these technologies have the potential to deliver improved thermal efficiency and hence to reduce $CO_2$ emissions per unit of electricity generated." (Ref:* ***CO_0275****)*

[84] $CO_2$ Capture and Storage.

- *"As effective as these emissions reductions have been using the latest pollution abatement technologies, the relative effectiveness of new technologies is becoming increasingly marginal (...)" (Ref: **CO_0276**)*
- *"The emission reductions across the EU27 since 1990 have been achieved as a result of a combination of measures, including fuel-switching in energy-related sectors away from high sulphur-containing solid and liquid fuels to low sulphur fuels such as natural gas, the fitting of flue gas desulphurisation abatement technology in industrial facilities and the impact of European Union directives relating to the sulphur content of certain liquid fuels." (Ref: **CO_0233**)*

## Interactions with the Social Domain

No particularly relevant interrelationships have been found.

## Interactions with the Economy Domain

### *Regional differences in economics*

- *"In most of the major world economies, carbon capture and storage (CCS) is seen as an important greenhouse gas (GHG) abatement option. In many regions, energy and environmental policy frameworks are beginning to be established to support CCS, but significant gaps still remain." (Ref: **CO_0275**)*

### *Market regulations*

- *"CCS mandates and GHG emissions caps will result in higher costs for electricity generators and industry. In jurisdictions where electricity markets are regulated, electricity generators need to be reassured that the cost of their investments in new technology will be recoverable either directly or through regulated prices (Cowart, et al., 2007). In setting prices, energy regulators are attempting to strike a balance between acknowledging the investment risks faced by electricity producers and the need to protect consumers from inefficient investment or excessive profit taking." (Ref: **CO_0275**)*
- *"The expansion of CCS will raise a number of legal and regulatory issues. The most important of these include: developing regulations for $CO_2$ transport; establishing jurisdiction among international, national, state/provincial and local government actors; establishing ownership of storage-space resources and legal means for acquiring the rights to develop/use such resources, including access rights; developing clear guidelines for site selection, permitting, monitoring and verifying $CO_2$ retention; clarifying long-term liabilities and financial responsibility for $CO_2$ storage operations; and, in the case of offshore $CO_2$ storage, complying with appropriate international marine environment protection instruments." (Ref: **CO_0275**)*

### *Fiscal policy*

- *"Among other issues, the proposal aims to promote sustainability by restructuring the tax base of both registration taxes and annual circulation taxes so as to include elements directly related to $CO_2$ emissions of passenger cars in those Member States that apply such taxes." (Ref: **CO_0250**)*

## Interactions with the Environment Domain

### *GHG mitigation*

- *"The 2007 strategy aimed at reaching the Community objective of an equivalent of 120 gCO2/km by 2012 through a legislative framework addressing supply oriented measures. The package of measures listed the following elements:*
  - → *to reach an objective of 130 g$CO_2$/km for the average new car fleet by means of improvements in vehicle motor technology;*
  - → *setting minimum efficiency requirements for air-conditioning systems;*
  - → *the compulsory fitting of accurate tyre pressure monitoring systems;*
  - → *setting maximum tyre rolling resistance limits in the EU for tyres fitted on passenger cars and light commercial vehicles;*
  - → *the use of gear shift indicators, taking into account the extent to which such devices are used by consumers in real driving conditions;*

- → *fuel efficiency progress in light-commercial vehicles (vans) with the objective of reaching 175 $gCO_2$/km by 2012 and 160 gCO2/km by 2015;*
- → *increased use of biofuels maximizing environmental performance." (Ref: **CO_0250**)*

- *"With the world's dependence on fossil fuels not expected to abate significantly in the short to medium-term, CCS[85] is a critical technology to reduce CO2 emissions and decarbonise both the industry and power sectors." (Ref: **CO_0185**)*
- *"If carbon capture and storage (CCS) is available and applied on a large scale, gas may become a lowcarbon technology, but without CCS, the long-term role of gas may be limited to a flexible backup and balancing capacity where renewable energy supplies are variable. For all fossil fuels, carbon capture and storage will have to be applied from around 2030 onwards in the power sector in order to reach the decarbonisation targets. CCS is also an important option for decarbonisation of several heavy industries and combined with biomass could deliver carbonnegative' values. The future of CCS crucially depends on public acceptance and adequate carbon prices; it needs to be sufficiently demonstrated on a large scale and investment in the technology ensured in this decade, and then deployed from 2020, in order to be feasible for widespread use by 2030." (Ref: **CO_0245**)*
- *"Monitoring provides a basis for risk management to ensure that $CO_2$ remains contained within pre-defined geological structures, and does not flow back to the surface or into subsurface zones where it may be detrimental to other resources such as fresh water or oil and gas reservoirs." (Ref: **CO_0275**)*
- *"Monitoring requirements will be different for different phases of a $CO_2$ storage project Benson, 2007):*
  - → *During site selection, assessment and certification, measurement will be essential for setting the project baseline from an environmental and hydrological perspective;*
  - → *During injection, monitoring will help to enable the control of injection parameters (e.g. rates of injection) and confirm the validity of predictions from modelling simulations. In the event of discrepancies, monitoring will allow project operators to update and re-optimise the project parameters;*
  - → *Monitoring during closure and after closure will also be necessary. After $CO_2$ injection has stopped, and a project's performance has been assessed, government and project operators must work together to establish post-closure monitoring parameters. The post-closure phase will involve the documentation of $CO_2$ plume migration and information on well monitoring, among other things." (Ref: **CO_0275**)*

#### *Pollution levels and emissions standards*

- *"The power sector is the most important potential contributor to global emission reductions in both low-carbon scenarios." (Ref: **CO_0275**)*
- *"Authorities can choose from a range of abatement options. Low emission zones (in combination with retrofit initiatives), traffic planning, and measures aiming at a shift of motor vehicle mileage to other transport modes, are all examples of important management elements to reduce air pollutant concentrations. A ban of studded tires (as used in certain Scandinavian countries during winter) is an example of an effective measure to help abate non-exhaust PM pollution." (Ref: **CO_0238**)*

### Impacts on Mobility and Transport

#### *Fossil fuel based journeys*

- *"Most people in Europe live in urban areas and mainly travel short distances. Such journeys are estimated to account for 40% of all CO2 emissions from road transport. The EU target for 2030 is to cut the number of fossil-fuelled vehicles in urban areas by half and to phase out these vehicles by 2050. CO2-free transport and logistics in large cities is the target for 2030." (Ref: **CO_0234**)*

[85] Carbon Capture and Storage

### 1.5.6 The Energy Factor

#### *1.5.6.1 Renewable Energy Production*

**Driver description**

- *"Renewable energy is already helping to generate the electricity that we use every day." (Ref: **CO_0270**)*

| | |
|---|---|
| Wind | 20.9 % |
| Solar (photovoltaic thermal) | 1.3 % |
| Biomass | 19 % |
| Hydro | 57.7 % |
| Geothermal | 1 % |
| Total electricity generation EU-27 | 3 374 TWh |
| Total renewable energy sources | 567 TWh |
| Share of renewable energy sources | 16.8 % |

Source: Eurostat

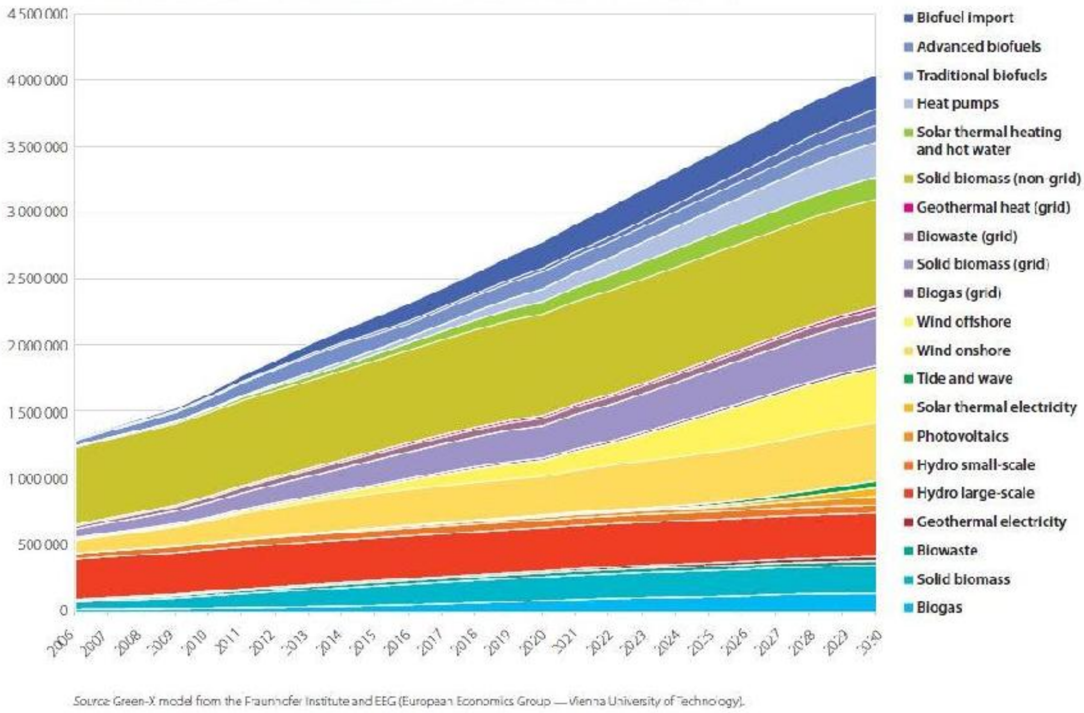
Source: Renewables make the difference (Ref: **CO_0270**)

**Figure 1-89 Contribution of renewables to electricity production, 2008 (TWh[86] and %)**

- *"Wind energy is one of the most promising renewable energy technologies and an area which has seen many developments that have made its electricity generation more effective. Between 1991 and 2006, cumulative wind power capacity in the EU increased by an average of 33 % per year. Between 1995 and 2009, cumulative wind power installations in the EU increased their capacity from 2.497 MW to 74.767 MW." (Ref: **CO_0270**)*
- *"Solar power can be converted into electricity using photovoltaic (PV) solar cells to convert light directly into electricity. This can also be done using concentrating solar power (CSP), where parabolic solar collectors or solar towers are used to focus the light to heat a single point, thereby creating steam to drive a turbine. PV plants can be connected to batteries for storage, or feed into the electricity grid. CSP heat can be stored so that power can be produced during the absence of sunlight." (Ref: **CO_0270**)*
- *"Biomass is derived from different types of organic matter such as energy plants (oilseeds, plants containing sugar) and forestry, agricultural or urban waste including wood and household waste. Biomass can be used for heating, cooling, producing electricity and transport biofuels. (…). Different types of biomass use different technologies and processes for the production of bioenergy." (Ref: **CO_0270**)*
- *"Hydro power is produced from the movement of a mass of water such as a river, canal or stream. Hydro schemes convert the potential energy of the water, flowing with a certain fall (or 'head'), into usable energy. Such schemes require a suitable rainfall catchment area, a hydraulic head, a pipe or device to carry water to a turbine, and a turbine house containing power generation and water regulation equipment. Water is returned to its natural course after it has been used." (Ref: **CO_0270**)*
- *"As renewable technologies have matured, production of renewable energy has risen steadily, and costs have come down. However, development has been uneven across the EU, and renewable energies still represent only a small share of the EU's total energy mix." (Ref: **CO_0270**)*
- *"In the power sector, renewable energy technologies, led by hydropower and wind, account for half of the new capacity installed to meet growing demand." (Ref: **CO_0152**)*

[86] Terawatt hour

- *"Renewable electricity generation has grown rapidly over the last 20 years as a result of government support in many OECD European countries. In 1990, renewables excluding hydro generated 20 TWh. This grew by a factor of 10, to 209 TWh in 2007, mainly owing to support policies such as renewable feed-in tariffs or green certificate schemes in many European countries. Most of the growth is from wind (+104 TWh) and biomass (+75 TWh)." (Ref: **CO_0153**)*
- *"Renewable energies are set to produce increasing amounts of electricity over the coming years — with projections showing that renewable electricity output could roughly triple between 2004 and 2020. Renewable heating is also on the rise — with output projected to increase consistently up to 2030. Both elements are clearly demonstrated in the graph below." (Ref: **CO_0270**)*




Source: Renewables make the difference (Ref: **CO_0270**)

**Figure 1-90 Green X-model estimate of renewable growth for the 'EU–27, 2006–2030, GWh[87]'**

- *"The share of renewable energy sources (RES) rises substantially in all scenarios, achieving at least 55 % in gross final energy consumption in 2050, up 45 percentage points from today's level at around 10 %. The share of RES in electricity consumption reaches 64 % in a high energy efficiency scenario and 97 % in a high renewables scenario that includes significant electricity storage to accommodate varying RES supply even at times of low demand." (Ref: **CO_0245**)*
- *"Because external costs of fossil fuels, such as environmental impact, are not fully considered, renewable energy is still not competitive." (Ref: **CO_0270**)*
- *"Without a significant change in policies, global electricity generation will continue to be largely based on fossil fuels to 2050 and beyond." (Ref: **CO_0153**)*
- *"(…) while renewables have begun to make their mark and provide more environmentally-friendly energy, the potential remains to increase their market share and establish them as cost-effective, widely used options." (Ref: **CO_0270**)*
- *"There is a need to invest in new renewable technologies, such as ocean energy and concentrated solar power and second and third generation biofuels. There is also a need to improve existing ones, such as by increasing the size of offshore wind turbines and blades to capture more wind and to improve photovoltaic panels to harvest more solar power." (Ref: **CO_0245**)*

[87] Gigawatt-hour per year.

- *"A number of other factors may (…) impede the financing of renewable energy projects. These may be inherent in the type of technology in question, or may vary according to project location. For example:*
  - → *A higher proportion of the cost of a renewable project is often incurred upfront than is the case with conventional, fuel-based technologies;*
  - → *Some renewable energy resources, such as wind and concentrating solar power, may be located far from demand centres. This increases the cost of interconnection. The allocation of grid connection costs is an important factor in investment decisions;*
  - → *Permitting can be a lengthy process, particularly if a project requires multiple agency approval, in some cases at local, regional and national levels of government. Projects may be delayed, and costs increased, by issues such as unforeseen public opposition or local environmental concerns,*
  - → *Perceived policy risk, driven by the possibility of negative or arbitrary changes over time in the policy environment for renewable energy technologies, can undermine investor confidence, in turn pushing up the required risk premium on investments." (Ref: **CO_0154**)*

## Interactions within the Technology Domain

### *Technology development in general and innovation diffusion*

- *"(…) the renewable energy technology industry is one which keeps on (…) developing new technologies." (Ref: **CO_0270**)*

### *Traction technologies*

- *"Vehicles running on electricity produced from renewable energy sources are another means of increasing use of renewable energy for transport. Use of such vehicles is currently low but expected to grow rapidly." (Ref: **CO_0270**)*

## Interactions with the Social Domain

### *Households structure and distribution*

- *"Energy demand in the buildings sector is driven by population, climate, incomes, service sector value added and cultural factors. These factors have an impact on the number and size of households, the heating or cooling load, the number and types of appliances owned and their patterns of use." (Ref: **CO_0153**)*

### *Education*

- *"PV power is booming, but how sustainable are the growth rates? There could be more than 600 GW of installed PV capacity by 2030, but will there be a sufficient number of skilled installers?" (Ref: **CO_0267**)*
- *"A specific skill set is required for PV installations." (Ref: **CO_0267**)*
- *"The lack of qualified installers is quite evident." (Ref: **CO_0267**)*

### *Health*

- *"Renewable energy will also help reduce air pollution thereby having a direct effect on our daily health." (Ref: **CO_0270**)*

## Interactions with the Economy Domain

### *GDP tends*

- *"(…) at a time of economic uncertainty, the renewable energy technology industry is one which keeps on growing." (Ref: **CO_0270**)*
- *"There are some signs that the necessary changes in power generation are starting to happen. Investment in renewable energy, led by wind and solar, reached an all-time high in 2008 and stayed at similar levels in 2009 despite the economic downturn. In 2009, more wind power was installed in Europe than any other electricity-generating technology." (Ref: **CO_0153**)*

*Employment*

- *"(…) the renewable energy technology industry is one which keeps on (…) providing jobs." (Ref: **CO_0270**)*
- *"According to the Europe 2020 Strategy, a more mature market for renewable energy technologies is also expected to bring about social and economic benefits such as new jobs." (Ref: **CO_0197**)*
- *"Investing early in the low carbon economy would stimulate a gradual structural change in the economy and can create in net terms new jobs both in the short and the medium-term. Renewable energy has a strong track record in job creation. In just 5 years, the renewable industry increased its work force from 230.000 to 550.000. Also for the construction sector low carbon investment offers large short-term job opportunities. With some 15 million employees in the EU, it was particularly hard hit by the economic." (Ref: **CO_0194**)*

*Energy availability and prices*

- *"As in the transport sector, shifting energy consumption towards low carbon electricity (including heat pumps and storage heaters) and renewable energy (e.g. solar heating, biogas, biomass), also provided through district heating systems, would help to protect consumers against rising fossil fuel prices and bring significant health benefits." (Ref: **CO_0194**)*

*Fiscal policy*

- *"As technologies mature and renewable deployment increases, so incentive policies will need to evolve and become more market-oriented." (Ref: **CO_0153**)*
- *"The advantages and benefits of investing in the clean energy and innovative sectors should be actively promoted whilst encouraging a more entrepreneurial spirit amongst venture capitalists." (Ref: **CO_0267**)*

## Interactions with the Environment Domain

*Climate change impacts*

- *"Using renewable energy is one effective way of making our energy supply more environmentally friendly." (Ref: **CO_0270**)*

*GHG mitigation*

- *"Renewable energy sources (…) emit no greenhouse gases or only small amounts during their lifecycle." (Ref: **CO_0270**)*
- *"Use of biomass significantly reduces greenhouse gas emissions. The carbon dioxide it gives off when burned is counterbalanced by the amount absorbed when the plant in question was grown. However, there are always some emissions from processes like cultivation and fuel production, so biomass is not completely carbon-free." (Ref: **CO_0270**)*
- *"Renewable energy sources can generate electricity with low or very low net CO2 emissions over their lifecycle. They therefore have the potential to make a significant long-term contribution to decarbonising the power sector." (Ref: **CO_0153**)*
- *"Some low-carbon generation technologies raise unique challenges. For example, system integration will be needed to support large quantities of variable renewable (such as wind, solar PV, run-of-river hydropower, and wave and tidal power)." (Ref: **CO_0153**)*

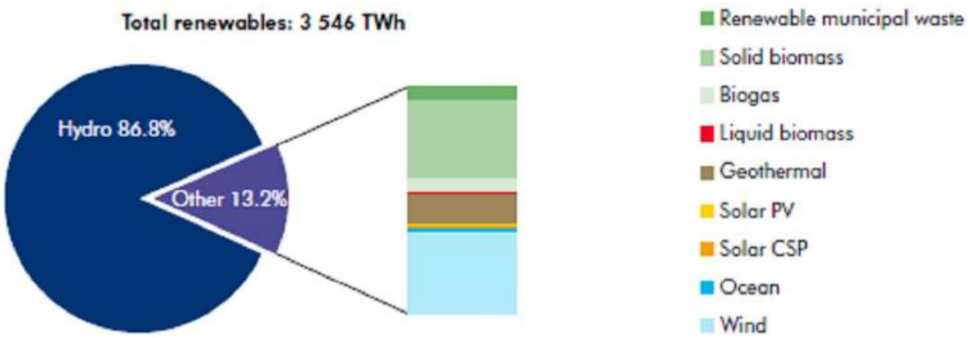
*Pollution levels and emission standards*

- *"Renewable energy will also help reduce air pollution." (Ref: **CO_0270**)*
- *"(...) the effect of renewable energy sources may be positive — the availability of wind and solar energy — or negative — the increased use of biofuels, while nominally CO2 'neutral', could lead to increased emissions of other air pollutants over a life-cycle basis." (Ref: **CO_0230**)*

*Energy availability, production and consumption*

- *"There are some promising signs of increased activity to develop and deploy low carbon electricity generating technologies." (Ref: **CO_0153**)*

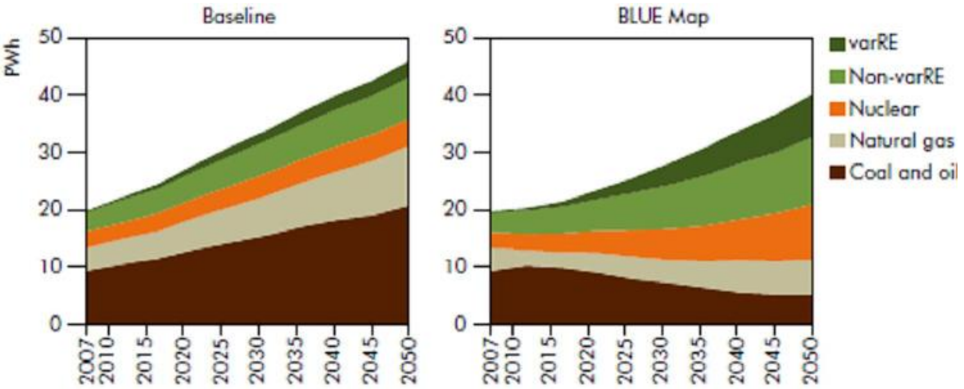
- *"Electricity generation from renewable energy grows almost threefold in the Baseline scenario. As a result it increases its share of global electricity generation from 18% in 2007 to 22% in 2050. The growth in non-hydro renewables is even more dramatic, with almost a ninefold increase. By 2050, these "new" renewables have a share of 10%, up from 2.5% in 2007." (Ref:* ***CO_0153****)*




Source: Energy Technology Perspectives 2010 (Ref: **CO_0153**)

**Figure 1-91 Composition of renewable power generation, 2007**

- *"By 2050 in the BLUE Map scenario, the carbon intensity of electricity generation has been reduced by almost 90% compared to 2007 levels. Renewable energy accounts for almost half of total global electricity production, while nuclear energy's share is just less than one-quarter. The remainder is from fossil fuels, largely combined with CCS." (Ref:* ***CO_0153****)*




Source: Energy Technology Perspectives 2010 (Ref: **CO_0153**)

**Figure 1-92 Global electricity generation mix**

- *"The share of non-hydro renewables in power generation increases from 3% in 2009 to 15% in 2035, underpinned by annual subsidies to renewables that rise almost five-times to $180 billion. (...) Accommodating more electricity from renewable sources, sometimes in remote locations, will require additional investment in transmission networks amounting to 10% of total transmission investment: in the European Union, 25% of the investment in transmission networks is needed for this purpose." (Ref:* ***CO_0152****)*

### Scarce resources of fossil fuels

- *"Given the particular vulnerability and oil dependence of the transport sector, the Renewable Energy Directive also specifies a 10 % minimum target to be achieved by all EU Member States for the share of renewable energy (biofuels, renewable electricity) in overall EU transport petrol and diesel consumption by 2020." (Ref:* ***CO_0270****)*

### Impacts on Mobility and Transport

Electricity produced from renewable energy sources might become an important source for the transport sector. So far the number of vehicles running by electricity produced from renewables is low but is expected to grow rapidly; this objective is in line with the Renewable Energy Directive which sets a 10 % minimum target to be achieved by all EU Member States for the share of renewable energy in EU transport petrol and diesel consumption by 2020.

#### 1.5.6.2 Energy Efficiency

Driver description

- *"Energy efficiency is a measure of the overall efficiency of providing energy services, i.e., the efficiency with which energy is produced from primary resources, transformed into useful forms, delivered to end users and consumers." (Ref:* ***CO_0026****)*
- *"The efficiency of the transport system as a whole is measured by transport intensities. An important measure of the efficiency of individual transport modes, is their load factors, whilst a first indicator for assessing energy efficiency and externalities is the share of modes with low energy consumption." (Ref:* ***CO_0298****)*
- *"Without energy, our society cannot survive or thrive. Yet the European Union today faces a series of tough energy challenges, due to a growing dependence on energy imports, dwindling supplies of fossil fuels and concerns about their impact on climate change. It also continues to waste a fifth of its energy through sheer inefficiency. Energy efficiency is a proven and cost-effective solution." (Ref:* ***CO_0269****)*
- *"New efficient coal technologies and the renovation and modernization of existing inefficient thermal power plants are by far the most important priorities in the short to medium term, as coal will remain a primary energy source of many OECD and developing countries, particularly China and India." (Ref:* ***CO_2019****)*
- *"In the EU we have made good progress driving greater energy efficiency into every sector — with new policies, measures and action. Energy labels can today be found on many items ranging from fridges to buildings." (Ref:* ***CO_0269****)*
- *"Improved efficiency in energy use offers one of the greatest opportunities to address energy security, price, and environmental concerns." (Ref:* ***CO_2019****)*
- *"(...) it also holds the potential to reduce CO2 emissions by 30% from current levels by 2050. Achieving this target requires a combination of improved fuel efficiency; new types of vehicles, such as battery electric (BEVs) and plug-in hybrid electric vehicles (PHEVs); and alternative fuels capable of reaching very-low CO2 emissions per kilometre (e.g. advanced biofuels)." (Ref:* ***CO_0185****)*
- *"Energy efficiency is high on the EU's list of priorities, because it contributes to many of the Union's economic, social and environmental goals. The energy efficiency plan 2011 helps keep them on track by proposing energy efficiency measures across the whole economy." (Ref:* ***CO_0269****)*
- *"Special emphasis will be paid to energy efficiency in the public sector, which is being called on to set a good example to others, as well as industry, transport and consumers." (Ref:* ***CO_0269****)*
- *"Increasing energy efficiency in all transport modes will contribute to reducing CO2 emissions. To this end, European policy and research aims to contribute to developing an appropriate fuel efficiency regulation, which will be set to support research on new technologies and engines, and to promote the market for clean and energy-efficient road transport vehicles." (Ref:* ***CO_0234****)*

Interactions within the Technology Domain

No particularly relevant interrelationships have been found.

Interactions with the Social Domain

No particularly relevant interrelationships have been found.

Interactions with the Economy Domain

*GDP trends*

- *"Since 1990, GDP in the EU has grown by about 45 % in real terms, and increased by around 2.1 % per year on average between 1990 and 2008 (ECFIN, 2010). In contrast, primary energy consumption growth over this period was 8 % (Eurostat, 2010b), which, given the GDP increase, represents a substantial improvement in energy efficiency in the production of goods and services." (Ref:* ***CO_0134****)*

*Employment*

- *"Further benefits include the creation of new business opportunities and a more innovative and competitive economy, through the development of energy-efficient technologies, products and services." (Ref: **CO_0269**)*
- *"Who knew that both unemployment and excessive energy use could be tackled by a single programme? (…) longterm unemployed individuals have been trained as energy-savings advisors." (Ref: **CO_0267**)*

*Regional differences in economics*

- *"Several factors explain why these variations in energy consumption levels per unit of economic output are so different amongst countries. Part of the difference reflects variations in energy efficiency. However, it would be misleading to rank energy efficiency performance according to a country's energy consumption per GDP measured using either PPP or MER." (Ref: **CO_0183**)*

*Availability of public and private resources and investments in the transport sector*

- *"By saving energy, we can save money." (Ref: **CO_0269**)*
- *"The plan provides guidance for all Europe's energy efficiency efforts. It injects new impetus into EU efforts to achieve the target of 20 % energy saving by 2020. If we can reach the 20 % target by 2020, everyone will enjoy the benefit of substantial cost savings. Europe could, for example, then reduce its annual energy bill by some EUR 200 billion, which is the equivalent of not using around 370 million tonnes of oil. Per household, this means EUR 1 000 saved every year." (Ref: **CO_0269**)*
- *"Financial barriers to energy efficiency measures must come down as quickly as possible, whether they apply to the private or public sectors. With an eye on its 2020 energy and climate goals, the EU is boosting investment in and mobilising the market for energy efficiency through new financial programmes and instruments, innovative partnerships and better use of existing funds." (Ref: **CO_0269**)*

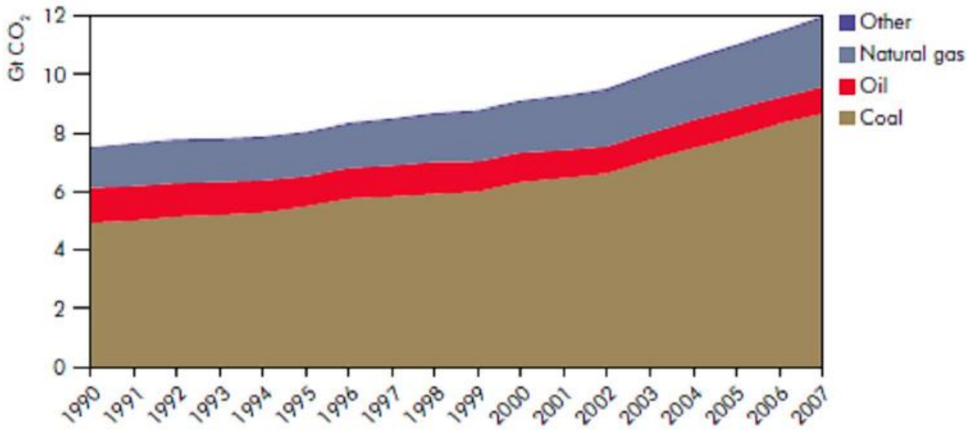
*Energy availability and prices*

- *"These findings provide an important policy conclusion — that the changes caused by the oil price shocks in the 1970s and the resulting energy policies did considerably more to control growth in energy demand and reduce $CO_2$ emissions than the energy efficiency and climate policies implemented in the 1990s." (Ref: **CO_0183**)*
- *"Taken over the whole 40-year period, it is estimated that energy efficiency and the switch to domestically produced low carbon energy sources will reduce the EU's average fuel costs by between € 175 billion and € 320 billion per year." (Ref: **CO_0194**)*

## Interactions with the Environment Domain

*Climate change impacts*

- *"Accelerating energy efficiency improvements is a crucial challenge for energy and climate policies." (Ref: **CO_0183**)*
- *"Between 1990 and 2007, CO2 emissions from global electricity production increased by 59% to reach 12 Gt (…). Most of the rise in CO2 emissions was driven by increases in electricity generation from coal. In 2007, coal-fired power plants accounted for 73% of total emissions from the sector, up from a share of 66% in 1990. Total CO2 emissions from natural gas-fired plants are around only 25% of those from coal, despite the fact that they generate nearly half as much electricity. This is due to gas having a lower carbon content than coal per unit of delivered energy, together with the higher average efficiency of gas-fired electricity generation compared to coal plants." (Ref: **CO_0153**)*




Source: Energy Technology Perspectives 2010 (Ref: **CO_0153**)

**Figure 1-93 $CO_2$ emissions from global electricity generation**


Source: Towards low carbon transport in Europe (Ref: **CO_0234**)

**Figure 1-94 GHG emissions in the EU27 by transport mode**

*GHG mitigation*

- *“If the EU delivers on its current policies, including its commitment to reach 20% renewables, and achieve 20% energy efficiency by 2020, this would enable the EU to outperform the current 20% emission reduction target and achieve a 25% reduction by 2020. This would require the full implementation of the Energy Efficiency Plan (...) which identifies measures which would be necessary to deliver the energy efficiency target.” (Ref: **CO_0194**)*
- *“By saving energy the EU (…) can reduce carbon emissions and move more swiftly towards its goal of a 20 % reduction in primary energy use by 2020.” (Ref: **CO_0269**)*
- *“Significant reductions in greenhouse gas emissions can be achieved by increasing the energy efficiency of transportation equipment.” (Ref: **CO_0272**)*
- *“Energy efficiency can potentially make the largest contribution to reducing energy use and carbon dioxide (CO2) emissions over the period to 2050. Historically, improvements in energy efficiency have been one of the most important drivers of reductions in energy intensity. Without the energy efficiency gains achieved in OECD countries over the last 35 years, current energy use would be 63% higher than it is.” (Ref: **CO_0154**)*
- *“The longer the distance travelled per unit of fossil fuel, the more fuel-efficient the transport mode. Thus, an increase in a vehicle’s fuel efficiency will reduce its CO2 emissions.” (Ref: **CO_0234**)*
- *“Global CO2 emissions from (LDV) will fall by roughly 0.2 gigatonnes (Gt) in 2020 and 1.5 Gt in 2050. This excludes savings . (trucks, ships, aircraft, etc.) by estimated achievable amounts (improvement of 30% to 50% efficiency, depending on the mode) yields total savings to the transport sector of approximately 0.5 Gt in 2020 and 3 Gt in 2050.” (Ref: **CO_0185**)*

- *"The developments in the energy sector over the next 30 years depend crucially on the role of some key technologies and fuels on both the demand and the supply side. They act to lower CO2 emissions through a combination of:*
  - → *improvements in energy intensity by e.g. increasing the energy efficiency on the demand and supply side, a substitution of energy-intensive products, and lower demand;*
  - → *switching from fossil fuels to fuels with lower carbon content, e.g. from coal to natural gas;*
  - → *increasing the share of non-fossil fuels and technologies, e.g. renewable energies and nuclear power." (Ref: **CO_1027**)*

*Pollution levels and emissions standards*

- *"(...) energy efficiency improvements and other measures that encourage reducing fossil fuel combustion provide general benefits by also reducing emissions of air pollutants." (Ref: **CO_0230**)*
- *"(...) measures to achieve greater fuel efficiency and carbon intensity will also improve local air quality and that measures to manage demand can have much wider impacts on congestion and safety." (Ref: **CO_0054**)*
- *"While many resource-efficiency initiatives relate to production, questions regarding consumption are also being addressed. Studies are being carried out on the 'rebound effect' – the idea that the introduction of technology and policy instruments intended to improve environmental efficiency might have the unintended side effect of increasing consumption. Home insulation, for example, to make a home more thermally efficient and cheaper to heat, might result in householders leaving the heating on for longer or at a higher temperature, cancelling out the efficiency gains." (Ref: **CO_0243**)*

*Energy availability, production and consumption*

- *"By saving energy (…) the EU can enhance the security of its energy supply." (Ref: **CO_0269**)*

*Scarce resources of fossil fuels*

- *"The benefits of more efficient use of energy are well known and include reduced investments in energy infrastructure, lower fossil fuel dependency (...)" (Ref: **CO_0183**)*
- *"We are reducing our reliance on fossil fuels by increasing energy efficiency and developing alternatives." (Ref: **CO_0195**)*
- *"In the electricity generation sector, if all countries produced electricity at current best practice levels of efficiency then fossil fuel consumption for public electricity generation could be reduced by between 23% and 32%." (Ref: **CO_0183**)*

*Scarce resources of raw materials*

- *"The industrial sector is dominated by the production of few major-intensive commodities such as steel, paper, cement, and chemicals. In any given country or region, production of these basic commodities follows the general development of the overall economy." (Ref: **CO_0105**)*
- *"Greenhouse gas emissions and energy use by industry are still dominated by a relatively small number of basic energy-intense industries (...). The industries are primarily involved in upgrading natural resources to materials used in society and are relatively large emitters of pollutants and greenhouse gasses (...). Material consumption is still increasing and this growth is apparent for "classic" materials (e.g. cement, steel) and for new materials (e. g. plastics, aluminum)." (Ref: **CO_0105**)*

**Impacts on Mobility and Transport**

*Energy efficiency and transport*

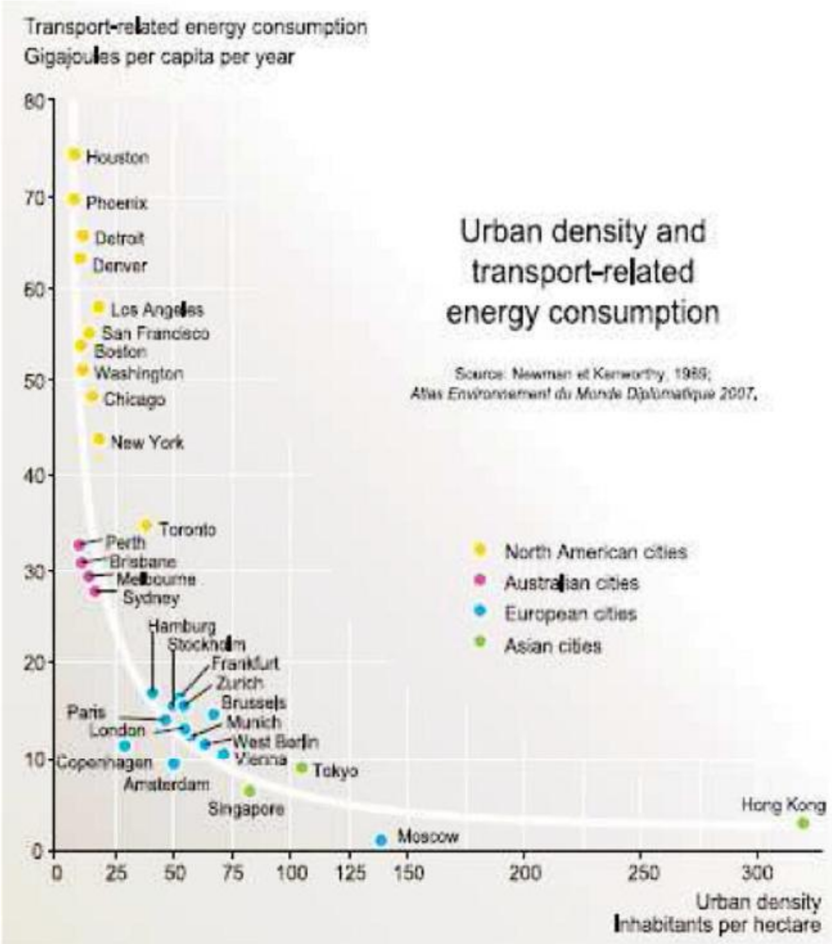
- *"Transport has the second largest potential (in energy saving)." (Ref: **CO_0198**)*
- *"(...) transport – which accounts for 32% of final energy consumption – is a key area for energy savings.)" (Ref: **CO_0198**)*
- *"The overall energy intensity of freight transport declined by 5% between 1990 and 2005 as reductions in the intensity of individual modes more than offset the increased share of energy-*

*intensive trucking. In the case of trucks, the reduction in the energy intensity of trucking was most strongly influenced by an increase in load factors." (Ref: **CO_0183**)*

- *"Globally, energy consumption grew most quickly in the transport and service sectors, driven by rising passenger travel and freight transport, and a rapid expansion in the service economy." (Ref: **CO_0183**)*
- *"According to the U.S. Department of Energy (DOE), transportation energy use is expected to increase 48 percent between 2003 and 2025, despite modest improvements in the efficiency of vehicle engines." (Ref: **CO_4012**)*
- *"There is an impressive variety of technology options to improve the fuel efficiency of passenger cars: in the next 10 to 15 years it is technically feasible to reduce the specific fuel consumption by more than half while retaining today's vehicle characteristics. If reductions in power and vehicle size are taken into account, even higher reductions can be achieved." (Ref: **CO_0017**)*
- *"Energy intensity can be reduced by improving the efficiency of the vehicle drive train, reducing dissipative forces on the vehicle (for example, by improving aerodynamics, reducing vehicle weight, or lowering rolling resistance), changing drivers' acceptance of smaller vehicles and less powerful engines and driving behavior (reducing "lead-foot" acceleration and deceleration)." (Ref: **CO_5046**)*
- *"The pace of technological change in railway rolling stock is fairly slow because railway rolling stock have long lives. Locomotives are typically rebuilt many times. The relatively slow turnover of both locomotives and freight cars has slowed the penetration of energy-efficient technologies into the railroad system." (Ref: **CO_0272**)*
- *"Fuel efficiency standards can be tightened, tyre programmes can be extended to other auxiliary vehicle components, and eco-driving training can be more frequent and widespread. Monitoring and enforcement of existing policies is crucial to ensure full compliance with the measures. There are also other new policies, not recommended by IEA, which warrant consideration." (Ref: **CO_0247**)*
- *"However, increasing energy efficiency of the transportation system takes time, typically 15 years or more between efficiency gains in new equipment and comparable efficiency gains for the entire fleet of transportation vehicles." (Ref: **CO_0272**)*
- *"The transport system of 2030 will at least superficially resemble that of 2010: It will be based on cars, trucks, trains, planes and ships, but these will be much more efficient than today." (Ref: **CO_0284**)*

***Making transport greener***

- *"Some modes are generally less $CO_2$-intensive and also more efficient than other modes. For example, rail is less $CO_2$-intensive (more efficient) than air for both freight and passenger movement." (Ref: **CO_0153**)*
- *"Greenhouse-gas reductions for transport will come from three main sources:*
  - → *Modal shifts in urban short-distance travel and in long-distance travel from, for example, the greater use of high-speed trains.*
  - → *Efficiency improvements from new technologies that allow vehicles to reduce their energy use and from operational changes in truck transport management.*
  - → *Alternative fuels which allow vehicles to emit less $CO_2$-eq per unit of energy used, for example through the use of less carbon-intensive energy sources." (Ref: **CO_0153**)*




Source: Urban transport energy consumption: determinants and strategies for its reduction (Ref: CO_0208)

**Figure 1-95 The Newman and Kenworthy hyperbola: Urban density and transport-related energy consumption**

- *"Enhancing the fuel economy of vehicles and vehicle fleets is the single most important measure to put into action over the next decade to curb fossil fuel use and reduce CO2 emissions within the transport sector." (Ref: **CO_0185**)*
- *"Green Public Procurement is a powerful market mover for the introduction of new technologies and stimulates procurement of energy-efficient and low-carbon vehicles. This initiative is directed to national, regional and local contracting authorities and contracting entities and operators of public transport services. Directive 2009/33/EC on the Promotion of Clean and Energy Efficient Road Transport Vehicles (EC, 2009c) aims at stimulating broad market introduction of environmentally friendly vehicles. The Directive requires that energy and environmental impacts linked to vehicle operation be incorporated in purchase decisions. These lifetime impacts include vehicle energy consumption, CO2 emissions, and emissions of the regulated pollutants of NOx (Nitorgene Oxide), NMHC (Non-Methane Hydrocarbon) and PM (particulate matter)." (Ref: **CO_0234**)*

## 1.6 Conclusions on Key Trends Influencing Current and Future Mobility Patterns

### 1.6.1 Premise

This section is intended to present the authorsôunderstanding of current and future trends potentially impacting on mobility patterns as emerged during the literature review. The authors are aware that diverse interpretations may arise from the reading of the document as in several cases reviewed literature provided different, if not contradictory, interpretations of the same phenomenon. Additionally, several other hypothetical scenarios may arise when considering the combination of different factors, thus making it more difficult to reach an indisputable point of view.

Therefore the synthesis provided in the next pages should not be intended as substitutive for a full reading of this deliverable which will allow the reader to draw his/her own conclusions.

### 1.6.2 Key Drivers and Trends

In the sections above the reader was provided with a wide, even though still not exhaustive, review of key factors and drivers that will contribute to the development of the next European scenarios and its future mobility patterns.

The scanning of the Social, Economic, Environmental and Technological domains has revealed that all of them could play an important role in reshaping future mobility: every domain has relevant driving forces that, by their own or in combination with others, could substantially impact on transport demand.

The review has also disclosed that in most cases it is hard, if not impossible, to predict the intensity of such impacts as well as their rapidity in the course of the years. In fact, the speed by which environmental and technological mutations could take place is really hard to predict, and thus their implications on the planning and development of the future transport system.

As witnessed by the current European situation, it is also very hard to predict the development and the implications of economic, political and financial decisions on the global market, affecting in second order overall mobility of people and goods. Less challenging could be the prediction of the impacts deriving from demographic factors whose dynamics, unless there are disruptive events, can be more easily understood and forecast.

The literature review confirmed that some drivers will have a central role in shaping future mobility patterns.

The **ageing of European population** is the result of different demographic factors: trends in fertility showing a reduction of birth rates, increased life expectancy due to the medical progress as well as migration dynamics and policies. Population ageing is an ongoing phenomenon that is expected to have an impact on several domains.

As shown in some studies, the overall size of the population is projected to be slightly larger in 50 years time, but much older than it is now: by 2060, the median age of the Europeans is projected to be more than 7 years higher than today and the number of people aged 65 or more is expected to represent 30% of the population as opposed to 17% today.

Ageing is expected to occur differently across Member Countries: the highest shares of old age population are likely to be found in Eastern Germany, North-West of Spain, Italy and some parts of Finland. In Central and Eastern Europe the impacts of ageing will be delayed owing to their younger population and lower life expectancy.

According to some authors, an ageing population could represent a huge problem for the economy: given the decline in labour supply, the annual average potential GDP growth rate for the EU27 is projected to decline. The decline in the working age population will vary across countries with some regions (suffering from a combined effect of low fertility and high out-migration) particularly hit.

The fiscal impact of ageing is projected to be substantial in almost all Member States, with effects becoming apparent already during the next decade. Most of the projected increase in public spending will be on pensions, health care, and long-term care.

Recent demographic projections show that in 2060 there will be only two active workers for every pensioner. Therefore it can be expected a big pressure on the European economic system in the next decades probably only in part mitigated by new pension reforms that have been developed in many countries in recent years.

Generally, the average income from receiving a state pension is much lower compared to an average income earned by an economically active person. Therefore the ageing population is an important concern when considering poverty reduction.

While life expectancy is slightly increased in the last decades reaching 82 and 76 years respectively for women and men, healthy life years remained almost stable at a threshold of about 62 years for both genders. These gaps in life expectancy and healthy life are expected to lead to increasing numbers of elderly with disability and the need of long-term care in some Member States.

The ageing of population will change the householdsô structure (smaller family units) so that social institutions will be required more and more to replace family care. More resources will be needed for structures and services dedicated to people in age: their specific needs will have to be addressed in urban planning, infrastructures and services design.

As far as mobility is concerned, also transport supply will need to adapt to elderly people, especially in terms of accessibility, availability of public transport, user-friendliness of payment systems, safety and security.

In this respect the future technology will play a fundamental role in preserving and supporting the mobility of the elderly through the adoption of new vehicle design for both private and public transport sector, the provision of new services expressly tailored to the new needs and, given the reduced capabilities, the development of devices that are easy to use.

The effect of ageing on the total amount of transport demand is not straightforward to predict since it strictly depends on activity rates and income distribution. If the retirement age will be raised, everyday mobility patterns might not change dramatically even if a tendency towards shorter distances and public transport could be observed. However, if elderly people will be able to enjoy many years retired with a good income, commuting daily trips could be reduced whereas leisure and tourist trips could be increased.

**Migration** has become an increasingly important phenomenon for Europe: in 2009, about 3.0 million people immigrated into one of the EU Member States while at least 1.9 million emigrants were reported to have left an EU Member State.

A particular distinction must be made between intra-EU migration and migration from outside of the EU. Subject to some transitory restrictions on citizens of new Member States, EU citizens have the right to live and work in other EU Member States; they are not subject to limits on the numbers that may be admitted, and are exempt from restrictions as to duration of residence and access to the labour market that may be applied to third country nationals (persons who are no citizens of an EU Member State).

**Intra-European** migration flows are very diverse. They comprise retirees from northern European regions moving south to the Mediterranean regions as well as East-European workers in search of jobs moving to West-European countries.

Alongside traditional migration and mobility, new forms of mobility are taking place. People are moving abroad for shorter periods to seek work, pursue their education or other life opportunities. These mobile people tend to be well-educated young adults, towards the higher end of the occupational scale. Increasingly, this form of mobility is based on personal preferences and life choices, and not only on economic opportunities.

Intra-European flows will probably intensify in a scenario shaped by weakened national borders and increased regional disparities.

When looking at **inter-European** migration, recent studies show that in 2010 4% of the total EU-27 population (20.1 million) were citizens of a non-EU27 country. The distribution by continent of origin of third country nationals living in the EU shows that 7.2 million people were citizens of a European country outside the EU (of which more than half were citizens of Turkey, Albania or Ukraine). The second biggest group was from Africa (mainly North Africa, often from Morocco or Algeria), followed by Asia (in particular from India or China) and the Americas (Ecuador, Brazil and Colombia).

Patterns of migration flows are influenced by several factors such as labour migration, historical links between origin and destination countries and established networks in destination countries.

Future trends in migration are hard to anticipate, as they depend on future events across the world ranging from economic and social factors to political developments. Even though the global economic crisis has slowed emigration in many parts of the world, with economic recovery and job growth, most consider this slowdown to be temporary.

Recent projections for the EU as a whole show that annual net inflows are estimated to increase from about 1 million people in 2010 to 1.2 million by 2020 and thereafter declining to 878,000 people by 2060. The cumulative net migration to the EU over the entire projection period is 55 million, of which most is in the Eurozone (42 million).

Migration flows are projected to be concentrated on few destination countries: Italy, Spain and the UK. For countries that are currently experiencing a net outflow (mainly Eastern European countries), this is projected to taper off or reverse in the coming decades.

Whereas migration used to be in the past predominantly a one-off movement leading to permanent resettlement, recent migration is more fluid, thanks to improved transport and communication networks. Migrants today may make consecutive stays in different countries, or alternate residence between countries.

Given the lower median age of migrants, migration flows could mitigate the speed of European population aging. However, studies reveal that in order to offset the population decline, immigration to Europe should double in the coming years. Unless future migration policy will not change dramatically, the ageing of European population and its impact on labour will only be slightly compensated by younger migrants.

Although the travel behaviour of immigrants and their attitudes toward different travel modes are generally scarcely researched by national travel survey in European countries, some studies reveal that, especially at the beginning of their experience, migrants are mainly concentrated in urban areas and, given the lower economic standards, have generally lower access to cars, travel less and mostly by public transport or by walking.

Nevertheless, studies reveal also that many of the immigrants had access to a car and a driver license in the country of origin, and many would like to have a car and a driver license in the future again. This implies that their current mobility patterns are expected to change in case of improved economic conditions (following their integration in the society), and thus the differences in mobility between the immigrants who have stayed longer in their new country and the domestically born is expected to decline in the future.

When considering long-distance mobility, migration and tourism tend to become mutually interacting phenomena whose importance is rapidly growing. Some empirical results show that as the stock of immigrants increases from a certain country ceteris paribus the number of VFR (Visiting Friends and Relatives) trips from that particular country rises.

Given the expected trends in migration flows, increased movements of people within Europe and between Europe and the origin countries can be easily forecast, as well as an increase in the demand for international and intercontinental transport services.

Mobility is strictly dependent on **income level**: lower incomes are usually accompanied by reduced trip rates while on the contrary higher incomes are associated with increased mobility. The main source of income for individuals and households in the EU is earnings from employment. Nevertheless, the reviewed literature showed that both earnings and income inequalities have increased in recent decades for most EU states, with the level of inequality varying between Member States as well as within them.

Some studies show that a combination of factors, including economic restructuring, reduction of protection in the labour market, cuts to the welfare states, restrictive monetary policies within the stubborn anti-inflationary European Monetary Union framework account for these increases in inequality in the last two to three decades. In particular labourôs share of value added has fallen especially among the low paid. This means that employment no longer provides a guarantee against poverty and exclusion. In 2007, 17 families out of 100 in Europe were considered at risk of poverty.

Several authors argue that boosting debt as a way to sustain demand depressed by stagnating wages plays a major role in the current global crisis.

In addition, new forms of social exclusion and poverty are emerging: ñinfrastructure-poorò (Eastern Europe); ñfeminisation of povertyò, mainly among single, immigrant mothers (Southern Europe); ñimmigrant povertyò (Central Europe and other countries); ñyoung people at risk of povertyò (Eastern and Southern Europe); ñthe vulnerable elderlyò (Eastern and Western Europe).

Given the current policy orientation to address the debt crisis affecting the European economy, it might be expected that the trends in inequality and in poverty will be not slowed or reversed in the near future, especially in those countries suffering more from the current situation. Additionally, income inequalities might increase migration flows given prevailing wage differentials and employment opportunities between poor and rich countries.

Since transport systems must be planned in order to offer transport choices for both rich and poor people, in a scenario with increasing income inequality and poverty this aspect could be a major challenge for the future. Private mobility might become unsustainable for an increased share of the population and reliable, safe, and affordable public transport options might have to be offered to an expanding number of poor people, thus putting more pressure on public transport policies and on the need for subsidies. The need for cheaper public transport options, both for short and long distances, might be also exacerbated by fiscal policies increasing fuel and car ownership taxes. On the other side, people with higher income could increase their demand for faster transport modes.

In a scenario of recovered economic growth and rising income levels, a rising demand for mobility might be expected, both in terms of number of trips and total length, with travellers shifting from public modes (bus, railroads) to the private car and increasing the demand for faster modes (high-speed rail and air).

**Car ownership** is an important determinant of passenger travel behaviour and it is fundamentally interconnected with residential location and decision-making regarding motorised trips.

Ownership rates increased significantly during the 70s, and for lower-income households during the 80s, but flattened and declined in some cases during the 90s. The period of growth in per capita vehicle ownership rates coincided with Baby Boomerôs peak driving years, significant growth in the proportion of women employed outside the home, rising disposable income, low fuel prices, and suburbanisation.

In industrialised countries most of these factors have peaked and many are now reversing.

The car ownership rate in Western Europe is reaching saturation point, and a confluence of events and changes in lifestyle may lead to a possible reduction in the next decades.

Nowadays people living in urban areas are provided with several public transport and car sharing options to satisfy their mobility needs, and slow mobility (walking and cycling) is gaining increasing attention; the ageing population will inevitably modify its long-term mobility patterns relying more and more on public transport as driving capability will expire; the observed trends of re-urbanisation and consumersô increased preference for walkable neighbourhoods will probably slow down the urban sprawl trends and reduce car dependency; in addition, (as further explained later on when discussing the change of lifestyle) younger generations are showing more interest in technological gadgets and social networks rather than in owing a car.

Despite the positive environmental effects, reduced car ownership might have implications for the European transport sector finance given the consequent reduced revenues from fuel and vehicle ownership taxes, and alternative sources might have to be found to support investment in the sector.

Economic development has historically been strongly associated with an increase in the demand for transportation and particularly in the number of road vehicles. This relationship is also evident in the developing economies today with car ownership rapidly expanding with important implications for transport and environmental policies, as well as for the global oil market.

In the past decades the development of European cities was driven by **urban sprawl** with cities becoming much less compact even in the absence of demographic pressure. Urban expansion was mainly driven by economic growth and restructuring, new employment opportunities, growth of transport infrastructure, household change, as well as a decline of traditional rural economies.

Ruralï urban migration and the transformation of rural settlements into towns and cities have been important determinants of rapid growth of cities but there has also been a general convergence in lifestyles between urban and rural areas as advances in transportation and telecommunication have caused distance and time to collapse. Urban functions are being spread over larger and larger geographic areas so that the traditional distinction between urban and rural areas is becoming increasingly redundant for many purposes.

From an economic perspective urban sprawl is a costly form of urban development due to: increased household spending on commuting from home to work over longer and longer distances; the cost to business of the congestion in sprawled urban areas with inefficient transportation systems; the additional costs of the extension of urban infrastructures including utilities and related services across the urban region. On the environmental side, sprawl related growth of urban transport and greenhouse gas emissions have major implications for global warming and climate change, with the expectation of increasingly severe weather events in the coming years and increased incidences of river and coastal flooding.

Recent studies shows that urban sprawl, as a dominant trend in the post-war era, is not expected to disappear in the coming years, but for reasons linked to land scarcity and costs and to appreciation of city life, the increase in urban sprawl may diminish. There is some evidence that sprawl has already reached its peak in many cities and, in parallel with the sprawl reduction, a certain trend towards **re-urbanisation** is being observed with inner-city areas becoming more attractive to new target groups (e.g. high-income households, small families, older people etc.).

The reduction of urban sprawl may have major implications for mobility and transport especially on reduced travelled distance, lower dependency on the car, and thus on fuel, and reduced road congestion in accession to the city.

Specific transport adjustment and planning might be needed, as urban areas will increasingly need to manage the demand profile: by 2050 more than 80% of European population is expected to live in urban areas, thus putting more pressure on urban transportation systems.

Some studies identify Intelligent Transport Systems (ITS) as playing a key role in this given their great possibilities to monitor networks, manage pricing schemes, provide traveller information and enable use of in-vehicle devices.

On the supply side, the diversification of energy sources, fuel types, and vehicles might be greatest in urban environments where the transport and distance requirements are more compatible with diversified energy types and new energy distribution infrastructures.

Although planning and technology can do much to improve mobility, many future challenges are shaped by peopleœ behaviour and preferences. Sustainable mobility concepts are more likely to emerge in the urban environment, with greater attention of people towards active travel (walking and cycling), combined with the use of high quality public transport (which can be more cost-effectively organised in compact urban environments) and information services. Currently, cycling and walking account for approximately 13 % of urban passenger-km in Europe, but best-practice examples show this share can be much higher.

Like in the rest of the world, the European tourism industry was severely affected by the global economic recession in 2008-2009 with the region overall suffering a decline in arrivals and a fall in receipts. Although in 2011 the sector showed a certain recovery, surpassing the previous peak set in 2008 of about 494 million arrivals (both intra-European and non-European), new signs of eroding gains began to appear: recent studies show that travel to European destinations has slowed in recent months reflecting the combination of fiscal austerity and financial market stress brought about by the Eurozone debt crisis which is affecting both consumer and business behaviour. Furthermore, the spectre of a global recession is not an insignificant risk as even emerging markets have begun to slow.

These trends confirm once again the great dependency between economic welfare and **tourist flows** and make it extremely difficult to make forecasts for future trends.

In a suffering economy travellers may heavily change their behaviour by reducing tourism trips and shortening both distance and duration. Also business travel may be affected through companies curtailing business trips. As already registered, an economic recession may be associated with a decline in air travel.

In contrast, in a scenario of growing economy, tourist trips would increase both in number and distance, as witnessed by the growing domestic and intra-regional tourism also in emerging economies. Migration can further boost this phenomenon by increasing the demand for visiting-friends-and-relatives trips.

Besides the economic factor, other aspects may influence the development of tourist flows, making their prediction more difficult, especially in the longer term. Europe has always been one of the preferred destinations for tourism and is expected to remain a 'dream' leisure and cultural destination especially for intercontinental travellers: it now receives about 3.8 million Chinese annually, exceeding the Japanese incoming flow by 200,000 units, and the Indian market has been generating increases in tourist numbers, even for the mature European destinations that are finding it difficult to attract larger numbers from their traditional markets.

Nevertheless, as shown by some literature, non-European tourism demand growth over the foreseeable future could be compromised by cost and new emerging alternatives: developing economies are increasingly more open to explore newer destinations and many of these are in Asia. Furthermore some studies highlight the impact of the way a visa is delivered in either facilitating inter-European tourist flows or hindering them considerably. As an example, the European destinations that have most benefited from the growing demand from Russia in recent years have been those offering visa-free travel, or at least visas on arrival.

On the environmental side, reviewed literature unanimously shows that climate change may also reshape the distribution of seasonal tourist destinations. Contradictory views can be detected when exploring the potential impacts of GHG mitigation policies (implemented through fuel taxes or carbon-emission charges) on the tourism sector: some studies maintain that these policies might increase costs of tourism and reduce its growth, while other studies find no significant impacts.

Mobility patterns are also heavily affected by **changes in lifestyle and values**, but it is difficult to make future estimates about the intensity and timing with which these will impact on levels and distribution of demand. These changes could affect both short and long-distance mobility.

Everyday mobility can be reduced given the home-working and home-entertainment options provided by new technologies. Different kind of activities can be currently executed via web (e.g. e-shopping, e-banking, e-booking of different services etc.) with these options becoming more and more available in the future with an increasing number of users due to the natural decline of digital illiteracy in the population. Additionally the diffusion of immersive networking technology, especially among young people, may lead to the development of different sets of mobility preferences with future generations who are likely to spend more time in virtual spaces.

Nevertheless the potential impacts of telecommunications technology on life-style and travel demand tend still to be educated guesses. One critical difficulty is the lack of data that can support the effort to determine whether in-home activities may substitute for out-of-home activities, whether out-of-home activities will be suppressed, or whether new out-of-home activities will be induced as a result of new telecommunications technology.

In any case it seems hardly believable that a dramatically decrease in everyday mobility will occur given the natural and psychological need of movements in human beings: some studies highlight that the daily amount of time spent on travelling by individuals is around 1.1 hour a day and it only slightly changed over historic periods.

On the other side, the intensification of information flows is increasing the interest of Europeans in international experiences. This factor, together with the reduction of air fares, has heavily changed mobility by increasing the demand for long-distance leisure trips and changing the way Europeans conduct business or, more in general, their lives.

The technological development has played an important role in this respect allowing for consumers to search the internet intensively for offers and bargains, book at the last minute and be very price-sensitive.

Changing values can also impact on demand distribution ñn spaceò as in the case of re-urbanisation driven by a new perception of urban living, ñn timeò as in the case of flexible working times taking place in several economic sectors, and ñn modesò as in the case of increased environmental consciousness especially among young people. This last factor is further supported by the evidence, included in several studies, that obtaining a driving licence as part of the initiation into adult society is no more considered as a need among young people and that the popularity of the car as a status symbol is declining, especially as alternative status symbols (such as smart technology devices) emerge.

The impact of an emerging ñsustainable consumptionò culture on transport could be important. During the Twentieth Century, walking, cycling and travel by public transport were stigmatised, but in recent years alternative modes have become more socially acceptable. For example, bicycle commuting is increasingly accepted and even prestigious. Although cars are still expected to be the dominant mode in the future, with the largest mode share and mileage, alternative modesô growth rates are expected to be larger.

The degree to which travel behaviour will actually change will be also driven by current and future policy and planning decisions: travel demand will be increasingly amenable to alternative modes and mobility management strategies. So far not enough distinction was made between users on the basis of their different orientations, needs and demands. Instead they are treated as a homogeneous group. The TRANSvisions study already highlighted the need to identify and address target groups for different services of sustainable transport, thus identifying the groups who contribute to a greater or lesser degree to GHG emissions and who could therefore be more targeted by incentives or restrictions.

As far as the **economy domain** is concerned, the analysis of the documents gathered and surveyed has highlighted several relationships between this field and the transport sector; in this respect, the interaction seems bidirectional, as the demand of transport (both for passengers and freight) may sustain the economic growth, while on the other hand, economic growth is generally positively associated with the growth of travel demand. Moreover, a wealthier economy (namely, higher per-capita GDP) encourages people to change habits, beliefs and values for example demanding for more expensive transport modes, inducing higher car ownership rates, high speed train services and diversion to air transport.

Nevertheless, the understanding of the whole interaction remains knotty and still difficult to disentangle, because of the complex causal and feedback mechanism that are involved. Decoupling economy and transport is a cornerstone, as the historic link between GDP and traffic growth should be broken-up towards a more sustainable economic growth based on a lower transport intensity rate.

After the economic peak of 2000, within the European Union the GDP per capita grew rather slowly during the downturn between 2000 and 2003. This was followed by a period of relatively higher growth rates until 2007 and thereafter it switched to a negative trend when the fragile foundations of that growth (debt, real estate bubbles and so on) became eventually too weak to sustain the economy. The future is highly uncertain, especially for the Eurozone. Currently its outlook is rather negative at least until the end of 2012. According to influential economic scholars, the longer term perspectives depend on the capacity of European and national institutions to tackle the structural problems of the European Monetary Union, first of all the productivity imbalances between European countries within a single currency area but independent fiscal policies. This way the deliberate deflationary policy of the most productive countries cannot be counterbalanced by currency depreciation of less productive ones. However, this issue seems not to be amongst the priorities of the current political agenda for the crisis, so the break-up of the Eurozone might not be excluded and consequences are hardly predictable.

Therefore, in the current European scenario any long-term forecast about the **GDP trend** is extremely hard. According to recent predictions of the International Monetary Fund, nowadays the economic recovery remains still uncertain and the unemployment rate is foreseen to stabilise at high levels within the mid-term. As a consequence, it seems hard to envisage any noticeable variation of transport demand both for passengers and freight.

Even energy consumption is strongly related to the economic status. In turn, it will depend on the availability of resources of raw materials, till energy production will be mainly based on renewable sources. Records on the link between energy intensity and economy show that energy intensity decreased from 1996 to 2000, remained almost constant from 2000 to 2003 and fell again from 2003 to 2009. This is a result of GDP growth slowing faster than gross inland energy consumption during economic downturns.

In the survey carried out about the economy domain, the attention has been focused also on the interactions with the environmental side emphasising that the impacts of the economy and transport activities are related to contingent patterns, as clearly shown by the reduction of GHG emissions in 2008 and 2009. Crisis periods have influence both on mobility and production rates, determining a remarkable reduction of the pollutants emission; in detail, within the OECD countries the amount of $CO_2$ due to transport related activities has fallen by nearly 4% from 2007 to 2008 and all transport sub-sectors have seen emissions fall as a result of the crisis, except for international aviation.

Broadly, it has been argued that any GDP variation influences the environment. Nevertheless this relationship relies not only on economic growth, but also on governance; under this assumption, advancements in governance are positively associated with higher quality of air and water.

Predicting transport flows on a large scale, the GDP as driver variable cannot be looked at in aggregate terms because of the dispersion of the rates led by local and specific territorial differences.

In 2009 GDP per capita in the European Union varied widely amongst Member States, showing figures higher than the EU average in Luxemburg (by 171%), Ireland (by 27%), The Netherlands (by 31%), Austria (by 24%), Denmark (by 21%) and Sweden (by 18%). The countries below the EU average were in Eastern Europe, namely: Romania (54%), Latvia (48%) and Lithuania (45%). Economies vary across regions due to uneven distribution of wealth, resources endowment, openness to international trade and the possibility of the population to access available resources. The gap between regions is expected to enlarge due to the persistence of the current economic situation.

As regards the most advanced European countries, they have built much of their growth on intra-EU export especially towards less productive countries, lately also thanks to the single currency area. Careful attention should be given to the voice that suggests that this intra-EU export (of goods and capitals) strategy has significantly contributed to the imbalances which are putting the Eurozone, and therefore even the prosperity of current winners, at risk. In parallel, emerging and transition economies are no longer (just) outsiders, since the growth rates of China and India have already outpaced most of the Western Europe ones. Forward looking, **regional differences** will become more evident in countries where underlying drivers, such as population growth, agglomeration economies, diffusion and development of technologies (R&D), globalisation and favourable economic policies (e.g. sustained public investment) will continue supporting a stable pace.

The phenomenon of emerging economies is reshaping the distribution of economic power across-the-board and new equilibriums are to be sought, especially with respect to consumption patterns.

Developing countries will become more urbanised, with higher motorisation rates and even more dependent from energy sources. This could determine an anticipated shortage of oil reserves, as well as an increase of the prices of the products related to oil with unavoidable consequences throughout all the transport sectors worldwide.

Economic growth drives also the quality of the environment, and the differences amongst countries have effects on the level of pressure put on it (explaining the variance in emission intensity between regions). Emerging countries are still less inclined to address and issue measures to contain emissions, since these policies might slow down the gained progress rate; in the most advanced economies, where environmental issues have been given increased importance, great concern has been developed and policies to take care of the problem have been discussed amongst politicians.

Due to the present crisis, differences across regions will be more likely to occur, and environmental pollution will increase amongst countries until governments will develop an even awareness in this respect.

In emerging economies major transport investments can be expected to improve their accessibility domestically, from/to neighbouring countries and even further. Migration and tourist flows, as well as the trade sector, will highly benefit from improved accessibility. In particular, an increase of the air transport market is expected in emerging economies: by 2030 the combined domestic markets in China and India are projected to overtake the current US domestic market which, in 2010, was the largest in the world.

Regardless of the place, when building a robust economy, the labour force is pivotal for a well based development as both number and skills of employees are crucial; broadly, high **employment** rates contribute to the economic prosperity, in terms of higher quality of life, social inclusion and accessibility to all the resources available for achieving personal tasks. Currently, in the EU27 employment is projected to record an annual growth rate of only 0.3% over the period 2010 to 2020 and to reverse to a negative growth rate of a similar magnitude over the period 2020 to 2060.

In particular, the share of workers within the range 55-64 years old is forecast to increase from 46.3% in 2010 to 56.1% in 2020 and to 62.7% in 2060, reflecting the expected impact of recent pension reforms in many European countries, aimed at postponing the retirement age.

Figures on unemployment by age and gender show that the labour market situation is worst for young people within the range from 15 to 24 years old. More than 20% of people in this group were unemployed in the second half of 2009. Moreover, the employment rate of women is projected to rise from 62.1% in 2010 to 65.9% in 2020. Scenarios seem to be not encouraging also because full employment has not been in the policy agenda since the faith in market and supply-side economics has restricted labour policies to those targeted on improving (or trying to improve) labour participation. After decades of remarkable unemployment (the unemployment rate in the EU has rarely fallen below 7% in the last 30 years) and low income workers, the relevance of consumption as major driver of growth and employment should be rediscovered. The drivers of productivity growth are variables that either depend on the quality of labour or the availability of capital (depending on different allocation of these factors).

Besides the aforementioned and straightforward relationships with the economy domain, the employment rate shows several other interactions with the other domains considered in this project. In this respect and under a social perspective, education remains a pillar to build individualsôskills and when looking for opportunities in larger and more specialised areas of production of goods and services.

On the environmental side, evidence has been found that environmental policies could have a positive impact on the overall number of jobs. Nevertheless it has also been argued that policies that promote environmental innovation, or environmental tax reforms, are more likely to influence the composition of the labour market, rather than its size.

Socially, employment as well as unemployment may both drive migration flows between regions. In the first case, skilled workers seek job opportunities in places where advanced capabilities are more likely to be required, on the other hand, unemployed people living in distress and dwelling in depressed areas are more inclined to move to urban centres, where they could strive for becoming better off. If migration to specialised labour markets flows from rural and remote areas to the more urbanised ones, then occupation patterns will definitively also affect urban development and mobility.

The United Nations predict that the immigration flow from outside Europe is expected to continue to grow as it will contribute to fill employment gaps, especially in low-skilled jobs.

Eventually, the economy cycle impacts on public spending possibilities **for investments in the transport sector**. Under the current policy environment, budget constraints of Governments are manifold and hit transport mainly in terms of reduced funds granted to subsidise public transport and with respect to investments in new infrastructures.

According to The World Bank, all over the world public investment in transport typically accounts for 2.0 to 2.5 per cent of GDP and it may rise to 4% (or even more, e.g. China is running at 9%) in countries implementing development plans.

From a macro-economic perspective, public investment in transport infrastructure may foster a suffering economy, although such a policy has not a clear and perfect causal-effect relationship. As a matter of fact, transport infrastructure may require a huge amount of financial resources and the returns on investments may not be perfectly overlapped with the real pattern of the economic cycle. It might be the case that when the investment is completed, its effect on the economy might be no longer so relevant, as the economy could have recovered a pre-crisis growth due to other reasons. Moreover, investments not correctly appraised ex-ante could become a further burden on a governmentsô balance sheet for generations to come. This is not to say the public investments in transport are utterly useless to promote growth, but rather that *cœteris paribus* investments in other public sectors might show higher returns (e.g. in education and research)..

Europe invests on average 5% of GDP in transport infrastructure, with an increasing share of these resources being placed in upgrading and extending the trans-European rail network. The cost of EU infrastructure that would be required to match the demand for transport is estimated at over ú 1.5 trillion in the time span 2010-2030. Additionally it can be supposed that additional investments might be needed in the future in order to address the emerging mobility needs of the elderly working people: private and public vehicles will have to respond to new comfort and safety requirements and transport infrastructures will have to be adapted accordingly to reduced perceptions of aged people.

However, as introduced above, in the coming years and decades there might be an increasing difficulty in finding the means for investing in transport infrastructure, given that a larger amount of resources will be absorbed by social services provided to the ageing population.

Additionally, the recent economic crisis has severely hit public budgets and private lending with direct impacts on the building of infrastructures and on the viability of companies providing transport services. A substantial cut in investments between 2007 and 2008 has led to lower financing to all modes, with road investments falling from 60% in 2000 to 52% in 2003, while funds granted to rail networks have been declining since 2003.

Besides this, it is often difficult to determine whether the construction of a new transport infrastructure yields new created jobs or jobs relocation, and short or long-term jobs.

New infrastructures have again effects on the environment, and climate change impacts are envisaged to be reduced, if the investments are allocated to environmentally friendly modes (e.g. rail, maritime and inland waterways).

The **Market structure** is going to influence future mobility trends to the extent that rules and regulations (e.g. more or less market liberalisation) will exert an impact on transport demand and supply via relevant drivers. The literature review has in fact established a correlation between market structure, ranging from lower levels of regulation (i.e. liberalised markets) to stricter rules (regulated markets), and important drivers of transport demand and supply, namely: a) GDP trends, correlated to higher market liberalisation, and leading to higher mobility rates; b) foreign trade and liberalisation, resulting from higher market opening and integration, leading to higher freight transport growth rates; c) technology development and innovation, assumed as a by-product of more competition and R&D investment, determining a positive impact on mobility of goods and people.

It is important to stress the implications of the market structure on the use of transport modes and the characteristics of travel, e.g. average distance. In market-oriented economies, mobility is more likely to be based on open-market structures that sustain economic integration through long-distance mobility (e.g. shipping and air transport), both for passengers and freight. On the other hand, a market structure with higher fragmentation and national-inward orientation may have the opposite effect, namely favouring short distance trips.

**Fiscal policy** addresses the strategy of reaching a sustainable equilibrium between public revenues and expenditure. In the context of this report, this aspect basically concerns problems like the design of fiscal policies in facing pension expenditures, involving accumulation of assets and contributing positively to coping with the long-term outlook for public finances. Declining revenues from capital taxation, because of competitive fiscal policy to attract foreign investments and of hiding profits thanks to globalisation have greatly contributed to public budget problems in Europe (as well as in the US) putting at the same time the disposable income of labour-dependent households under pressure. The implications of the fiscal policy scenarios on transport trends concern, on the one hand, the impacts on disposable net income and, on the other, the influence of the use of most pollutant transport modes (internalisation of externalities via environmental taxation). The former aspect may reduce the future transport demand (in particular long-distance leisure trips), to the extent that a tight fiscal policy reduces the actual demand. The latter aspect could influence the use of the most polluting transport modes: levying carbon taxes based on fossil fuel carbon content would lead, in the near future, to the reduction of the use of the most polluting and intensive carbon-use transport modes, e.g. cars and airplanes.

In the next decades, the **globalisation process**, driven by the trade liberalisation policies and accelerated by the falling of transport prices, is expected to continue and to influence economic growth, employment and transport. Currently, 1% GPD growth corresponds to a world trade growth of 2.5%-3.0% and a parallel rise of transport services. According to the mainstream, globalisation's impacts on employment and regional wealth will depend upon the ability of European policies to respond to the increased competition that requires higher flexibility in the labour market and a deep restructuring of the industry sector. A significant number of authors are however more pessimistic and highlight how globalisation, especially in the form of outsourcing, has been objectively bad for workers and contributed to maintain unemployment and increase uncertainty in the labour market. For transport services, the escalation of the importance of time saving factor has favoured the rapid rise of road transport for freight and air transport for passengers. As mentioned at the beginning of this paragraph, the policy challenge of the next years will be to decouple economic development from transport growth and it will require a rethinking of the transport services with the reorganisation of the rail network and flight connections as well as the reorganisation of urban and regional communities.

**Energy availability and prices** are underlying in the process of globalisation and economic growth. Severe price fluctuations and a high oil price are able to slow growth, raise the unemployment rate and reduce trade and mobility. Oil prices are expected to remain high and subjected to price volatility. The rise in fuels prices, especially of oil, will influence transport costs, though might not reduce traffic flows very strongly, since 80% of them are considered as non price sensitive. Vehicle-miles travelled tend to rebound as consumers become accustomed to the new level of price or income levels rise, and for freight transport, transport costs represent a relative low share of total production and goods prices.

A high oil price might increase the deployment of various oil derivates that could exacerbate the competition for the use of scarce resources as exemplified by the competition between the first generation of biofuels with food production. Some literature indicates that in 2030, powering 5% of global road transport by biofuel could consume between 20-100% of the total quantity of water now used for agriculture worldwide. With the global governance lies the responsibility for promoting policies and investments able to manage shared resources in a sustainable way, considering the interrelatedness of water, food and energy security.

The whole analysis of the economy domain has shown that there exist strong and several relationships with all the other fields so far discussed, as it can be assumed as the main pillar of all the activities of human being. In a parallel with mechanics, the economy works as the engine of a vehicle. Only if such device will be suitably supplied with enough good quality fuel (namely fresh capitals and a highly skilled labour force), the business cycle will continue to run efficiently.

On the other hand, either any fuel leak or low-quality ingredients will definitively affect the amount of its internal revolutions, as well as their regularity, leading to a reduction in the production of goods and services.  An economy in recession is a coughing engine that suffers from disruption of capital and labour supply, or even from wrong investment planning (e.g. inefficient public spending). Re-starting all the correct functions properly is not always an easy task to be tackled, as it requires a deep knowledge on how the economy works, in particular through all the relationships known and discovered so far.

On the environmental side several factors may impact on transport sector.

Many impacts of **climate change** are already visible in Europe and worldwide and these impacts will become more pronounced in the future: many climatologists say the pace of changes is already much faster than they expected ten years ago.  Although there are some positive effects of climate change, like an increasing potential for agriculture at high latitudes and reduced cold stress to humans, most impacts are expected to be adverse.

In the short and medium term climate change will increase the occurrence of extreme weather events, while in the long run it will lead to an increase in average annual temperatures, alter rainfall, and raise the sea level and the risk of coastal erosion.

In Europe, several zones are supposed to be particularly vulnerable: they are generally located in the South and East of Europe, the whole of Spain, Italy, Greece, Bulgaria, Cyprus, Malta and Hungary, as well as most of Romania and southern parts of France.  This situation is mostly due to changes in precipitation and an increase in temperature, which have an impact on vulnerable economic sectors. River floods are also likely to contribute to the overall effect in Hungary and Romania.

Literature indicates that by 2050, under a relatively high emissions scenario, the temperatures experienced during the heat wave of 2003 could be an average summer.  In moderate climate zones the demand for energy during the winter months will decline but, on the other hand, in zones with higher temperatures demand for electricity for cooling will increase during the summer and heat waves could significantly increase mortality in older adults.

Although the net change in energy demand is difficult to predict, there will be strong distributional patterns with variations in demand for oil and coal in electricity production, having implications also for the transport sector.

Since much of the world's hydrocarbon reserves are in regions vulnerable to the impacts of climate change, instability is likely to increase generating greater energy insecurity and competition for resources.

The UN predicts that there will be millions of "environmental" migrants by 2020 with climate change as one of the major drivers of this phenomenon, and Europe is expected to be affected by increased migratory pressure.

Future projections of climate change suggest that the suitability of the Mediterranean for tourism will decline during the key summer months with an increase during other seasons (spring and autumn).

Changes can be expected also for skiing holidays leading to a shift towards those destinations with higher probabilities of sufficient snow, e.g. areas at higher altitudes.  This can produce distributional impacts in the major flows of tourism within the EU.

Effects of climate change on food production on a global scale show that especially countries at higher latitudes will become more suited for food production; countries at lower latitudes, among which the largest part of developing countries, will become substantially less suited.  The shift of food production will likely also hold for Europe, resulting in an increase in trade and freight flows from South- to North-Europe.

Most writing about climate change and transport emphasises the role of greenhouse gas emissions from transport as a contributor.  However, the inverse impact is also significant, since the transport system is liable to be adversely affected by climate change, particularly as a result of extreme weather conditions that might have immediate impacts on travel and damages that cause lasting service interruptions events. This is especially true in densely populated regions, such as many coastal areas around the globe, where one single event may lead to a chain of reactions that influence large parts of the transport system.

In coastal cities in particular, sea-level rise can inundate highways and cause erosion of road bases and bridge supports. Heavy precipitation and its effects in the form of flooding and landslides can cause lasting damage to transportation infrastructure such as highways, seaports, bridges and airport runways. Higher temperatures, in particular long periods of drought and higher daily temperatures, compromise the integrity of paved roadways and necessitate more frequent repairs.

Although attempts are being made on a worldwide scale to reduce greenhouse gas emissions, climate measures (even if successful) will be too late to avert climate change and its impacts over the next 50 years. It follows that the transport system needs to have resilience built into it in order to deal with these problems, and to stop relatively minor events turning into major catastrophes. Two aspects of such resilience are identified in the literature: a ñlong termò aspect in the sense that the transport system should be constructed and developed according to principles that recognise the likelihood and impacts of extreme weather events; contingency plans need to be formulated well in advance of such events occurring. In particular, such plans should try to ensure network connectivity of the transport system in the face of any disruption. Firstly this will ensure that ñnormal activitiesò can be maintained (as far as possible), thus maintaining territorial cohesion. Secondly, problems of disconnection are likely to have a direct impact upon the effectiveness of emergency services for dealing with the disruption.

Because of its dependency on fossil fuels in all modes, the transport sector contributes 23% of all CO2 emissions in the EU 27. Despite significant efforts to reduce emissions, transport has not achieved its decarbonising targets. Projections indicate that with the existing measures currently in place, emissions will decrease by 2020 in the main emitting sectors, except for the transport sector and emissions from industrial processes. If this trend continues, transport is expected to contribute 50% of all CO2 emissions in the EU by 2050, if not even within the next two decades.

Given the unsatisfactory results achieved so far in the transport sector and the additional concerns arising from growing motorisation in developing countries, it can be expected that greenhouse gas reduction will become more and more prominent on the agenda of policy makers worldwide. A great array of **GHG mitigation** measures can be undertaken to reach the emission targets. These include technology measures, new policies and a change in lifestyle for all citizens.

Some studies highlight that substantial improvements are achievable today just through greater utilisation of existing technology. Current vehicle technology can be improved in order to achieve greater fuel efficiency through the development of improved aerodynamic design (especially in the air transport sector), the reduction of vehiclesô weight, the lowering of rolling resistance and the adoption of alternative propulsion technologies.

Transport should become less dependent on fossil fuels, thus contributing to energy security, by relying more and more on low-carbon fuels to be provided at affordable prices and with an efficient distribution networks. Using a fuel mix of electricity, biofuels, and hydrogen could significantly reduce the number of gasoline-powered passenger vehicles on the road by 2050.

Supporting policies will need to pull existing technology in the marketplace and to promote technological development for the future, requiring a combination of performance standards, pricing mechanisms, and research, development, demonstration and deployment actions.

Major and sustained investments might be more and more polarised to the implementation and diffusion of ñgreenò transport solutions, acting as some of the key drivers for the modernisation of the EU economy with huge potential for economic growth and employment in the future. Recent studies already identify various forms of low carbon energy sources and their supporting systems and infrastructure (including smart grids, passive housing, carbon capture and storage, advanced industrial processes and electrification of transport including energy storage technologies), the key components which might form the backbone of efficient, low carbon energy and transport systems after 2020.

This will require on average over the coming 40 years, the increase in public and private investment to around ú 270 billion annually, thus representing an additional investment of around 1.5% of EU GDP.

Planning measures, especially at urban level, will become more urgent with the need to develop compact communities more conducive to an efficient provision of public transport as well as to shorter vehicle trips and non-motorised travel. Nevertheless, the literature recognises that initiatives to mitigate climate change through urban design and development are complex and difficult to manage.

Soft measures, such as demand management policies and pricing schemes, might instead constitute an essential part of future policies, having a more direct impact on the spatial and temporal distribution of mobility.

Most strategies to reduce transport GHG emissions also reduce emissions of local conventional pollutants providing environmental co-benefits on air quality, and those that involve reduced vehicle use also reduce traffic congestion and noise.

Energy and CO2 emissions can also be reduced through interventions aimed at increasing driversô acceptance of smaller vehicles and less powerful engines and changing driving behaviour, such as reductions in excessive vehicle acceleration and driving speeds. Eco-driving measures could be massively promoted both in the urban and inter-urban environment through training and information guides, and actively supported by technologies providing real-time information by the vehicle to its driver.

All these measures have a great potential to highly influence both the transport system and demand structure in the future.

The European Union is leading global efforts to reduce greenhouse gas emissions from human activities and, as the cornerstone of its strategy to cut greenhouse gas emissions cost-effectively, has developed the EU **Emissions Trading Scheme** (ETS) entered into force on 2005.

Around 40 % of EU greenhouse gas emissions are currently covered by the EU ETS, with the transport sector as one of the biggest sectors not covered so far.

To tackle the fast-growing emissions from the aviation sector, from 2012 the EU ETS includes also CO2 emissions from civil aviation (all international flights ï from or to anywhere in the world ï that arrive at or depart from an EU airport).

The literature indicates that the impacts on air transport are expected to be somewhat neutral for airlines with companies expected to pass on, to a large extent or even in full, the cost of participating in the scheme to their customers, which by 2020 might represent an increase of ú4.6 to ú39.6 per flight, which is a value significantly lower than rises due to oil prices change in recent years.

It might be expected that similar actions will be implemented in the mid to long term also to cover other transport modes: the European Commission has recently launched an on-line public consultation on possible measures to be taken for reducing greenhouse gas emissions from ships.

Measures to reduce **noise** and **environmental pollution** from the transport sector are already in place in the most of European countries.

Generally, action to reduce noise has had a lower priority than actions taken to address other environmental problems such as air and water pollution. However, as more information has become available about the health impacts of noise, the need for a higher level of protection for European citizens has come to be recognised.

Road traffic is the main source of noise in urban areas, accounting for about 80% of total noise pollution. Recent data suggest that around 40 million people across the EU are exposed to noise above 50 dB from roads within agglomerations during the night. More than 25 million people are exposed to noise at the same level from major roads outside agglomerations. A Swedish noise annoyance study identified motorcycle noise as by far the most annoying form of vehicle-related noise in urban areas.

Noise reduction measures are naturally also needed in the rail and air traffic sectors. Noise pollution from railways remains one of the main barriers for expanding their use in urban areas and along densely populated rail freight corridors; and aircraft noise is often the reason for the difficulty of expanding airport capacity at major European hubs.

However, the local authorities have very limited scope for action in the rail and air area, due to the involvement of national and international administrative bodies. For this reason railway noise abatement is part of the EC Greening transport package, which aims to move transport further towards sustainability, and aircraft noise reduction strategies are implemented in EU legislation by Directive 2002/30/EC, which deals with the introduction of noise related operating restrictions at EU airports.

There are essentially two routes to noise abatement. Firstly, noise emissions can be reduced at their source, through technical measures (e.g. solutions applied to power trains, tyre/road interaction, retrofitting of existing rail rolling stock), infrastructure solutions (e.g. poroelastic asphalt, rail track upgrading) and traffic management schemes (e.g. reduction of vehiclesô speed in sensitive areas, access restriction for noisy trains); also fiscal policies are active in some countries to incentivise the use of low-noise vehicles.

Secondly, noise can be abated by reducing the exposure of people by means of anti-propagation or insulation measures (by increasing the distance between source and recipient, for example, or hampering noise propagation by insulating buildings or constructing noise barriers).

The limiting of noise in urban areas could play an essential role in future city planning and management and noise exposure standards might be set and enforced for several different environments (outdoor living area, dwelling interiors, schools, etc.), as is the case with current EU air quality standards. The potential for closer co-ordination and integration of air quality and noise management has been suggested frequently.

This might require the introduction of more diffused traffic management schemes potentially impacting on demand distribution by diverting demand towards less sensitive (and thus free from restrictions) areas, as well as on modal split by inducing a higher usage of public transport modes.

As far **air pollution** is concerned, the reviewed literature indicates that, at present, particulate matter, nitrogen oxide and ozone are the most problematic pollutants in terms of health effects in most European urban areas. Traffic emissions of particulate matter (PM10 and PM2.5) and nitrogen oxide (NOx) are the local pollutants of most concern as the daily limit value of PM10 and the annual limit value for NO2 are exceeded most extensively.

Ozone is a strong photochemical oxidant which, in elevated concentrations, causes serious health problems and damage to materials and vegetation. The road transport sector is a major source of the ozone precursors NOx and CO by contributing respectively about 42 % and 34 % of total EU‑27 emissions in 2009.

Air pollution may also impact the Earth's climate since some air pollutants interfere with the Earth's energy balance leading to a net warming effect in the atmosphere.

The application of technology has been the primary means of reducing the environmental impacts of transport in the last two decades; the Euro standards for vehicles have been, and continue to be, introduced in phases, with the introduction times and actual standards varying by pollutant, vehicle category and vehicle weight class or engine volume and fuel type. To further reduce road transport's impact on air quality, diesel NOx emissions could for example be targeted through technologies for diesel-powered vehicles such as selective catalytic reduction (SCR) (especially for heavy-duty vehicles).

Directive 2009/33/EC on the ñPromotion of Clean and Energy Efficient Road Transport Vehiclesò aims at stimulating broad market introduction of environmentally friendly vehicles. The Directive requires that energy and environmental impacts linked to vehicle operation be incorporated in purchase decisions. These lifetime impacts include vehicle energy consumption, CO2 emissions, and emissions of the regulated pollutants of NOx, non-methane hydrocarbon (NMHC) and PM.

Besides these interventions targeted to vehicle fleetsô innovation also traffic management measures and pricing policies are becoming more frequent at local level to reduce the exposure of population living in urban areas from high concentration of air pollutants.

Such kind of solutions might become more common in the future, with cities more and more obliged to apply ever-stricter air quality legislation, and to reduce transport-related emissions in line with increasingly stringent European and global targets. Greater priority will be placed on policies for the prevention and avoidance of congestion, which will inevitably include measures such as access control and road charging to manage the level of demand.

**Energy** is a basic need for the society and its pattern of **availability, production and consumption** are of greatest relevance in the context of the economic and environmental domains. When looking at European energy demand in all sectors data show that demand increased by 77 million tonnes of oil equivalent (TOE) from 2000 and 2008 and then sharply dropped by 99 million TOE to 2009, with this decrease due to the economic crisis. This sharp decrease confirms once again the strong relationship between economic growth and energy demand.

When looking at the fuel mix used to produce energy in Europe it can be noted that small changes have occurred since 2000. After plummeting from 27 % to 18.5 % in the previous decade, the share of solid fuels in total consumption fell to 15.7 % in 2009. The share of crude oil and petroleum products also decreased slightly from 38 % to 36.5 % between 2000 and 2009. Natural gas consumption, on the other hand, increased from 23 % to 24.5 %, and renewables consumption went up from 6 % to almost 9 % during the same period. Nuclear energy was the only energy source that experienced a trend reversal: after growing from 12 % to 14 % in the 1990s, consumption fell slightly to 13.5 % in 2009.

Europe is relatively resource poor and it relies on foreign resources to meet its growing energy needs. Recent statistics show that dependence on energy imports grew from 46.8 to 53.9 % between 2000 and 2009; in 2009 dependence was highest for crude oil with an import share of 83.5 %, followed by natural gas (64%) and hard coal (62 %).

Worldwide demand for energy is growing at an alarming rate and projections suggest that by 2030 world energy use will probably have increased by more than 50 per cent, thus exacerbating the competition for the primary energy sources. Nowadays the dynamics of energy markets are increasingly determined by countries outside the OECD and it is expected for non-OECD countries to account for 90% of population growth, 70% of the increase in economic output and 90% of energy demand growth over the period 2010 to 2035.

Electricity production accounts for 32% of world global fossil fuel use and around 41% of total energy related CO2 emissions. Not only the burning of fossil fuels (coal, lignite, oil and natural gas) is the largest source of carbon dioxide emissions, but the extraction of coal, oil and gas as well as leaks from gas pipelines are among the main sources of energy-related methane emissions.

Current trends are economically, socially and environmentally unsustainable and, without decisive actions, global electricity generation will continue to be largely based on fossil fuels. In that case energy-related greenhouse emissions will more than double by 2050 and increased oil demand will heighten concerns over the security of supplies.

In this context of great European energy dependence and environmental concerns, it seems hard to predict what might be the fuel mix of EU energy production in the next decades. Most measures to reduce greenhouse gas emissions in some way target energy consumption and the fuel mix. One such measure is shifting from solid fuels, which are high-carbon sources of energy, to lower-carbon sources such as natural gas. This, however, has been one of the underlying causes of greater energy dependence in the EU. Today the majority of Russiaĉs exports continues to go westwards to traditional markets in Europe, but a shift towards Asian markets gathers momentum, increasing the concern about energy availability.

Some studies predict that in 2050 more domestic energy resources would be used, in particular renewables. Imports of oil and gas might decline by half compared to today, reducing the negative impacts of potential oil and gas price shocks significantly.

While there is agreement that electricity will have a role in transport, opinions diverged on how large its potential is. Some see a broad scope, arguing that electricity is the way forward even if electricity production releases carbon, simply because electric engines are more efficient than internal combustion engines. This view was challenged on the grounds that the additional electricity produced for transport will come from carbon-intensive fuels until the extra demand is large enough to justify investments in other sources.

Alternative sources of energy in transport might be biofuels; nevertheless the literature review showed that the economics of conversion processes need to be further improved for biofuels to be really competitive with fossil fuels without subsidies in the longer term.

Despite the uncertainty surrounding the future sources of European energy production, it can be more certainly argued that energy ñsavingò and ñefficiencyò measures will become more and more prominent in the next decades especially in the transport sector which is the largest energy-consuming sector in the EU27 with road transport the biggest consumer with the strongest reliance on fossil fuel.

Energy efficiency in transport will rely on a broad range of technological solutions: traction technologies encompassing new engines and alternative sustainable fuels, improved vehicles aerodynamics and weight, regenerative breaking devices, modernising infrastructure and optimising operations.

Also information and communication technologies are considered to offer a great potential for achieving a more efficient and less energy consuming intelligent transport system. They may have strong influence on personal decisions (for instance on purchasing vehicle or on choosing the travel mode), thus driving human behaviour towards more sustainable patterns.

Some literature suggests that the private economic cost of transport fuels will be by far higher than those of today, whatever mix of sources, carriers, and conversion systems there may be in the future. Therefore, the role of efficiency in the transport sector will become critical, not only in terms of the environment, but also in terms of the overall affordability of mobility.

While it is clear that the roadmap for the transport system is to shift from carbon to low-carbon energy sources, it is unclear when this shift would be completed and whether this might occur in time to avoid major problems arising from the **scarcity of fossil fuels** and especially from oil.

Fossil fuel reserves are concentrated in a small number of countries. Some 80 % of the coal reserves are located in just six countries and the EU has just 4 % of the global total. The EU share of the world's reserves decreased from 4.6 % in 1980 to 1.3 % in 2009. More than half of the global stock is found in only three countries: Iran, Qatar and Russia.

Oil production has long been expected to peak. Some think that this is now imminent at least within the next 10 years. For others the scarcity of oil supplies, including unconventional sources and natural gas liquids, is very unlikely before 2025. Some others consider this horizon could be extended to 2040 by adopting known measures to increase vehicle efficiency and focusing oil demand on the transport sector. Additionally, some economists believe that the scarcer and more expensive a commodity becomes, the more effort will go into finding it, and that the market will ensure plentiful supplies of fossil fuel for many years ahead.

Even though it cannot be said with certainty that we will run out in the next thirty years, extracting and delivering the remaining oil to market is becoming increasingly difficult and costly: as reserves that are easy to access run out, the oil production has to rely on less accessible resources and on fossil fuels with lower energy content. Fossil fuels that are currently extracted from deposits would have been considered uneconomic two decades ago. This requires more transport and more energy with higher environmental impacts per unit of material or energy produced.

While improving vehicle efficiency is by far the most important low-cost way of reducing oil consumption and carbon emissions in the transport sector, biofuels are supposed to play a significant role in replacing liquid fossil fuels suitable for planes, marine vessels and other heavy transport modes that cannot be electrified.

Nevertheless, reviewed literature has highlighted the presence of several barriers to be removed for a massive diffusion of biofuels.

Firstly, when considering production costs, biofuels are not competitive with fossil fuels today and scale and efficiency improvements are indispensable to reduce costs over time. For all biofuels, there is scope for cost reductions: capital costs are expected to come down as a result of scaling up (particularly for advanced biofuels). Co-location with existing biofuel plants, power plants or other industrial facilities reduces capital costs and can bring further benefits such as more efficient use of by-products; conversion costs can be brought down through scaling up and technology learning. Further improvement of conversion efficiency (e.g. through more efficient enzymes) and energy efficiency should also help to reduce costs; feedstock costs cannot be predicted and are subject to agricultural commodity prices, oil prices and other factors. Enhancing feedstock flexibility will create access to a broader range of biomass sources with potentially low costs (such as residues) and reduced price volatility. Improving and creating transport infrastructure could further reduce biomass supply costs.

Secondly, there is an urgent need to scale up investment in low-carbon energy technologies. Current investment levels are insufficient to make the necessary transition, and investment in traditional fossil-based technologies needs to be shifted towards low-carbon energy technologies.

Fiscal policy measures might be important in helping to redress investments. As a first step, fossil fuel subsidies, which are still applied in many countries, should be phased out. A taxation system based on the environmental and energy performance of individual fuel types, including a carbon tax (as is already the case in Sweden) might be one way of placing value on biofuelsô environmental and societal contribution, and of reducing gaps in competitiveness with fossil fuels.

Nevertheless, a key non-economic barrier to the development of biofuels is uncertainty regarding their sustainability. The sometimes controversial public debate on competition with food production and the potential destruction of valuable ecosystems has put biofuels into the centre of a sustainability discussion that concerns all forms of bioenergy and which (in parts) is relevant to the entire agricultural and forestry sector. For biofuels to provide the envisaged emission reductions in the transport sector, it is essential to avoid large releases of GHG caused by land-use changes.

Besides the scarcity of fossil fuels, reviewed literature showed that other kinds of shortages are expected to occur in the next decades which might have impacts on the European transport sector. The accessibility and affordability of non-energy, non-agricultural **raw materials** is in fact crucial for the production of vehicles and transport infrastructure which require large amounts of materials and might be hampered by a limited or more costly supply of certain raw materials.

Stocks of 14 groups of raw materials are considered 'critical' due to their high economic importance and high supply risk within the next 10 years. The EU has very few reserves of some, such as gallium (used in photovoltaics and microchips), tantalum (used in microelectronic capacitors), germanium (used in fibreglass cables) and neodymium (used in high performance magnets), which are essential for high-tech applications.

Due to rising raw material input costs in the steel and non-ferrous metals industry, the automotive industry might face serious challenges, since cars are complex products consisting largely of steel, non-ferrous metals, as well as polymers, rubber and glass.

Furthermore, as a result of the future developments in car-design, the demand for critical raw materials is expected to increase. Environmental standards and requirements and customer convenience play an especially crucial role here.

According to the European Automobile Manufacturersô Association (ACEA), the demand for rare earths and lithium will rise, due to more use of advanced electronics, magnetic materials, new surface treatment systems and alternative propulsion technologies. This might increase the competition on such kind of resources. A study on resource productivity points out that, if the prices of more raw materials inputs used in the car production go up, the product price for the final customer would also go up significantly thus reducing the affordability of cars.

Resource-efficient technologies and the use of recyclates and substitutes are the two main strategies the automotive industry is deploying to reduce dependency on raw materials. The recycling of scrap cars is of key importance and it is adequately regulated by the End-of-Life Vehicle Directive (ELV Directive 2000/53/EC). The more recent Directive on Reusability, Recyclability and Recoverability of motor vehicles Directive 2005/64/EC) set new requirements for vehicle recycling. In 2008 total reuse, recovery and recycling rates varied between 79.8-92.9% in the Member States, with Germany having the highest rate in Europe.

Nevertheless ACEA estimates that the first significant volumes for recycling of electrical vehicles, which contain rare earths, cobalt and lithium, will come around 2025-2030 at the earliest, while demand for these materials is expected to boom around 2015-2020. In this context it becomes crucial for the competitiveness of the industry to have a new generation of batteries based on other materials by 2025-2030.

On the technological side several factors are expected to contribute to the development of the future transport system and to influence mobility patterns.

The **technology development in general and the diffusion of innovation,** if considered in its stricter sense, has influenced human activities since the beginning of historical times, but in the last few decades its pace has become faster and faster. New technologies are affecting almost every aspect of our life (labour, travel, leisure, health, etc.) and have started to change our daily habits significantly.

With a major focus on travel habits in particular, within these new spreading technologies the most pre-eminent role is played by information and communication technologies (ICT). ICTs in fact have the great potential to lessen (and sometimes also to cancel) the conventional constraints of time and space, which are the two physical dimensions that give rise to the need of travel.

New patterns of mobility are emerging since “tele-working” and “on-line shopping”, just to name a few, have become feasible. Nonetheless, the reviewed literature has shown that it would be misleading to conclude that the increasing diffusion of ICTs could reduce the need to travel in general. Innovation per se has not this powerful influence and the introduction and the diffusion of technology may produce some “rebound effects”: in most cases the improvements in the efficiency of the transport system (increasing speed, decreasing congestion, improving transport conditions) may lead to an increase in travel demand.

The awareness of this one-to-one connection between transport and technologies has to be widely achieved yet. Technologies can not only be considered simply as one among all the external factors impacting on the transport sector: they have, indeed, a key role in shaping its development and their diffusion within the sector has become a more and more impelling need. Negative environmental impacts (climate change impacts, pollution levels, GHG emissions) and several inefficiencies (loss of energy, inefficient use of raw materials and resources and waste of time) are, in fact, some of the key drivers for the continuous development of innovation and technologies in the sector.

All the efforts undergone in this sense are directed towards a sustainable way of travel, aiming at minimising environmental and social negative impacts. As the literature review confirms, a shift from “technology-push” innovations towards “demand-pull” innovations has started to occur and users have become the core target of new technologies.

New challenges are emerging: for instance, one main issue would be the improvement of the quality of time spent during travel (e.g. enhancing the possibilities to perform different activities such as using laptops, phones or tablets while being seated in a train or a bus, or, in future, even being driven by our own car in a “drive-train”). These new objectives are replacing the traditional search for technologies aiming at increasing speed further, even also some physical constraints seem, at the time, impossible to be overcome.

Thus, emerging users habits, lifestyles and needs will account increasingly for the provision of new technologies. Changing behaviour and shortening the digital divide (inequalities in accessing new IT technologies depending on different levels of education, disposable incomes and professional positions) with educational efforts are the prerequisites for a wide and equal diffusion of innovation and technologies across different countries and social groups. Within the literature several documents clearly assert that a strong political commitment is needed in order to face these new challenges.

Furthermore, the need for public support and funding has become more evident through the years: innovation may only be spread, if funds for investments are available and, in this respect, policy and planning play an essential role.

On the other side the application of technology developments in the transport sector might reduce the need for funding new infrastructures through the optimisation and integration of the existing ones.

Especially under a global downturn in the economy, a deeper insight should be reserved to “soft” innovations driven by technology improvements which proved to be the most effective in tackling transportation issues without major infrastructure investments.

The analysis of which impacts may derive from the spread diffusion of innovation in the transport sector started from an insight about of the **design of vehicles**.

The reviewed literature showed that the impact of technological innovations is not the same in relation to the different transport modes. In rail transport the slow pace of innovation is almost inherent in its nature: public spending and large amounts of investment in infrastructures and networking could not easily justify further investment aiming at the introduction of “disruptive technologies”. If adopted, however, these disruptive technologies would lead, for instance, to the replacement of tracks with something totally different, thus changing radically the mode itself (traction, infrastructure, vehicle, etc.). New technological improvements, as far as the railway mode is concerned, are envisaged in a general trend towards increasing adaptability of the railway to different spatial dimensions, trying to stimulate the spread of rail in the largest number of contexts and especially in urban areas (e.g. suspended light-rail within urban areas).

On the contrary, major technical advancements have traditionally involved air transport. In this case, entrance barriers to the market and high-skill technological expertise has led to a logical and quite regular “step by step” technological development. At present, more attention has started to be reserved to airports and land-side facilities and infrastructure, trying to manage successfully the increasing air travel demand. However, improvements in aerodynamics and in engines are still at the core of the research given their potential in increasing the energy efficiency.

On the basis of these considerations, it can be easily argued (and literature confirms it) that the private mode is by far the more suitable one for testing innovations and for diffusing them. Firstly, cars can offer a wide range of aspects to be improved both concerning their body (material, aerodynamics, etc.) and several on-board appliances and equipments (which are increasingly indispensible to the functionality of vehicles themselves). Secondly, within this mode there are less constraints (physical but also financial) which have the power to hinder the development of new technologies. A great variety of car manufacturers compete worldwide in order to pioneer innovations resulting from their R&D activities.

From the literature review it clearly emerged that innovations in cars are driven mostly by environmental concerns. The main targets of current technological development are the reduction of occupied space (in order to decrease congestion) thus designing micro city-cars to be used in urban schemes and the mitigation of the environmental impacts (pollutant emissions and noise).

Literature shows that one of the most common trends (at least in urban areas) is towards smaller electric vehicles (for instance stackable city-car or folding scooters) with a high level of automated driving devices, offering valid solutions to meet environmental sustainability, safety issues and users’ emerging needs. Some of these vehicles are already purchasable (for instance the Renault Twizy).

New vehicles are also generally characterised by a wider diffusion of new equipments for elderly drivers and occupants.

The major barrier to innovations is however related to a general conservative attitude affecting people, who might be reluctant to changes in their travel habits.

Thus, all these new vehicles designed in order to tackle environmental and societal issues, will provide only little benefit to the transport sector (with measurable impacts only on a small portion of trips), until they will become so pervasive to present themselves as a self-reliant technology which can act a as a driving force in leading daily choices of future generations.

Strictly connected with the sphere of the design for new vehicles, improvements and diffusion of innovations in **advanced driving devices** are gradually emerging from a niche position market to a massive diffusion. More and more vehicles are being equipped with these devices, even the cheaper ones.

Primarily these equipments are targeted at improving safety conditions for the vehicles.

Safety may be hampered by weather (scarce visibility, diminished grip on the roadway due to fog, rain etc.) and road conditions (accidents which are occupying the carriageway) on one side and by driver conditions on the other (drowsiness, slow reflexes especially in elderly people, lack of attention).

Most of these devices can be classified as active devices as they are able to avoid collisions. Other devices are instead developed in order to improve the quality of health assistance in case of an accident (Automated Emergency Call).

In particular, from the literature review a greater attention towards these automated devices is emerging, not only because they address the expected aging of population, but mainly because of the willingness to achieve the final aim in the near future ñto be driven by the vehicle, rather than drive itò. Some tests have already been carried out in order to check the feasibility of ñroad-trainsò (a sort of chain of communicating vehicles led by an intelligent one giving instructions to the others). This technology has proved to be cost effective (no huge investments are required to adapt the infrastructure), environmental friendly (reduction of fuel consumption and decreasing congestion) and, last but not least, benefiting also drivers as they might spend their time performing other activities (writing, working, eating, etc). And value of time is known to be one of the most important factors in the choice of the transport mode.

The other major branch of development of these devices is the provision of information to the drivers in order to prevent them from driving into possible bottlenecks caused by road works or accidents.

In addition to the cultural change needed to let these new technologies become the daily habits of our future life, also political and legislative aspects have to be tackled with (interoperability of the systems at European level, road prescriptions, etc).

In the field of vehicle innovation, **traction technologies** are the most explored and investigated.

According to the literature review it can be stated that the internal combustion engine (ICE) will still play an important role in the future. Obviously, many improvements are to be performed regarding GHG emissions, energy efficiency and costs, but, at the moment, though many alternatives are quite fully developed, no one of these has proved to be totally successful in replacing the ñoldò conventional ICE.

It is not feasible at the moment to state with any certainty which technology will be the real breakthrough in the traction of vehicles. Nevertheless, literature seems to agree that the most likely would be electricity. Until the massive diffusion of fully electric vehicles (FEV) will take place, nowadays hybrid solutions (HV or PHEVï plug-in hybrid vehicles) are gradually gaining higher and higher market shares. Hybrid vehicles have many advantages in terms of energy efficiency, even though these advantages are still counterbalanced by the weight of the batteries, which make the vehicles heavier than traditional ones and also raise some safety issues.

Thus, in parallel, research has started to look for new **materials** for lighter and high-performance batteries (super-capacitors). New materials will allow in general a reduction in the weight of vehicles and an increase in vehiclesô performance, thus improving fuel efficiency and environmental impacts. Nanotechnologies and materials with higher performances are now a major focus for the research and development sector and it can be easily foreseen that specific raw materials are going to be exploited more extensively than ever.

As electricity is supposed to become the major source of traction in the next future, its availability and sustainable production is one of the most impending challenges.

Besides the engine factor, the other main branch of research on new traction technologies regards fuels. Most alternative fuels come from bio-sources (biofuels): such a production still raises significant concerns about its sustainability in terms of biodiversityôs preservation, land-use mitigation and total life-cycle assessment emissions. Thus, in more recent years, the production of biofuels has moved towards the so-called second and third generation (from waste material, such as cellulosic ethanol).

Other potential for fuel is considered to be in hydrogen, but in this case new technological improvements are needed to significantly reduce total GHG emissions.

As these new traction technologies are today less powerful than ICE in terms of covered kilometres, urban areas have proved to be the most suitable environment to test innovative tractions, both for small distances usually covered in cities and for the high costs of equipping roads with proper infrastructures to refill vehicles (supply stations and/or alternative fuels station).

From an economic point of view, large amounts of funds and investments will be of vital importance to further develop innovations and making them widely affordable. This aspect is of crucial importance especially if the target is a real breakthrough in traction. The public fiscal revenue from oil fuels still represents one of the strongest hurdles in this sense. However, the reviewed documents solidly support the hypothesis that smart and effective policies could help to get over such barriers. .

ICT and telematics contribute to the innovation of transport modes for a major part: doubtlessly, during the last few years, the most significant changes occurred in travel habits and modes of transport have been driven by the increasing role of ICT.

**Traffic management systems** started to be applied in the rail sector to manage signalling information for trainsôcirculation. As technology improved and became more low-cost and accessible, it started to be applied also on the road network. Intelligent transportation systems (ITS) were initially developed in order to find a solution to reduce congestion in urban areas, trying to improve the efficiency of the infrastructures. As they proved to be quite effective, their use has increasingly developed. Nowadays ITS applications are common both in urban (parking information, variable message signs (VMS), public transport prioritisation, etc.) and in interurban areas, managing problems connected with rerouting (accidents or weather conditions), tolling or for automated enforcement for safety reasons. Some cooperative systems have recently been developed: one of the new challenges to be addressed relates to the interoperability of the different systems (between vehicles, between vehicles and infrastructure, between countries, etc). Further innovations will be required in integrating, processing and disseminating data, in order to make information fully comparable and useful.

Traffic management systems and information in general are, according to literature, very important tools for planning. With relatively small investments, they can lead to significant improvements in public transport, in reducing congestion, waste of time and avoiding further large investments, for example in constructing new roads. Traffic management systems are now spread in all major European cities, as their benefits are more and more evident in terms of environmental impacts (reduced congestion, emissions, fuel consumption) but also for levy management (tolling, road charging).

Continuity and standardisation are essential for fully exploiting the potential of such technologies for international journeys. Very important achievements in optimising the freight scheduling have also contributed to improve general traffic conditions.

To conclude, it is commonly agreed, that traffic management systems can really help in tackling main negative aspects of transport: other potential applications to be further explored are those supporting new services or schemes (e.g. the sharing of private vehicles) paving the way for new sustainable mobility patterns.

**Information systems** are playing a key role in the transport sector. As literature shows, thanks to the wide spread of information, people are becoming increasingly more conscious of their mobility choices, discovering benefits of using public transport and taking advantage of well-planned intermodal journeys.

The availability of real-time information has been one of the most significant changes in recent years. Real-time data from monitoring sensors, for example, is a key element for traffic management centres and for public transport operators (e.g. for fleet location as well as for informing users on schedules, fares, and delays). From the literature review clearly emerges the “social” role played by ICT today. The way we work, do our businesses, purchase things (goods or services), has being strongly affected by the spread of real-time information provided by ICT, thus changing the reasons for which we need to move and finally the way we actually do it. Some social trends are being enhanced by information systems: it is the case for instance of the increase in migration flows which is somehow fostered by the evidence that keeping in touch with people from the origin country has become easier and more convenient. Re-location of housing in peripheral and suburban areas has been amplified by the feasibility of teleworking. ICT is also knocking down barriers allowing disabled people and elderly to move comfortably across different modes thanks to increasing dedicated services.

From an economic perspective the literature review confirms that information systems can have several benefits: individuals can save time and money thanks to less congestion; public transport operators and authorities may improve efficiency and reliability and increase their income by attracting more users through innovative services such as booking and payment; manufacturing and freight companies can improve their productivity thanks to a more efficient logistic chain.

Last but not least, society as a whole has real benefits in terms of lives saved and reduced insurance and health costs related. Thanks to less congestion and to an increased flow of information regarding road conditions the number of accidents has diminished and, on the other side, emergency services have improved. Intelligent Transport Systems are able to pinpoint accidents, help determine their entity, direct emergency vehicles to the accident site more quickly and find the best route to hospitals.

Efficiency in general is a key factor in tackling environmental impacts (GHG emissions, pollution, energy consumption, etc.) and the contribution of Intelligent Transport Systems in reducing such inefficiencies (by efficiently redirecting traffic flows throughout the road network) is confirmed in the majority of the reviewed documents.

Amongst the main barriers related to the spread of these technologies and systems there are regulatory issues and a digital divide. Many regulatory actions should be implemented in order to diminish market fragmentation between different operators and countries. The interoperability of the different transport systems can be achieved from a technological perspective: further efforts need to be made instead in terms of policy actions to achieve a real cooperation between operators for building a seamless transport system.

A second aspect to be taken into account is the different level of digital skills across countries and within each country between people from different economic and social conditions. Though the spread of “smart-phones” is increasing very fast, purchasing them is not affordable for everyone, and today not everyone has adequate skills to exploit the transport applications offered by these devices.

The first effect of an increasing availability of information on different modal options is the need for interlinked connections also from the point of view of tickets and fares. Information technology is fostering more and more the diffusion of electronic **booking and payment systems**. Nowadays it is quite common to book and purchase travel tickets on-line for different transport modes. Ticketing systems present great advantages in terms of general efficiency for the transport sector. Users can save time (or even avoid trips to purchase tickets in advance) and can sometimes also save money (as electronic ticketing systems calculate the lowest fare for their trips); on the other side public transport operators may rely on precious data on users' travel habits and behaviour thus having a better chance to efficiently plan different targeted solutions. Nonetheless, thanks to these revolutionary systems, tickets and fares can be treated as a “consumer product” to all effects: discounts and low rates can be easily foreseen and applied for specific time slots (non-peak hours) or particular areas. In general traffic conditions can be efficiently improved thanks to considerable reductions in waiting time, for instance at toll-barriers or while catching the bus. The interoperability of ticketing systems has great potential for international tourist flows and business trips.

Providing information requires collecting it. **Monitoring** systems have been increasing in number and application in recent years. Sensors are being installed along roads for different purposes: speed cameras to detect vehiclesô speed (for safety reasons), inductive loops to count traffic flows and measure speeds and send this data to traffic management (for information) and Closed Circuit Television (CCTV) for plate recognition (for road charging).

The Literature review commonly agrees on the evidence that monitoring devices can contribute to increase transport safety e.g. through systems for blind spot detection, speed monitoring and breakdown diagnostics.

On-board devices are more and more frequently installed in vehicles in order to increase safety both in an active way (preventing accidents by informing the driver of potentially dangerous situations; some equipments are also able to take actions to avoid accidents) and in a passive way (to reduce the impacts of the crash in case of unavoidable collision).

Causes of accidents may also be better investigated thanks to special monitoring devices on vehicles, thus offering the real picture of what happened in the car before the impact. This deeper knowledge may help to improve accident prevention.

Also in terms of energy, technology has been playing an increasing role in the last decades: new sources for energy production are always under development. Earlier on energy has been discussed in terms of demand, consumption and production, while this section focuses on **renewable energy**: the desirable and environment-friendly shift to electric traction or hybrid engines will imply a boost in energy demand for the transport sector, and therefore the investigation of new sources for renewable energy will likely be the main stream of research in the field of energy. The target is to achieve a less fossil-fuel based system. Some literature states that without any relevant change in policies and actions, the future production of energy will be still dominated by fossil fuels. This scenario looks totally unsustainable.

So far the number of vehicles running by electricity produced from renewables is low, but it is expected to grow rapidly; this objective is in line with the Renewable Energy Directive which sets a 10 % minimum target to be achieved by all EU Member States for the share of renewable energy in EU transport petrol and diesel consumption by 2020.

Several companies and governments started to finance investments in the sector of renewables. The increasing spread of renewable sources impacts positively both on the environment (GHG emissions can be significantly reduced thanks to this energy production) and on the economic sector as well (new jobs can be created due to an increasing share of investments in renewable sector even though under economic downturn periods).

Globally, energy production from renewable sources has increased, with a different mix in different countries.

In addition to research efforts in terms of technological improvements, there is still much to do in order to overtake policy barriers: incentives have to be urgently foreseen in order to sustain the development of these sustainable alternative energy sources.

The other main target that technology development and innovation may help to achieve is the reduction in energy consumption (fixed in a 20% cut by 2020 in the Energy Efficiency Plan 2011). Energy is vital for social and economic aspects of our life: without energy our society cannot survive or thrive, and, as already pointed out above, the demand for energy is expected to grow further while (as already explained above) Europeœ energy security still largely depends on extra-EU imports.

Against these unsustainable trends, **energy efficiency** can be a cost-effective solution. Policies started to pave the way in this direction introducing the concept of energy labels for most household appliances and recently extending its use to other sectors (buildings, and tyres will be soon labelled as well). More consciousness in consumers has risen in recent years thanks to these policies, making people more aware of the environmental effects of their choices when purchasing home-appliances or cars. But there is still much to do from the political side for addressing the challenge of energy efficiency. Incentives and investments should be introduced systematically in every sector, and in transport in particular as it accounts for 32% of final energy consumption. Investing in energy efficiency might also have substantial positive impacts on the economic domain (in particular on employment - creating new jobs) and on the environmental domain as each gain in term of energy efficiency directly results in a reduction in emissions and pollutants.

As far as the transport sector is concerned, innovative solutions in vehicles (related to traction technologies, vehicle design, on-board devices and materials) can provide remarkable results in terms of energy efficiency. In moving towards these targets, the public sector is supposed to play a leading role, thus giving the example to the private sector (both to companies and to citizens), by being a precursor in adopting these solutions.

Future **planning** and policy interventions are crucial in addressing the new challenges deriving from the key drivers. To meet the traveller needs of an ageing population the transport system needs to be adapted to cope with the reduced physical and cognitive capabilities of elderly. Transport policy measures are supposed to increasingly address the characteristics and the needs of the future population in order to support both private and collective mobility of elderly as long as possible.

As urbanisation continues to be a relevant phenomenon, urban and suburban transport networks must be properly planned to face an increasing number of people that will travel in and across urban centres. Measures to tackle congestion, air pollution and noise will be applied more and more in metropolitan and urban areas. Public transport has to be properly planned and subsidised in order to satisfy the potential increase in demand.

The emerging ñsustainable consumptionò culture on transport which is contributing to and increasing the shift towards alternative mobility by walking and cycling in urban areas should be properly incentivised by adequate planning and policy measures.

Awareness campaigns and training on environmental issues, already proved to be cost-effective, should become a major priority for policy makers.

In parallel with increasing efforts in enhancing environmental consciousness, appropriate fiscal policy measures and market regulation should be more and more implemented, in order to make environmental aspects enter the market (ETS, polluter-pays and user-pays policies to be extensively applied). In addition market regulation should be properly developed in order to prevent inefficiencies and/or inequalities while applying these mechanisms.

Increasing scarcity of fossil fuels and environmental concerns are accelerating the pace for technological development. Policy measures have to increasingly support the investments sustaining the spread of innovations in the ñgreen transportò sector.

Future transport planning should take account of the possibility for the transport systems to be severely affected by extreme weather conditions and disruptive events in order to develop some resilience to these aspects and to prevent major damage from services and network interruptions.

It is up to all policy levels (European, national and local) to take into account all the challenges deriving from expected trends and exploiting all the potential in order to satisfy future traveller needs and to drive the changes on a sustainable track.

| | | | Population ageing | Migration flows | Households structure and distribution | Income structure and distribution | Car ownership | Gender roles | Urbanisation | Planning | Touristic flows | Change of lifestyle and values | Education | Health | GDP trends | Employment | Regional differences in economics | Availability of public and private resources and investments in the transport sector | Market regulations | Foreign trade, globalisation | Energy availability and prices | Intensified competition for scarce resources use | Fiscal policy | Climate change impacts | GHG mitigation | Emissions trading schemes | Noise levels and emissions standards | Pollution levels and emissions standards | Energy availability, production and consumption | Scarce resources of fossil fuels | Scarce resources of raw materials | Technology development in general and innovation diffusion | New vehicles design | Advanced Driving Devices | Traction technologies | Material technology | Traffic management systems | Information systems | Booking and Payment systems | Monitoring | Pollution abatement and monitoring | Renewable energy production | Energy efficiency |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Social | | | | | | | | | | | | Economy | | | | | | | | | Environment | | | | | | | | Technology | | | | | | | | | | | |
| | | | Demographics | | Structure | | | | Spatial distribution | | Behaviour | | | Health | Economic performance | | | Investments | Market structures | Global trade | | | Policy | Climate change | | | Pollution | | Resources | | | Technology development | Vehicle technology | | | | ICT and telematics | | | | Pollution | Energy | |
| Social | Demographics | Population ageing | |x|x|x|x|x|x|x|x|x| |x|x|x|x|x| | |x| |x| | | | |x|x| | |x|x|x| | | |x|x| | | | |
| | | Migration flows |x| |x|x|x| |x| |x| | |x|x|x|x| | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Structure | Households structure and distribution | | | |x|x| |x|x| | | | | |x| | | | | | | | | | | | |x| | | | | | | | | | | | | | |
| | | Income structure and distribution | |x|x| |x| |x|x|x|x|x|x| | | |x| | | | |x| | | | |x| | | |x|x| | | | | | | | | | |
| | | Car ownership | | |x| | | |x|x| |x| |x| |x| |x| | | | |x| | | | |x| |x| | | | | | | | | | | | | |
| | | Gender roles |x|x|x|x|x| | |x| |x|x| | |x| | | | | | | | |x| | | | | | |x| | | | | | | | | | | |
| | Spatial distribution | Urbanisation | | | | |x| | |x| |x|x|x| |x| |x| | | |x| |x|x| |x|x|x|x|x|x| | | | |x|x| | |x| |x|
| | | Planning | | |x| | | |x| | |x| |x| |x|x|x| | | | | |x|x| | | |x| | |x| | | | | | | | |x| | |
| | Behaviour | Touristic flows | |x| | | | | | | |x|x| |x|x|x| | |x| | |x|x|x| | | | | | |x| | | | | | |x| | | | |
| | | Change of lifestyle and values | |x| |x|x| |x|x|x| |x|x|x|x|x| | | |x| | | |x| | |x|x| | |x| | | | | |x|x| |x| |x|
| | | Education | |x| |x| | | | | |x| | | |x| |x| | | | | | |x| | | | | | |x| | | | | |x| | | | | |
| | Health | Health |x| | | |x|x| | |x| | | |x|x|x|x| | | | | | | | | | | | | |x| | | | | | | | | | | |
| Economy | Economic performance | GDP trends | |x| |x|x| | | | |x| | | |x|x|x| | | | |x|x|x| | |x|x| |x| | | | | | | | | | | | |
| | | Employment | |x| |x| | |x| | | | | |x| |x| | | | | | | | | | | | | |x| | | | | | | | | | | |
| | | Regional differences in economics | |x| |x|x| |x| | | |x| |x|x| | | | | |x| | |x|x| |x| | | |x| | | | |x| | | | |x| |
| Economy | Investments | Availability of public and private resources and investments in the transport sector | | | |x| | |x| | |x| | |x|x|x| | |x| | | |x|x| |x|x| | | |x| | | | |x|x| | |x|x|x|
| | Market structures | Market regulations | |x| | | | |x|x| |x| | |x| | | | |x| |x|x|x|x| | | |x| |x|x| |x| | |x| | | | |x|x|
| | Global trade | Foreign trade, globalisation | |x| | |x| |x| | | | | |x|x|x| | | | | | |x| | | | | | | | | | | | | | | | | | | |
| | | Energy availability and prices | | | |x| | | | |x| | | |x|x| | | |x| | | | | | | | | | | | | | |x| | | | | | | |x|
| | | Intensified competition for scarce resources use | | | | | | | |x| | | | |x| |x| | |x|x| | |x| | | | | | | |x| | | | |x| | | | | | |
| | Policy | Fiscal policy | | |x|x| | | |x| | | | |x|x|x|x| |x| | | | |x| | | | |x| |x| | |x| | | | | | | |x|
| Environment | Climate change | Climate change impacts |x|x| |x| |x|x|x|x| |x|x|x| |x|x| |x|x|x| | |x| | |x|x|x| | | | | | | | | | | | | |
| | | GHG mitigation | |x| | | | |x|x| |x|x| |x|x| |x| | |x| |x|x| |x| |x|x|x| |x|x| |x| | | |x| | |x|x|
| | | Emissions trading schemes | | | | | | | | |x| | | |x| |x|x| |x|x| | |x|x| | | |x|x| |x| | | | | | | | |x|x|x|
| | Pollution | Noise levels and emissions standards | | | |x| | |x|x| | |x|x|x| | |x| | | | |x| | | | |x| | | |x|x| | |x| | | | | | |x|
| | | Pollution levels and emissions standards |x| | | | | | | | | | |x| | | | | | | | |x|x|x|x|x| |x| |x| | | | | | | | | |x| | |
| | Resources | Energy availability, production and consumption | | |x| | | |x|x| | |x| |x| |x| |x| |x|x|x|x|x| | | | |x| | | | | | | |x| | | |x|x|
| | | Scarce resources of fossil fuels | | | | | | |x| |x| | | |x|x|x|x| | | |x|x|x|x|x| |x|x| | | | | |x| | | | | | |x|x|
| | | Scarce resources of raw materials | | | | | | |x|x|x|x| |x|x| |x| |x|x| |x|x|x|x| | |x| | | |x| | | | | | | | | | |x|
| Technology | Technology development | Technology development in general and innovation diffusion |x| | |x| |x|x| | |x| | |x|x| | |x|x|x| | |x|x| |x|x|x| |x| |x|x|x| |x|x|x| |x| |x|
| | Vehicle technology | New vehicles design | | |x| | | | | | | | | | | |x|x| |x| | | | |x| |x|x|x|x| | | | |x|x| |x| | |x| |x|
| | | Advanced Driving Devices |x| | | | | | |x| | | | | | | |x| | | | | | |x| | | | | | | | | | | |x|x| | | | |x|
| | | Traction technologies | | | | | | |x|x| |x| |x|x| |x|x| |x|x| |x| |x| |x| |x|x|x| | | | |x| | | | |x| |x|
| | | Material technology | | | | | | | | | | | | | | |x| | | | | | | |x| |x|x|x| | | | | |x| | | | | | | |x|
| | ICT and telematics | Traffic management systems | | | | | | |x|x| |x| | | | |x|x|x| | | |x| |x| |x|x| | | |x| |x| | | |x| | |x| | |
| | | Information systems |x|x| | |x| |x|x| |x|x|x| |x|x|x|x|x| | | | |x| | |x| | | | |x|x| | |x| |x|x| | |x|
| | | Booking and Payment systems |x| | | | | |x|x|x|x| | | | | |x| | | | | | | | | |x| | | |x| | | | | |x| | | | |x|
| | | Monitoring | | | | | | | |x| | | | | | | | | | | | | | | | | | | | | | | |x| | |x| | | | | |x|
| | Pollution | Pollution abatement and monitoring | | | | | | | | | | | | | | |x| |x| | | |x| | | | | | | | |x| | | | | | | | | | | |
| | Energy | Renewable energy production | | |x| | | | | | | |x|x|x|x| | | | |x| |x|x|x| | |x|x|x| |x| | |x| | | | | | | | |
| | | Energy efficiency | | | | | | | | | | | | |x|x|x|x| | |x| | |x|x| | |x|x|x|x| | | | | | | | | | | | |

**Figure 1-96 Matrix of identified interactions**

# 2 EMERGING TRAVELLER NEEDS

## 2.1 INTRODUCTION

### 2.1.1 Task 3.2 Objectives

The identification and satisfaction of user needs have been an integral part of European transport policy (Debbah, 2009). For example, The 2001 Transport White Paper (CEC, 2001) stressed users at the ó*Heart of transport policy'* and in a review of Common Transport Policy (CEC, 2009) stressed the ó*Need to focus future European transport policy on the pursuit of an integrated, technology-based and user-friendly transport system...whilst ensuring that users, with their needs and rights are always kept at the centre of policy making.*

Set against this policy background, the main objectives of COMPASS Task 3.2 are:

*To perform a systematic and comprehensive review of available literature on 'the needs' of current (and potential) travellers, taking into account the forecasted key trends in mobility trends across Europe. This will entail identification of key search words/terms, followed by a search of online and project partner library resources to identify relevant previous EU projects, academic papers and other research reports. The review will include the needs of the full range of travellers, including more vulnerable groups, (such as older and mobility-impaired, people with young children), although, the focus will be on those groups identified as important in terms of forecasted key trends, e.g. older people, gender differences and migrants. The review of user needs will be structured to cover all transport modes both singularly and also in combination when making multi-modal trips.*

*The review will take particular account of the related analyses carried out in KITE, ORIGAMI and USEmobility.*

- *In KITE, they examined user requirements for long-distance journeys using a combined literature review and supplementary stated preference based survey, and concluded that cost and time are the main user requirements. However, the survey was limited in terms of focussing on instrumental (time/cost) factors and did not consider the full range of user need requirements that are known to be important for determining user satisfaction and ultimately modal choice decisions. The review in COMPASS will expand on this research by examining evidence related to the full range of instrumental, affective, physical and technological factors that are important, and the relative importance to each other in short-distance journey decisions and mode-option use;*
- *Whereas ORIGAMI (Task 3.2: Review of user needs) focussed solely on long-distance journeys, the 'related' review in COMPASS will focus specifically on short-journeys (less than 100km), and also take into account relevant situational factors, as well as how user requirements differ according to key socio-demographic factors.*

Accordingly, unlike the ORIGAMI report, user needs for air and long-distance coach journeys will not be considered here, and the analysis will be restricted to those modes that are typically used in short-distances, namely rail, local bus, metro and ferries.

In line with current EU objectives to encourage sustainable transport choices (i.e. non car use), this section of the report will also not consider user requirements for car use per se, although it will examine the reasons as to why people are so óattachedô to their cars, and the barriers that prevent people from switching from car use to alternative modes.

*The review will also explore how user requirements are related to actual mode choice decisions, in particular the requirements that are identified as most important that would encourage people to switch to/use alternative more sustainable transport modes. COMPASS will therefore take into account the related research of the USEmobility project, specifically the results of their survey, which aims to retrospectively examine modal choice decisions. Furthermore, the review will include evidence on how user needs are affected via both the physical mode characteristics, e.g. how the physical/ergonomic characteristics of different mode options, both singularly and for combined mode trips can restrict ease of use from a user perspective (trip suppression), as well as psychological factors, e.g. perceptions of safety, perceived confidence and comfort affect trip making decision and modal choices. Evidence related to both physical and psychological aspects will be analysed both* *separately and then together in a more holistic way in order to identify the key barriers and facilitators relevant to users.*

#### 2.1.2 Structure

For any traveller, undertaking an intermodal journey can be a complex task, as this may involve several transport modes and require several transfers or interchange points. User needs will thus differ according to the different transport modes and the number and type of interchange facilities involved in each of these journeys.

Taking this into account, this second part of D 3.2 begins by considering user needs for short-distance intermodal trips at a generic level (i.e. for all transport modes and interchange points), before looking at user needs at an individual mode level (i.e. rail, bus/coach/metro and ferry) to identify any mode specific user requirements, as well as specific user needs relating to the access/egress intermodal journey stage (i.e. local public transport, walking, cycling).

Evidence as to how user needs vary according to personal factors, specifically to the key demographic factors identified in the first part of the deliverable (i.e. age/mobility-impairment, gender and migrants), as well as situational factors (i.e. trip purpose) is then presented.

The relationship between user requirements and modal choice decisions, specifically modal shift decisions for private car use to more sustainable travel choices is then discussed, followed by a short discussion and conclusions on which are the key user requirements for people undertaking intermodal journeys, as well as highlighting recommendations for future research to address any specific gaps in knowledge identified.

### 2.2 Generic User Needs for Intermodal Journeys

#### 2.2.1 Key User Needs for Short-Distance Intermodal Journeys

At a generic level several recent European research projects have examined user requirements for intermodal journeys (ILS, 2004; LINK, 2007; KITE, 2007; CLOSER, 2010) - see also Carreno (2011), who recently reviewed this evidence, specifically in relation to user needs for long-distance intermodal journeys.

In his review of evidence Carreno (2011) identified a total of 16 key user needs. However, much of the evidence for these conclusions was derived from studies examining user needs for intermodal journeys generally (i.e. neither specifically for long- or short-distance travel) and thus many of the studies reviewed there are also relevant for this report. Accordingly, the more detailed overview provided by Carreno will not be replicated here, and only a brief summary of the key user needs identified is presented, except where new evidence has become available, or for key intermodal aspects such as interchange facilities. The key user needs identified by Carreno are briefly described below.

#### 2.2.2 Network Characteristics

Network characteristics of a transport system relate more to the operating practices of the transport services involved, which from a user perspective should ideally match up to their specific requirements for each intermodal journey. These include:

- **Frequency of services**: Transport services should depart and arrive at transport terminals that match up with users specific requirements, e.g. to allow them to arrive at work on time, or to catch their next modal leg;
- **Convenient departure/arrival times**: Related to frequency of services, available transport services should depart and arrive at times which are suited to the needs of travellers;
- **Spatial coverage**: Available transport services should serve an area, or specific destinations that users wish to travel to;

- **Reliability of services**: Available transport services should run on time, which is particularly important for intermodal travellers, especially when several modal transfers are required in their journeys.

### 2.2.3 Interchange Facilities

A second key user need identified relates to the interchange (or transfer) points involved in the journey. Several classifications of user needs for interchanges have been proposed (e.g. MIMIC, 1999; GUIDE, 2000; PIRATE, 2001; SWITCH, 2001; Wardman, Hine and Stradling, 2001; KITE, 2009a; and Transport for London (TfL), 2009a). A more detailed summary of these suggested user need classifications was presented in Carreno (2011) who identified the KITE (2009a) classification as the most up to date and comprehensive overview. However, given the prominence of interchange facilities in intermodal journeys, an overview of the KITE classification is also presented in this report.

KITE (2009a) suggested a comprehensive user requirement classification broadly divided into 4 main categories, namely:

- **Intermodal integration of modes**: *This field includes circumstances at an interchange terminal that integrate and promote the availability and the usage of all public transport modes (long-distance modes and local public transport) as well as good access for individual transport modes for passengers* (KITE, 2009a, 22). Aspects include:
  - Availability of long distance modes and quality of connections;
  - Availability of public transport (urban train, underground, bus, tram) for access to and egress from the terminal;
  - Provision of direct access to the major road network (e.g. motorway);
  - Supply of car parks or garages;
  - Availability of taxis in a central position;
  - Existence of cycle lanes leading to/from the interchange point;
  - Availability of cycle stands.

- **Passenger services to support intermodality**: *Beside the optimal availability and integration of different transport modes at the terminal, supporting services for their use are crucial to seamless passenger travel* (KITE, 2009a, 23). Aspects include:
  - Short transfer times between transport services ;
  - Sufficient information about arrival and departure times and about further connections (integrating all modes);
  - Short waiting times at all capacity restrain points (check-in, ticket counter);
  - Easy ticketing (ticketing vending machines, integrated tickets etc.);
  - Intermodal luggage handling.

- **Design aspects of the intermodal interchange**: *At railway stations, airports and ports the constructional design and interior equipment play an important role to guarantee seamless travel for passengers* (KITE, 2009a, 23). Aspects include:
  - Distances for transfer between transport services (between gates, platforms etc.);
  - Distances between transport modes and service facilities within the terminal;
  - Barrier free accessibility and interchange for disabled persons;
  - Easy way finding (good and understandable signage);
  - Feeling of safety within terminal.

- **Additional services for passengers' convenience**: *Further services, facilities and characteristics to support that passengers travelling on long-distance journeys for private as well as for business purpose feel comfortable during their stopover at an interchange terminal* (KITE, 2009a, 24). Aspects include;
  - Waiting conditions (e.g. availability of seats);
  - Availability of left-luggage lockers;
  - Shops and facilities;
  - Availability of accurate and easily understandable information about the destination (hotels, sights, events etc.).

As noted by Carreno (2011) the only notable differences between the KITE (2009a) classification and other classifications available (i.e. MIMIC, 1999; GUIDE, 2000; PIRATE, 2001; SWITCH, 2001; Wardman, Hine and Stradling, 2001; and Transport for London (TfL), 2009a) are that:

- Both Wardman, Hine and Stradling and SWITCH include additional psychological/social user needs, i.e.
  - Wardman, Hine and Stradling include more subjective additional needs related to the behaviour of other passengers, simplicity of obtaining tickets and protection from weather whilst waiting at and travelling to interchange facilities, and;
  - SWITCH include usersô fears and feelings for personal security; the need to overcome language, cultural, physical or sensory barriers; feelings of social exclusion due to socio-economic status;

### 2.2.4 Door-to-Door Information

A third key user need identified concerns the provision of information, which due to the increased complexity of intermodal journeys needs to be provided to users for each stage of the journey (Infopolis 2, 1999; FTA, 2003; Grotenhuis, Wiegmans and Rietveld, 2007; Waara, 2009). However, as noted by Carreno (2011) despite the general consensus that integrated multimodal public transport information is important for users, there has been little empirical research on what kind of multimodal information travellers need (see Grotenhuis, Wiegmans and Rietveld, 2007).

This complexity of information requirements is best described by Infopolis 2 (1999) who identified a list of questions that potential users may ask (and require information on) at various journey stages. The questions most relevant for each stage of intermodal journeys are as follows.

- **Pre-trip:** The pre-trip stage is essentially the travel planning step, when the user prepares his/her future travel at the origin of the travel, e.g. at a personøs home or work place. Users will want to know: How to find information about connections between networks? How to find information about connections between vehicles? How and where to find this information? Can I buy one ticket for the whole journey? And where is this information available?
- **Wayside (First stop):** Wayside locations can be bus stops, stations, ferry docks, public transport centres, park and rides, etc. Among wayside locations, first stop locations and interchanges can be distinguished. The difference is that at first stop locations travellers are usually much more familiar with the stop or station than on intermediate stops, which affects their need for information. Users will want to know: How to find information about delays or cancellations? Where is the next stop for next journey leg? Which vehicles / modes can I use for the next stage of journey? Where can I buy a ticket (if still required)? Where to board the next vehicle (door/cabin)?
- **On-board:** On-board information consists of information provided inside a vehicle, and is always preceded by pre-trip information and wayside information. Users will want to know: Can I still catch my next connection (any delays)? Is my ticket still valid for next leg of journey? Is this vehicle late or on time? Which is the correct stop to get off?
- **End trip:** These information requirements relate to the links between the final vehicle/interchange stop and the personøs destination. Users will want to know: How to reach their final destination

(modes available)? How to get information regarding the return trip? General information about the city/ location?

The specific questions that users may require answers to for each intermodal journey will depend on several factors, such as the type of trip, location of trip origin and destination and personal factors (e.g. level of mobility), and these differences in user information requirements are discussed later in the report.

### 2.2.5 Tariffs and Ticketing

Due to the nature of intermodal journeys, users require simple ticketing arrangements which will allow them to transfer between different modes, or same modes operated by different operators, without having to buy numerous tickets (e.g. SWITCH, 2001). This requirement is also linked to the ease to which tickets can be purchased, i.e. can they be purchased prior to the journey, from one website, or booking office, etc. (e.g. LINK, 2010a).

### 2.2.6 Baggage Handling

Whilst baggage handling/luggage storage facilities may be more relevant and important for intermodal travellers making long-distance journeys (EuroTraCS, 1998; Lanz & Manz, 2003; ILS, 2004; KITE, 2007b; KITE, 2009a; Carreno, 2011), for some short-distance travellers, such as those carrying shopping, fold-up buggies, or other 'objects', facilities for storage, on-board local buses, trains, metros, ferries, will also be an important feature.

### 2.2.7 Safety

The sixth user requirement, which applies to all journeys people make, is the need to feel safe. This requirement relates to both general safety issues (e.g. safety from accidents - Ben-Akiva and Morikawa, 2002) and also the requirements for passengers to feel safe when accessing, waiting for and using transport services (e.g. KITE, 2007).

### 2.2.8 Personal Security

Related to safety requirements is the need to feel personally secure when making a journey. This includes travelling to and from transport terminals, waiting at terminals and travelling on vehicles (e.g. Crockett et al., 2004; Eboli and Mazzulla, 2011).

### 2.2.9 Comfort

When travelling users need to 'feel comfortable', although, this user requirement is quite broad and highly subjective, covering a range of aspects including:

- General user needs such as protection from weather whilst waiting for services, cleanliness of vehicles and terminals, provisions of seating and waiting areas at terminals/interchanges (Ben-Akiva and Morikawa, 2002; Crockett et al., 2004), as well as;
- In-vehicle characteristics such as ride quality, seating comfort, ventilation and ambience (e.g. Wardman and Whelan, 2001).

### 2.2.10 Journey Time

Short journeys times are also a key requirement for most travellers, although for intermodal travellers whose journeys are by nature typically longer and more complex this has greater importance (McDonald et al., 2003). The time required for users to complete the whole intermodal journey is thus linked to *network characteristic requirements* (interconnections between services, reliability of services to avoid missed connections etc.) as well as the time taken to access transport terminals (First/Last mile).

### 2.2.11 Costs

Low overall journey cost is also consistently identified as a key user requirement for many intermodal travellers (CLOSER, 2010). This aspect is not only related to the actual cost of tickets, but also to costs associated with reaching transport terminals.

### 2.2.12 Transport Employees

When making any journey, users require (expect) employees (at interchanges and on-board vehicles/vessels) to be able to assist them (if required), provide the correct information to them, are smartly dressed and courteous.

### 2.2.13 Effort Expenditure

Users require that the total effort (i.e. physical, cognitive and affective) they need to expend to undertake a journey is of a ‘reasonable’ degree i.e. is acceptable for them, not too stressful, uncomfortable for them (e.g. Stradling, 2002; Crockett et al., 2004).

### 2.2.14 In-Vehicle Facilities

Users require (expect) various services to be provided, or be available for them (primarily for main mode elements of the journey), including aspects such as catering facilities, communication facilities (wireless access, plug sockets) and entertainment facilities (newspapers, TV/films, games etc.). This aspect is thus related to *Comfort* requirements - see earlier.

### 2.2.15 Environmental Concerns

It is increasingly common for travellers to be more environmentally aware of the impacts of their travel behaviour, and many users have expectations that transport companies and operators are taking actions to minimise the environmental impact, i.e. using low emission vehicles and fuel. (e.g. Széchenyi István University, 2008; Eboli & Mazzulla, 2011).

### 2.2.16 Accessibility / The First/Last Mile

The ability to access/egress from transport terminals is another key user requirement identified. In one respect this aspect will be more important for rail and ferry users as these transport terminals are typically located further from travellers’ starting locations, and the specific user requirements for this part of an intermodal journey will also be dependent on the modes used to reach the transport terminal.

In relation to accessing transport terminals, both KITE, 2009a and NICHES+ 2001b note that the key user requirements according to modes used:

- Cyclists: Apart from the existence of cycle lanes leading to/from terminals, relate to available, cheap and secure parking facilities at terminals;
- Taxi users: Apart from cheap and available taxi services to/from terminals, relate to taxi ranks at terminals (departure/arrival gates);
- Bus users: Apart from frequent /reliable services to/from terminals;
- Private car drivers: Apart from road access to/from terminals, relate to available, cheap and secure parking facilities at terminals;
- Pedestrians: Footpaths leading to/from terminals.

At a more general level the specific needs for pedestrians (e.g. Gallin, 2001; PROMPT, 2003; DfT, 2003; Carreno and Stradling, 2007; Coffel et al., 2009; Dowling et al., 2010) and cyclists (Dixon, 1996; DfT, 2003; Soren, 2007; Dowling et al., 2010) have been well documented and were summarised in Carreno (2011).

#### 2.2.17 Promotion of Intermodal Services

Finally, for users to make intermodal journeys, they need to be aware of the various services and options that are available, which would include for example, special offers or discounted intermodal ticket options that would entice them to use specific services (e.g. Stradling, 2002; Crockett et al., 2004; LINK, 2010).

## 2.3 User Needs for Individual Modes

This third part of Section 2 now considers evidence related to user needs for individual modes that singularly, or in combination could be part of the travel chain in intermodal trips. As stated in the introduction, rail, metro, local bus and ferry services are all potential transport modes that could be involved in short-distance intermodal journeys, and a summary of user needs for these modes is presented here. A more detailed review of user needs for these modes was recently presented in the ORIGAMI Deliverable (Carreno, 2011).

Based on the literature search, the most comprehensive and recent overview of user needs appropriate for short-distance intermodal journeys was Tyrinopoulos and Antoniouѕ (2008) classification. Tyrinopoulos and Antoniou suggested a user need classification for all local public transport modes in Athens, which includes local bus, trolley bus, metro and over ground light-rail services, as well as interchange facilities, making it highly suitable for short-distance intermodal journeys. The classification relates to four broad service dimensions and 23 associated sub-attributes, which are described in Column 1 of Table 2-1 and evidence related to individual modes (including ferries) in subsequent columns.

However, it should be noted that Tyrinopoulos and Antoniou do not include all 17 user needs identified in the previous section in their classification, although evidence to support these aspects as important can be obtained from studies that have examined user needs for specific modes, i.e.

- **Baggage Handling**: Crockett et al., 2004 for rail travellers, Pantouvakis, 2006, Kapros et al., 2011 for ferry travellers;
- **Safety**: Crockett et al., 2004, Van Hagen, 2005, Brons, Givoni & Rietveld, 2009, for rail travellers; Széchenyi István University, 2008, Eboli & Mazzulla, 2011 for bus travellers;
- **Effort**: Crockett et al., 2004, Van Hagen, 2005, for rail travellers;
- **In-vehicle facilities**: Crockett et al., 2004, Nathanail, 2008, for rail travellers, Jørgensen, Mathisen and Solvoll (2008), Kapros et al., 2011 for ferry travellers;
- **Promotion of services**: Crockett et al., 2004 for rail travellers; Stradling, 2002, for public transport users generally.

Furthermore, not all studies that have examined user needs for individual mode components include all of Tyrinopoulosô and Antoniouѕ suggested user requirements, or all of the 17 key user needs identified, although, for this latter point, collectively, the individual studies do include all aspects.

**Table 2-1 Suggested user need classifications: Public transport generally, rail, metro, local bus and ferry**

| Tyrinopoulos & Antoniou (2008) | Rail | Metro | Local bus | Ferry |
|---|---|---|---|---|
| **General characteristics of a public transport system** | | | | |
| ***Service frequency***: Frequent services (where passengers want/need to travel) | ã<br>Crockett et al. (2004); Nathanail (2008); Brons, Givoni & Rietveld (2009) | ã<br>Apostolopulou et al. (2000) | ã<br>Hensher, Stopher & Bullock (2003), Széchenyi István University (2008); Eboli & Mazzulla (2011); Diana (2012)[88] | ã<br>Jørgensen, Mathisen and Solvoll (2008); Lekakou et al. (2011) |
| ***On-time performance***: Services arrive/depart on-time | ã<br>Crockett et al. (2004); Van Hagen (2005) | ã<br>Apostolopulou et al. (2000) | ã<br>Hensher, Stopher & Bullock (2003), Széchenyi István University (2008); Eboli & Mazzulla (2011); Diana (2012) | ã<br>Jørgensen, Mathisen and Solvoll (2008) |
| ***Service provision hours***: Services operate at times passengers need | ã<br>Crockett et al. (2004) | | ã<br>Eboli & Mazzulla (2011) | ã<br>Pantouvakis (2007); Jørgensen, Mathisen and Solvoll (2008); Lekakou et al. (2011) |
| ***Network coverage***: Services operate to/from places (spatial coverage) people want/need to travel to | ã<br>Crockett et al. (2004) | | ã<br>Eboli & Mazzulla (2011) | |
| ***General information provision***: Sufficient information is provided to customers about the general characteristics of the transit services, such as the lines, terminals and stops points, departure times, tickets and passes available | ã<br>Crockett et al. (2004); Nathanail (2008); Brons, Givoni & Rietveld (2009) | ã<br>Apostolopulou et al. (2000) | ã<br>Hensher, Stopher & Bullock (2003), Széchenyi István University (2008); Eboli & Mazzulla (2011) | ã<br>Jørgensen, Mathisen and Solvoll (2008) |

[88] Diana (2012) user need classification covered local buses, trolleybuses and trams (for Italian multi-modal travellers), although, for the purposes of this report is included under local buses

| Tyrinopoulos & Antoniou (2008) | Rail | Metro | Local bus | Ferry |
|---|---|---|---|---|
| ***Types of tickets and passes***: Sufficient types of tickets and passes with respect to the coverage of the needs of the public are provided | | ã<br>Apostolopulou et al. (2000) | | ã<br>Pantouvakis (2007); Jørgensen, Mathisen and Solvoll (2008) |
| **Prices of tickets and passes**: The price structure of the various types of tickets and passes available, is good | ã<br>Crockett et al. (2004); Brons, Givoni & Rietveld (2009) | ã<br>Apostolopulou et al. (2000) | ã<br>Hensher, Stopher & Bullock (2003), Széchenyi István University (2008); Eboli & Mazzulla (2011) | ã<br>Pantouvakis (2007); Jørgensen, Mathisen and Solvoll (2008); Lekakou et al. (2011) |
| ***Tickets selling network***: Refers to the sufficiency of the tickets selling network and the ease to purchase tickets from the various selling points; | ã<br>Nathanail (2008) | | ã<br>Széchenyi István University; Eboli & Mazzulla (2011) | |
| ***Personnel behaviour***: The behaviour of the various types of personnel of the transport operator (e.g., drivers, station officers and ticket counter officers), when communicating and transacting with the passengers, is good and acceptable to users | ã<br>Crockett et al. (2004); Van Hagen (2005); Nathanail (2008); Brons, Givoni & Rietveld (2009) | ã<br>Apostolopulou et al. (2000) | ã<br>Hensher, Stopher & Bullock (2003), Széchenyi István University (2008); DelôOlio, Ibeas & Cecin (2010); Eboli & Mazzulla (2011) | ã<br>Pantouvakis (2007); Jørgensen, Mathisen and Solvoll (2008); Lekakou et al. (2011) |
| ***Existence of bus lanes***: Refers to the sufficiency and performance of the bus lanes to facilitate the efficiency of the transit service | ã<br>Brons, Givoni & Rietveld (2009) | | Not explicitly, although, Széchenyi István University (2008) refer to ‡journey speedô | Not explicitly, although, Pantouvakis (2007); Jørgensen, Mathisen and Solvoll (2008); Lekakou et al. (2011) all mention journey time |
| ***Measures for environmentally friendly public transit***: Refers to the contribution of public transit in the protection of the environment and the adequacy of the relevant actions and measures taken by the relevant authorities | | | ã<br>Széchenyi István University (2008); Eboli & Mazzulla (2011) | |

| Tyrinopoulos & Antoniou (2008) | Rail | Metro | Local bus | Ferry |
|---|---|---|---|---|
| **Terminals and stops** | | | | |
| ***Walking distance to terminals and stops***: The distance that passengers have to walk from the origin point to the closest terminal and stop, is as short as possible | ã<br>Crockett et al. (2004) | | ã<br>Hensher, Stopher & Bullock (2003), Széchenyi István University (2008); Eboli & Mazzulla (2011) | |
| ***Information provision at terminals and stops***: Sufficient information is available to the passengers about the services provided at the terminals and stops | ã<br>Crockett et al. (2004); Nathanail (2008); Brons, Givoni & Rietveld (2009) | | ã<br>Hensher, Stopher & Bullock (2003); Eboli & Mazzulla (2011) | ã<br>Jørgensen, Mathisen and Solvoll (2008) |
| ***Conditions at terminals and stops***: The conditions of the terminals and stops concerning shelter, visibility, seating capacity, etc. are acceptable to users | ã<br>Crockett et al. (2004); Brons, Givoni & Rietveld (2009) | ã<br>Apostolopulou et al. (2000) | ã<br>Eboli & Mazzulla (2011) | |
| ***Safety at terminals and stops***: Passengers feel safe when waiting at the terminals and stops to use the public transit service | ã<br>Crockett et al. (2004); Van Hagen (2005); Nathanail (2008); Brons, Givoni & Rietveld (2009) | ã<br>Apostolopulou et al. (2000) | ã<br>Eboli & Mazzulla (2011); Diana (2012) | |
| ***Vehicles*** | | | | |
| ***Onboard conditions***: The conditions inside the vehicle during the execution of a journey, mainly concerning crowded situations and the provision/condition of available facilities (e.g., seats and air-conditioning) are acceptable to users | ã<br>Crockett et al. (2004); Nathanail (2008); Brons, Givoni & Rietveld (2009) | ã<br>Apostolopulou et al. (2000) | ã<br>Hensher, Stopher & Bullock (2003), Széchenyi István University (2008); DelôOlio, Ibeas & Cecin (2010); Eboli & Mazzulla (2011) | ã<br>Jørgensen, Mathisen and Solvoll (2008); Lekakou et al. (2011) |
| ***Vehicles cleanliness***: The level of cleanliness of the vehicles from various standpoints (seats, handles, windows, doors, floor, | ã<br>Crockett et al. (2004); Van Hagen (2005); Nathanail (2008); | ã<br>Apostolopulou et al. (2000) | ã<br>Hensher, Stopher & Bullock (2003); | ã<br>Jørgensen, Mathisen and Solvoll |

| Tyrinopoulos & Antoniou (2008) | Rail | Metro | Local bus | Ferry |
|---|---|---|---|---|
| etc.) is acceptable for users | Brons, Givoni & Rietveld (2009) | | DelôOlio, Ibeas & Cecin (2010) | (2008) |
| ***Onboard information provision***: Sufficient provision of information inside the vehicle during the trip, such as next stop and estimated arrival time at the next stop | ã<br>Crockett et al. (2004); Nathanail (2008); Brons, Givoni & Rietveld (2009) | ã<br>Apostolopulou et al. (2000) | ã<br>Eboli & Mazzulla (2011) | |
| ***Accessibility to disabled and mobility impaired people***: Sufficient provision of facilities by the transit operator to facilitate the accessibility of transit services by disabled and mobility-impaired people | ã<br>Crockett et al. (2004); Nathanail (2008) | ã<br>Apostolopulou et al. (2000) | ã<br>Hensher, Stopher & Bullock (2003) | |
| ***Transfer points*** | | | NB: With the exception of Hensher, Stopher & Bullock (2003), studies reviewed here for bus user needs, focus more on the actual journey, and do not include transfer (interchange) aspects- see section 2.2.3 earlier | NB: Studies reviewed here for ferry user needs, focus more on the actual journey, and do not include transfer (interchange) aspects- although, see section 2.2.3 earlier |
| ***Distance between transfer points***: Minimal distances that passengers have to walk between transfer points in order to continue their trip | ã<br>Crockett et al. (2004); Van Hagen (2005); KITE (2009a) | ã<br>KITE (2009a) | ã<br>KITE (2009a) | ã<br>KITE (2009a) |
| ***Waiting time at transfer points***: Minimal time that passengers have to wait at transfer points in order to continue their trip. | ã<br>Crockett et al. (2004); Van Hagen (2005); KITE (2009a) | ã<br>Apostolopulou et al. (2000); KITE (2009a) | ã<br>KITE (2009a) | ã<br>Pantouvakis (2006); KITE (2009a); Kapros et al. (2011) |
| ***Information provision at transfer points***: Sufficient information is provided to passengers at the transfer points about the combination of the various lines and modes, and their time schedules | ã<br>Crockett et al. (2004); Nathanail (2008); Brons, Givoni & Rietveld (2009); KITE (2009a) | ã<br>Apostolopulou et al. (2000); KITE (2009a) | ã<br>Hensher, Stopher & Bullock (2003); KITE (2009a); Eboli & Mazzulla (2011) referring to bus stop | ã<br>Pantouvakis (2006); KITE (2009a); Kapros et al. (2011) |

## 2.4 THE RELATIVE IMPORTANCE OF USER NEEDS

Having identified the key user needs suggested as important for short-distance intermodal travellers, the forth part of Section 2 now presents a summary of evidence that has examined the relative importance of these needs to each other.

### 2.4.1 The Most Important Needs for Intermodal Journeys

Only a few authors have attempted to identify the most important aspects for users when making intermodal journeys, specifically for short-distance journeys (e.g. Last and Manz, 2003; KITE, 2009c). KITE (2009c) for example, concluded that mode choices for long-distance travel are based on time and cost. However, in this study only four factors were considered (travel time, access time, costs and number of transfers) which is typical in ‘stated preference design’ studies and as shown in this report, these are not the only user needs identified as important to travellers.

### 2.4.2 The Most Important Needs for Interchange Users

Only one study was identified that specifically attempted to rank the most important user needs for interchange facilities (PIRATE, 2001). In a survey involving transport users and non-users, PIRATE found that aspects related to *total impression*, were rated most important, more specifically *safety and security* which was the most important aspect for both groups. For users this was followed by *traffic and travel information provision, car parking availability, interchange location, operational efficiency and information (in general)* and *drop off and pick up facilities*. For non-users, *safety and security* was followed by the *walking environment leading to the interchange, car parking availability, traffic and travel information* and *interchange location.* However, not all of the user need attributes suggested in the KITE (2009a) interchange classification were measured in this study and further studies are required to validate these findings.

### 2.4.3 The Most Important Needs for Rail Travellers

Although several user need classifications for rail travel were identified within this report, none attempted to identify which aspects were most important for users. As such no real conclusions can be made and further research is required to address this knowledge gap.

### 2.4.4 The Most Important Needs for Bus Travellers

Only one study was identified that attempted to rank which aspects were the most important for local bus users (dell’Olio, Ibeas and Cecin, 2010). Based on focus group research, they suggested *waiting times (at stops)*, *journey time*, *vehicle occupancy*, *cleanliness of vehicles*, *driver attitudes* and *comfort (on bus)* are the most important user requirements. However, this research was limited in that it focussed on bus journeys generally, and for intermodal journeys additional considerations such as baggage handling, door-to-door information (etc.) are likely to affect these conclusions. As such no real conclusions can be made and further research is required.

### 2.4.5 The Most Important Needs for Ferry Travellers

Only one study was identified in this report which examined the most important factors for ferry users (Jørgensen, Mathisen and Solvoll, 2008). Overall, *cost* was identified as the most important aspect, followed by *available discounts*, *the likelihood of boarding (in summer and winter)*, and *frequencies of service and departure times*. However, not all of the 17 key users needs identified in this report (specifically all those identified for ferry users) were measured in this study, and further validation studies are required.

### 2.4.6 The Most Important Needs for First/Last Mile Stages

No studies were identified that attempted to rate the relevant importance of aspects related to the last/first mile of intermodal journeys. However, the relative importance of this journey stage will be dependent on the individual modes used to access/egress transport terminals. Accordingly, the relative importance of user needs related to this journey stage will be dependent of the individual modes used to access / egress from transport terminals - see above and Carreno (2011) for a more detail summary of user importance for access modes.

#### 2.4.7 The Role of Personal and Situational Factors in Determining Relative Importance

It should also be noted that both personal and situational factors will determine the relative importance of user needs for intermodal journeys, which are discussed in the following sections.

Locational factors will also affect the importance attached to different user needs. For example Wixey et al. (2005) noted that in many rural areas public transport services are typically *reduced* and aspects such as service frequency, punctuality of services and service operating hours are likely to hold greater importance for all users (e.g. Gray, 2001; Gaffron, Hine & Mitchell, 2001).

### 2.5 SPECIFIC ISSUES FOR DIFFERENT USER GROUPS

#### 2.5.1 User Group Differences: Introduction

Having looked at user needs at both a generic level for individual modes involved in short-distance intermodal journeys, this section now considers how user needs can vary according to personal factors, specifically according to the key trends identified earlier, of age, mobility-impairment, gender and migrant status.

Given that age and mobility-impairment are intrinsically linked, in that the incidence of mobility-impairment increases significantly with age (e.g. DETR, 1998; ILS, 2004; King, 2007; NICHES+, 2010c), and for the purposes of this report, the needs of these two groups are considered together. However, mobility-restrictions can affect many traveller groups, including those with mobility, sensory, cognitive and communication difficulties (Alauzet et al. 2009), people with environmental and sensitivity allergies (Stahl and Wretstrand, 2008), people who are overweight, particularly tall or short, pregnant women, using pushchairs and those carrying heavy luggage. (SWITCH, 2001).

#### 2.5.2 Older People/Mobility-Impaired Needs for Public Transport

A more detailed summary of older/mobility-impaired peoplesôneeds is provided by Carreno (2011), although a summary of the key points is provided here.

- DPTAC (2002) concluded that in many respects the transport needs of older / mobility impaired disabled differ very little from the general population as a whole, although for some user aspects, their requirements are of a different nature / or are more important to them.
- DETR (1998) concluded that for many older/mobility-impaired people their main user requirements relate to being able to board and alight from vehicles safely (accessibility issues), transport staff understanding their specific needs, assistance or ease of carrying bags/luggage.
- DPTAC (2000 & 2002) concluded that in addition to more frequent and reliable services, more comfortable services and lower cost services, improving access for disabled people is a key priority. Many priorities also relate to the ósofterô aspects, i.e. the way in which services are delivered rather than the actual services themselves. In particular, improving attitudes of transport staff is perceived as a key issue.
- ILS (2004) note that older/mobility impaired people have special needs and requirements with respect to intermodality, specifically in relation to aspects such as baggage handling, accessibility of interchanges and user friendly information.
- Smith et al. (2007) concluded that accessibility needs, including reaching transport stops, boarding and alighting vehicles was the main issue for mobility-impaired travellers, as well as adequate information provision, more so for visual and hearing impaired travellers, feeling safe and secure when travelling, and cost, as many mobility-impaired people are on low incomes.
- NICHES+ (2010c) note that for mobility-impaired travellers accessibility issues are the main requirement, both in terms of accessing transport services and using them.

- Waara (2009), Infopolis 2 (1999); DPTAC (2000) all note that as well as the more general information needs of all travellers:
  - Mobility-impaired travellers need to know if the network is adapted for them, i.e. *Will assistance be available for them?*
  - For people in a wheelchair, pre-trip information is particularly important, including aspects of *‘Is there an elevator/lift at the interchange station?ôAre the buses low platform?* Etc.
  - For sensorial disabled travellers (e.g. those who are blind, deaf) they need to know that information is presented in a media/format they can understand, e.g. large print, Braille, talking maps, etc. - see also Whitney, Keith and Kolar (2005) and DPTAC (2010).

Taken together, óaccessibility issuesôappear to be the main, or most important user requirement for older/mobility-impaired travellers, relating to accessing services, vehicles and interchanges, although, óunderstandableôinformation provision and staff assistance are also key requirements.

### 2.5.3 Gender Differences in User Needs

It is well documented that male and female travel behaviours differ (e.g. Grieco, 2007; Su & Bell, 2012), although there appears to be relatively little research specifically concerning male and female user needs.

For all studies reviewed for this report, any comparisons made between males and females concerning user needs (e.g. Law, 1999; Reid-Howie Associates, 2000; Hamilton et al. 2000; Hine & Mitchell, 2001; Wixey et al. 2005; Granville & Campbell-Jack, 2005; Smith, 2008; DfT, 2009), the general conclusion is that overall there is no real differences in their specific needs *per se*, although some females do attach greater importance to certain aspects. A summary of the main findings is presented below:

- **Accessibility:** Women often make *'encumbered'* journeys, i.e. travel with luggage, shopping, or young children, and in these cases share similar problems in using buses as those with restricted mobility (Smith et al. 2007), and are thus likely to have similar needs. Accessibility needs are more relevant for woman travelling with children, especially in relation to boarding and alighting vehicles (especially with buggies) and buying tickets as their journeys tend to be more complex, often involving multiple-stages (Reid-Howie Associates, 2000; Hamilton et al. 2000; Hine & Mitchell, 2001; Wixey et al. 2005).
- **Reliability:** Reliability of services is more relevant to woman, especially those travelling with young children, in that unreliable services cause long waits at bus stops, sometimes in bad weather (Hamilton et al. 2000).
- **Cost:** Public transport costs is particularly relevant for woman on low incomes (Reid-Howie Associates, 2000; Dobbs, 2005).
- **Information provision**: Due to often complex journeys that females make (e.g. dropping children off at school, then travelling to work, then collecting children from school) information regarding intermodal/trip chains is often not available (Reid-Howie Associates (2000).
- **Personal safety:** The most consistent finding to come out of these studies relates to differences in the level of importance attached to personal safety issues, i.e. woman have a greater sense of:
  - Fear of sexually related violence (Law, 1999; DfT, 2004);
  - Fear of crime generally (Crime Concern, 2002; DfT, 2004; Smith, 2008; DfT, 2009)
  - Travelling generally at night (Reid-Howie Associates, 2000; DfT, 2004; Granville & Campbell-Jack, 2005);
  - When walking and cycling generally (Ravenscroft et al. 2002; Dickinson et al. 2003).

It should however be noted, that since the time of many of these studies (certainly for those in the UK), accessibility issues may now not be as relevant as low floor buses and buggy spaces are now more widespread, public transport costs are relatively cheaper, and public transport information provision is now generally much improved (certainly in the UK).

#### 2.5.4 Immigrant Groups' User Needs

As with studies examining gender user needs, there is little available evidence related to the user needs of migrant travellers (Assum et al. 2011). The available evidence is summarised below, although, as with female's user needs, there does not appear to be any 'different' user needs *per se*, but rather greater importance attached to certain needs by some migrant traveller groups, specifically:

- **Feeling safe using public transport:** In the UK, a study examining perceptions of crime when using public transport found that perceived lack of safety, both in the general environment and on public transport, is greater amongst Black and Minority Ethnic (BME) people (Crime Concern & Transport and Travel Research, 1997);
- **Feeling safe walking/travelling at night:** BME people (particularly Asian people) living in the UK expressed greater concerns walking to and from bus stops or whilst waiting for buses during the evening/night time, compared to non-BME people (Crime Concern, 2002);
- **Clear, understandable information**: People in BME groups often have difficulty understanding transport information, if not presented in their own language, which can impact on the types of travel modes they use (Wixey et al., 2005).

### 2.6 SITUATIONAL FACTORS AFFECTING USER NEEDS

In addition to personal factor differences in user needs, there is evidence that user requirements are also dependant on situational factors, primarily the trip purposes of travellers, although these differences in user requirements are also linked to individual's familiarity with the specific journey. The main differences identified are:

- **Business travellers** place greater priority on requirements related to departure and leaving times, overall journey time, and to a lesser extent information provision and comfort factors;
- **Commuter's** main requirement concerns reliability (i.e. they need to get to work on time), although cost and flexibility are also important;
- **Leisure traveller's** most important needs are cost and information provision, whereas journey time is of relatively lower importance.

*Source: Preston, Wall and Whiteing, 2006 (for rail travellers).*

In relation to interchange facilities, Pantouvakis (2006), TfL (2009) and NICHES+ (2010b) come to the following conclusions:

- **Daily commuters**: they require to travel as smoothly, reliably and fast as possible (including through interchange facilities) as their main service needs revolve around reaching their destinations (workplace) on time.
- **Tourists / Leisure travellers and first-time users**: they require information, safety, cleanliness, staff assistance, support for orientation and complementary services.
- **Elderly and children:** they want to travel easily and safely. Therefore 'easy to reach, easy to use' design is a crucial factor, including aspects such as level surfaces, lifts / elevators, adequate lighting, and suitably trained staff to offer assistance (if required).

## 2.7 THE RELATIONSHIP BETWEEN USER NEEDS AND INDIVIDUALS' MODAL CHOICE DECISIONS

### 2.7.1 User Needs and Modal Choice Decisions: Introduction

This final section now considers how the user needs identified in previous sections influence individualsô modal choice decisions. In order to understand this relationship, it is useful to first understand why people are so attached to their cars and resistant to using more sustainable alternatives and the main barriers to modal shift that have been identified.

### 2.7.2 Why are People so Attached to their Cars?

Steg (2005) provides a summary of the main reasons to this question, by identifying three main, but interrelated factors, namely:

- **Instrumental reasons:** Relate to the general instrumental functions of cars, e.g.
  - Cars get people from A to B in the most direct way;
  - Cars are quick (but not always the quickest mode);
  - Cars provide people with the flexibility to make journeys how they want;
  - Cars provide the safest way to travel;
  - Cars can be the cheapest way to travel (e.g. for families).
- **Symbolic reasons:** Relate more to the symbolic functions driving a car produces, e.g.
  - Cars provide status and prestige (people feel important especially when driving expensive cars, i.e. a status symbol);
  - Cars convey an impression of ópowerô and success (especially big expensive cars).
- **Affective reasons:** Relate to the emotions that arise from driving cars, e.g.
  - People just love driving;
  - People feel free when driving;
  - People feel independent when driving;
  - People get a sense of personal identity when driving;
  - People feel good when driving.

See also Beirão & Sarsfield (2007).

Based on this classification, instrumental reasons for car dependency relate more to user needs for service provision and performance factors (e.g. service frequencies, punctuality, network coverage etc.); whereas symbolic and affective reasons relate more to psychological needs, including affective effort (Crockett et al., 2004, Van Hagen, 2005) - see section 2.3.1 earlier.

### 2.7.3 Barriers to Modal Shift: Which Factors Prevent People from Using Public Transport?

Having summarised the reasons why people are so attached to their cars this section now examines in more detail the specific barriers to modal shift that prevent people from switching to alternative transport modes.

#### *2.7.3.1 General Barriers to Modal Shift*

At a more general level, Brog (1982) concluded that barriers that prevent people from switching from car use to more sustainable travel options can be broadly grouped under:

- **Structural constraints**: These are related to existing land use patterns and transport systems. They result from the patterns of transport service provision and land use location and operating hours that require people to access locations at times when there are no suitable public transport services - but where, in principle, many of these issues could be removed or reduced through improved public transport service provision or through retiming or through relocation of services people want to reach. This is a particular relevant issue in rural areas where public transport services are less frequent and widespread.
- **Situational constraints:** These are person specific or trip specific. They reflect the requirements of the traveller or of the trip itself, such as the need to carry large or heavy items, or to transport people with mobility restrictions. Here improved public transport or more accessible land uses would not remove car dependence and some form of door-to-door transport is likely to be required.

Thornton *et al*. (2010) expanded on Brogõs definition and noted that a range of structural, attitudinal, behavioural and financial factors encouraged car travel, at the expense of other modes, namely:

- **Structural factors**:
  - Lack of suitable or direct routes emerged as a key barrier to both bus and rail travel, with slow, infrequent services also emerging as a key barrier to bus travel;
  - Safety concerns relating to traffic levels and distance emerged as key barriers to cycling;
  - Lack of time, perceived inconvenience and having things to carry were identified as key barriers to walking;
- **Attitudinal factors**:
  - People may have negative attitudes (or perceptions) towards some or all non-car alternative modes;
- **Behavioural factors**:
  - People may drive cars out of habit, and as such do not consider any alternative modes;
- **Financial factors**:
  - Cars may be the cheapest option for some people, and/or alternative options are too expensive to use.

Quite often there are multiple barriers, for example there may be no suitable alternatives (structural) and the only real alternatives are too expensive (e.g. taxis). At this more general level, barriers to modal shift are clearly related to many of the key user needs identified, specifically to ónetwork characteristicsô of transport systems, safety, cost and time requirements.

#### *2.7.3.2 Barriers to General Public Transport Use*

Having examined general barriers to modal shift, this section now presents a summary of the specific barriers identified to public transport use, both at a general (all public transport modes) level, for specific public transport modes, before looking at how these barriers can vary according to users socio-demographic backgrounds.

Based on a survey of German residents, VDV/TNS (2009) identified the following reasons why people do not use local public transport services. As can be seen in Table 2-2 the reasons for not using public transport or a non-change to public transport are in particular poor connections and transfers, high fares, unattractiveness of the offer, car availability, high cost, no customer-friendly tariffs and overcrowded vehicles.

**Table 2-2 Barriers to public transport use in Germany: VDV / TNS (2009)**

| Barriers to using public transport in Germany | % agreeing |
|---|---|
| **Bad connections** | 60 |
| **Fares too high** | 55 |
| **Not attractive option** | 45 |
| **Prefer car** | 36 |
| **Too slow** | 34 |
| **Tariffs not customer friendly** | 32 |
| **Crowded vehicles** | 28 |
| **Security/safety** | 16 |
| **Costs** | 9 |

#### *2.7.3.3 USEmobility Survey Results*

In a recent survey conducted as part of the USEmobility EU project (www.usemobility.eu), respondents were asked to retrospectively give reasons as to why they had increased or decreased their use of public transport in the past 5 years. The survey involved over 10,000 people living in Austria, Belgium, Croatia, Germany, Hungary and The Netherlands, who were ‘swing users’ (i.e. people who had either increased or decreased their use of public transport in the past 5 years). Most relevant to this report are the reasons as to *why* people have reduced or stopped or / reduced their level of public transport - see Figure 2-1.

As can be seen in Figure 2-1 (red columns to the left), the most important (or *Primary*) factors identified that reduce or stop people using public transport are:

- The length of journey time;
- Number of transfers involved / long waiting times;
- Loss of flexibility when using public transport;
- Costs, and;
- Frequency of connections.

These inhibitors or pull-out factors regarding public transport use are related to user needs of network characteristic and cost. Other pull-out factors identified (with the exception of social contact) were relatively lower importance, although again were directly related to the key user needs identified earlier in this report.

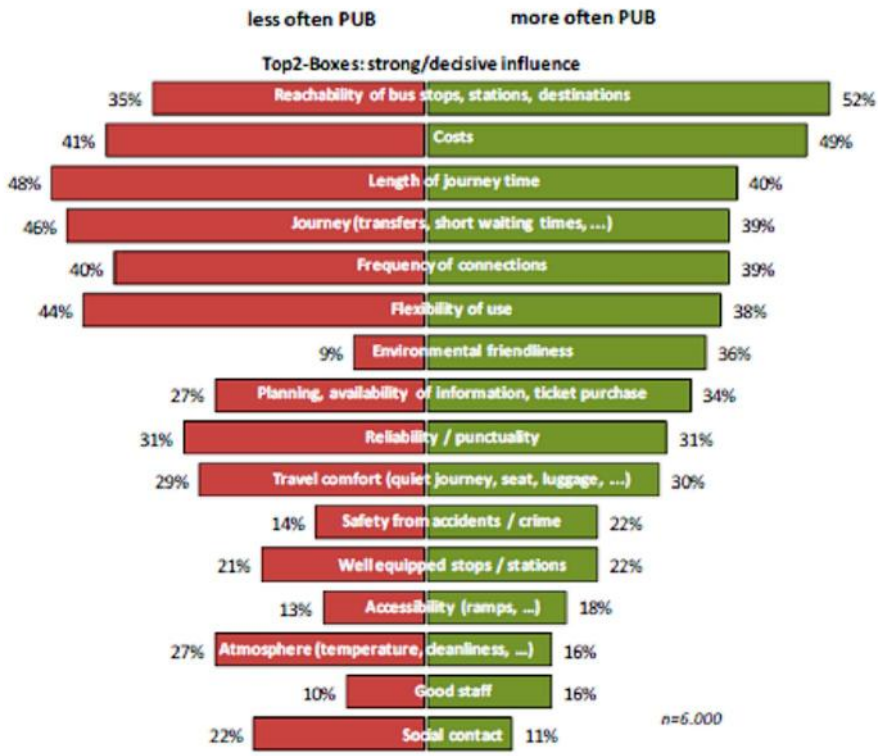



**Figure 2-1 Primary factors identified as inhibitors of public transport use**

In addition to these primary factors, USEmobility identified a range of secondary factors that for some people can also act as inhibitors to public transport use - see Figure 2-2. USEmobility suggests that these secondary factors can be classified as either *Crucial*, *Important* or *Add-on push-out* factors (i.e. they act as inhibitors). As with primary factors, the secondary factors identified are clearly linked to the key user needs identified earlier in this report.

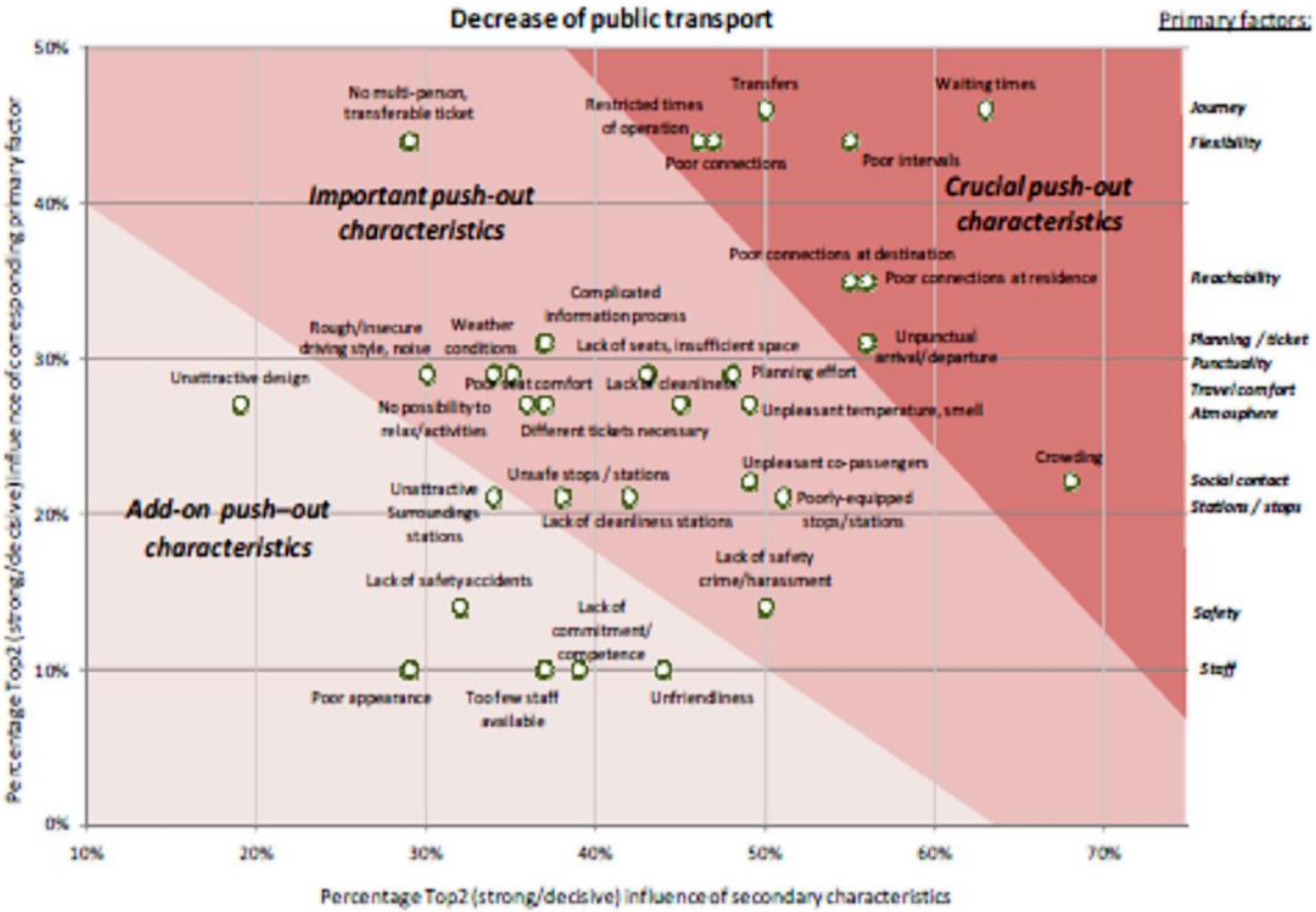



**Figure 2-2 Secondary factors identified as inhibitors of public transport use**

Whilst for many other aspects there does appear to be some consistency in relative importance attached to each aspect for all countries, for other factors there are clear differences between countries (Figure 2-3). For example: In Austria, Belgium and Germany ‘Complicated journeys’ (transfers, waiting times) was identified as the most important reason for *leaving public transport*, whereas in Hungary it was ‘length of journey time’, and in Belgium, Croatia and The Netherlands it was ‘cost’.

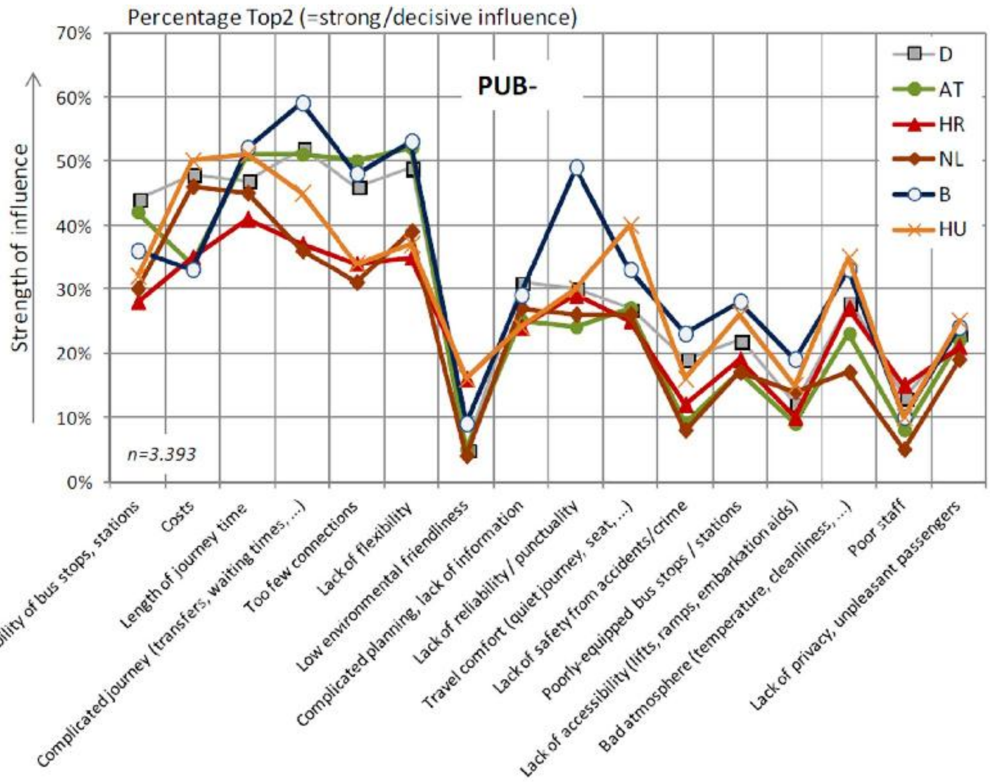



**Figure 2-3 Locational differences in the relative importance of primary inhibitor factors**

These findings perhaps best illustrate how the relative importance of inhibitors to public transport is dependent on situational factors, e.g. If fares are relatively high in a particular country, region or city, compared to others, this factor will become more important.

Personal factors (e.g. change in the personal / private situation, age, gender) of people making (or wishing to make) public transport journeys are also shown to affect both the type of inhibition, and relative importance attached to different barriers - see the USEmobility (2012) survey report for greater details and later sections of this report.

#### *2.7.3.4 Barriers to Local Bus Use*

Stradling *et al*. (2007) identified eight broad factors that people disliked/discouraged them from using buses in Edinburgh, Scotland, namely:

- Feeling unsafe (from other passengers);
- Preference for walking/cycling;
- Problems with service provision (e.g. no direct route);
- Unwanted arousal (e.g. buses are too crowded);
- Preference for car use;
- Cost;
- Disability and discomfort (e.g. not enough hand rails in bus);
- Self-image (travelling by bus does not create the right impression).

In a later study by Dobbie, McConville & Ormston (2010), who conducted a series of focus groups and in-depth interviews with Scottish 'infrequent or non-bus users', also identified a series of barriers to local bus use, including:

- Bad driving behaviour and poor driver attitudes (bus drivers);
- Concerns about other passengers committing anti-social or criminal behaviour, as well as more general concerns about other people's behaviour causing annoyance or discomfort;
- Fears about the physical condition of buses making them unsafe, unreliable or inaccessible (for participants with mobility problems), as well as concerns about cleanliness and comfort on board;
- Concerns about personal safety, comfort and the adequacy of information at bus stops;
- The perceived length of bus journeys, as well as the appropriateness of timetables for the journeys participants needed to make;
- A belief that buses cannot be relied on to stick to their timetables (unreliability);
- A perceived lack of direct and/or appropriate routes, as well as concerns about routes travelling through 'undesirable' areas;
- A belief that fares are too high, as well as complaints about the inconvenience of having to find exact change (typical on most Scottish buses).

Again, as with barriers to public transport generally, there is a clear relationship between the key user needs identified and barriers to modal shift to local bus services, although, as mentioned earlier, the relative importance of these barriers is likely to depend on situational factors and personal factors.

In relation to other modes (rail, ferries and metro / subways) no specific studies were identified that specifically identified barriers to their use, although a study by Transport for London (TfL) examined barriers to the use of the London light rail system - see below.

### *2.7.3.5 Barriers to the London Overground*

TfL (2009b) identified 13 main barriers to use of the London Overground system. From Table 2-3, it appears thatôservices do not match customersôrequirementsôand ‘they have no need to use servicesô are the main barriers, which are linked to user requirements for service characteristics. Other barriers that are linked to user needs appear to be of lesser importance, i.e. other service requirement aspects, cost, comfort, time and safety.

**Table 2-3 Barriers to London Overground: TfL (2009b)**

| Barrier to London Overground | % agreeing |
|---|---|
| **Doesn't go to destinations I travel to** | 21 |
| **No need to** | 20 |
| **Inconvenient** | 7 |
| **Prefer other modes** | 6 |
| **Too expensive/ other modes cheaper** | 6 |
| **No local station/station too far away** | 4 |
| **Too infrequent/ doesn't run when needed** | 5 |
| **Unreliable** | 3 |
| **Too overcrowded/busy** | 3 |
| **Takes too long/other modes faster** | 3 |
| **Unsafe/poor security/feel unsafe** | 1 |

Source: TfL (2009)

### 2.7.4 Barriers to Modal Shift According to Socio-Demographic Factors

#### *2.7.4.1 Barriers to Modal Shift for Older / Mobility-Impaired People*

Based on a survey of adults aged under 59, aged 59-69 and 70+ Gilhooly (2002) identified a range of barriers to public transport use - see Table 2-4.

Overall (all respondents), safety concerns were identified as the main barrier (see also Smith et al. 2006), followed by difficulties carrying heavy loads (e.g. shopping), personal preference (other modes available), uncertainties about services, long waiting times, reliability issues, safety concerns from other passengers, route availability, weather conditions, difficulties of travelling at times they want to travel and (highly relevant to intermodal journeys) difficulties interchanging. A range of other factors were also identified as barriers to travel, although by fewer respondents.

A significantly greater number of adults aged 59-69 reported certain aspects as barriers (e.g. difficulties carrying loads, having to wait, difficulties obtaining information about the journey) than younger respondents- see *'s in Table 2-4.

For the oldest respondents (aged 70+), the pattern of barriers identified was broadly similar, but a greater percentage of respondents identified all aspects as greater deterrents to public transport use, and as illustrated in Table 2-4, the rank ordering of the top 10 barriers differed from younger respondents.

**Table 2-4 Barriers to public transport use: Gilhooly (2002)**

| Barrier to public transport | % agreeing (all sample) | % agreeing, top 10 barriers for over 70's |
|---|---|---|
| Concerns about personal security during evening or at night | 65.1 | 79.8 (1st) |
| Difficulties carrying heavy loads | 59.0* | 66.3 (4th) |
| Alternatives to public transport are available | 54.5* | |
| Possibilities of cancellations | 51.2* | 66.0 (5th) |
| Having to wait | 51.2* | 68.0 (3rd) |
| Public transport running late | 49.3* | 68.3 (2nd) |
| Behaviour of some passengers | 48.1* | 63.5 (6th) |
| Difficulties of travelling where I want to go | 43.3* | 50.0 |
| Having to be out in bad weather | 41.1 | 53.8 (7th) |
| Difficulty of travelling when I want to go | 40.8* | 48.1 (10th) |
| Having to change transport | 40.6* | 53.3 (9th) |
| Difficulties in getting information about journey | 39.8 | |
| Concerns about being on time | 39.1* | |
| Difficulties accompanying other person who cannot travel alone | 36.4 | |
| Lack of cleanliness | 36.3 | 53.8 (7th) |
| Length of journey time compared to car | 35.8* | |
| Lack of public transport in my area | 35.8* | |
| Inaudible announcements | 30.1 | |
| Lack of toilet facilities | 28.9 | |
| Cost of public transport | 27.0* | |
| Discomfort of the ride | 22.2 | |
| Large amount of planning | 21.5* | |
| Amount of walking involved | 20.1 | |
| Lack of grab rails | 19.1 | |
| Difficulties in getting on/ off | 17.0 | |
| Hassle of buying tickets | 13.5 | |
| Concerns about personal safety during the daytime | 9.3* | |
| Risk of being in a crash | 7.6 | |

*indicates statistically more agreement for older people (aged 59 +) than younger people (under 59).

In addition (or in confirmation) to the barriers identified by Gilhooly above, a summary of other study results is presented below:

- People with learning difficulties are often restricted from making spontaneous journeys, if they are not provided with sufficiently clear information prior to the journey (DETR, 2000);
- Similarly, DPTAC (2002) noted that accessing information about transport services may be more difficult for many disabled people, particularly those who are blind or partially sighted;
- Barrett et al. (2003) also identified the attitude and approach of transport staff as an important aspect for disabled people, in that negative staff attitudes, lack of disability awareness and unhelpful staff could act as a disincentive to travel;
- Interchanges within journeys can also be a particular problem for disabled people as the often have concerns about whether accessible transport will be available throughout the whole journey, and if these concerns are not addressed (i.e. through information) can prevent the journey been made (Reid-Howie Associates, 2004; Porter, 2002);
- Dobbie, McConville & Ormston (2010) noted for older / mobility-impaired people, greater emphasis was placed on specific factors, namely;
    - Safety concerns relating to drivers not waiting for people to get on and off and reach their seat;
    - Accessibility issues, relating to steps and to poles obstructing wheelchair spaces, as well as accessibility of information, with small font sizes for timetables a particular problem for those with visual impairments;
    - Overcrowding creating particular issues for participants who suffered from anxiety;
    - Lack of toilets, and;
    - Distance to walk to stops.

#### *2.7.4.2 Barriers to Modal Shift for Females*

As indicated earlier, female travellers place greater importance on specific user needs, and available evidence does suggest that for some woman these factors can act as a barrier to using public transport and travelling generally. Specifically:

- **Accessibility issues:** especially for woman travelling with small children, related to boarding and alighting vehicles (Reid-Howie Associates, 2000; Wixey et al., 2005);
- **Information issues:** especially when multi-stage intermodal journeys are involved (Hine & Mitchell, 2001; Wixey et al. 2005);
- **Reliability issues:** especially when multi-stage intermodal journeys are involved, and woman are travelling with small children Hamilton et al. 2000);
- **Cost issues:** especially for woman on low incomes (Reid-Howie Associates, 2000; Dobbs, 2005) and;
- **Personal safety issues:** both when using public transport or travelling generally, especially during the evening or night time (Crime Concern, 2002; Ravenscroft et al. 2002; Dickinson et al. 2003; DfT, 2004; Smith, 2008; DfT, 2009).

#### *2.7.4.3 Barriers to Modal Shift for Immigrants*

##### Barriers to public transport use for immigrants

Based on focus groups conducted with immigrants living in Austria, Belgium and Norway, Assum et al. (2011) concluded that barriers faced by immigrants were broadly similar to non-immigrants, although some aspects were more relevant for immigrants when they first moved to a city/area/country, namely:

- Problems with information: Due to their lack of understanding of the native language;

- Understanding of how public services operate: Related to information provision above, some immigrants were not familiar with local services (times, routes, connections etc.) and this understanding prevented them from using public transport;
- Low frequency: Many immigrants (initially) lived on the outskirts (or parts) of cities which had fewer available transport services;
- Cost: For some immigrants (especially those who had just moved) cost of public transport services acted as a barrier, although, over time as they found employment this barrier diminished.

#### Barrier to walking: immigrants

In the same study, Assum et al. (2011) identified the following barriers to walking:

- Walking is not suitable for long distances, as many immigrants lived on the outskirts of city centres;
- Unfamiliarity with routes (some immigrants expressed concerns about getting lost);
- Unsafe (especially during the evening/night);
- Sideways too narrow;
- Potential discrimination/harassment from other member of the public (e.g. due to wearing of headscarves).

As with barriers to public transport, some of the aspects mentioned were related to the length of time immigrants have lived in the city / country, and tended to become lesser barriers over time.

#### Barrier to cycling: immigrants

Participants in the focus groups were also asked to indicate barriers to cycling, which are shown below.

- Weather conditions (although, this was more relevant to participants in Norway, and perhaps reflective of weather conditions there);
- Too expensive (to purchase cycles);
- Lack of information on cycling possibilities;
- Lack of information regarding traffic rules (for cyclists);
- Cultural barriers (some muslim woman do not think it right for them to cycle).

Again, as with public transport and walking barriers, some of the above barriers were related to the length of time immigrants had lived in the city / country, specifically finding and been able to understand information about cycling possibilities and traffic rules.

### 2.7.5 Barriers to Public Transport Use by Trip Purpose

#### Commuter trips

There is also evidence that barriers to public transport use can be dependent on individualsô trip purpose. For example, as part of the wider Scottish Household Survey people were asked *why they do not use public transport for work trips*. The reasons given varied according to a range of factors, namely:

- Takes too long (56%); and
- No direct route (34%)

were identified as the greatest barrier for the majority of respondents; followed by

- Need car for work (13%) and Prefer to use car (13%);
- Work unusual hours (9%);
- Cost (8%) and Lack of service (8%)

- Public transport is unreliable (6%) and Too infrequent (6%);
- Too much to carry (5%);
- Uncomfortable (2%);
- Collect/drop of children at school (1%), Health reasons (1%) and Other (1%).

*Source: Transport Scotland (2011)*

See also Anable & Gatersleben (2005) and Dobbie, McConville & Ormston (2010) who found similar results.

### School trips

In contrast to work trips, the SHS also asks people (parents) why their childrendo not use (or were allowed to use) public transport for school trips.

In contrast to work trips, the main barriers identified for school trips were;

- Too young to travel on their own (55% for 4-11 year olds; 8% for 12-18 year olds);
- No service available (5% and 6%);
- Too far to bus stop (3% and 5%);
- Cost, too expensive (8% and 13%);
- Too short a distance, not worth it (6% and 4%);
- Prefer to drive (29% and 45%).

*Source: Transport Scotland (2011)*

See also Mullan (2003) and McMillan (2007) who also found similar results.

For this journey type, the main barriers appear to be more affective (prefer to drive), whereas for commute journeys the main barriers appear to be more instrumental (Steg 2005 earlier). However, in both instances, the barriers identified are clearly related to many of the key user needs identified earlier in the report.

## 2.8 Conclusions on Emerging Traveller Needs

Having reviewed and presented available evidence related to user needs for intermodal journeys, including interchange and individual mode elements, taking into account both personal and situational factors and the relationship between user needs and modal choice decisions, this evidence is now summarised and presented below.

It can be concluded that they are 16 main user needs for short-distance intermodal journeys. These are identical to those identified for long-distance intermodal journeys (Carreno, 2011), which suggests these needs are generic for all intermodal journeys, irrespective of distances involved. However, the relative importance of these users needs to each other is still not fully established, due to lack of research studies which have attempted to address this question. The relative importance attached to each user need, as well as specific attributes of these broad user requirements is also shown to be dependent on both personal (age, mobility-impairment, gender and migrant status) and situational factors (trip purpose).

A summary of these key user needs are presented below, and where personal and situation factors are known to influence the relative importance of each need, this is highlighted.

- **Network characteristics** - Users require:
  - Transport services that depart and arrive at interchange points that are of sufficient frequency to meet their needs for each journey;
  - Transport services are available that cover an area that allows them to travel to the places they want to go;
  - Transport modes are available to allow them to travel to their desired destinations that match their personal mode preferences, and;
  - Available transport services depart/arrive matched to times required by them (convenient); and available transport services run on time.

  For travellers making business or commuting trips fast (see journey time,) frequent and punctual services are key aspects of importance, especially those living in rural areas (where services are typically less frequent), compared with those on leisure trips, or in urban areas.

- **Interchange facilities -** Users require:
  - Interchange facilities that are designed, managed and equipped to a sufficient standard to allow them to make required connections between different modal stages of their journey as safely (see personal security later);
  - Quickly (see Journey time) and;
  - Comfortably (see comfort) as possible; interchanges also need to be fully accessible for users (i.e. barrier free), which includes use of facilities sited within interchanges including toilets, ticketing machine, shops, cafes etc.

  Barrier free access is the primary concern for mobility-impaired travellers, in relation to both navigating within interchange facilities as well as alighting / disembarking from transport vehicles.

- **Baggage handling facilities -** Users require:
  - Baggage handling / storage facilities to be provided that are safe, simple to use, and reliable.

  For some travellers, including Older / mobility-impaired people and parent travelling with young children, assistance may also be required.

- **Door-to-door information -** Users require:

- Information that is sufficiently detailed and of high quality and covers all aspects of their journey, i.e. for pre-trip, wayside and on-board journey stages to allow users to efficiently plan their whole journey.

For some travellers this information needs to be provided in formats that allow all users to fully use and understand the information provided (e.g. in Braille, talking maps etc.), and for some migrants and tourists who are unfamiliar with the transport services available more detailed, clearer information is required, and presented in languages they can understand.

➢ **Cost -** Users require:

- That costs involved in planning and undertaking the journey are affordable, according to their individual financial means;
- This includes costs involved to access (first mile) and egress (last mile to desired destinations) transport terminals, as well as the costs involved in each main mode component of the journey.

Cost issues are more important for travellers on low incomes.

➢ **Ticketing and Tariffs** - Users require:

- Simple ticketing arrangements that allow them to transfer between different modes, or same modes operated by different operators, as easily as possible, i.e. not requiring multiple tickets.

➢ **Comfort -** Users require:

- Transport services (vehicles) and facilities (interchange terminals) that are designed and maintained to ensure users are comfortable throughout the whole journey;
- This includes aspects such as ensuring facilities and vehicles are clean, and offer protection from weather conditions, seating and waiting areas, and food and drink facilities (see on-board facilities).

➢ **Safety -** Users require:

- The feeling of safety when making long-distance intermodal journeys (i.e. from the risk of accidents).

➢ **Personal security -** Users require:

- The feeling of security when accessing, and using different mode components of the intermodal journey (i.e. from theft, attack, intimidation etc.).

This aspect is important for all travellers, although is of greatest importance for woman, older / mobility-impaired and migrant groups.

➢ **Journey time -** Users require:

- The total journey time involved in each intermodal journey to be as short as possible (i.e. minimal access, waiting, transfer and in-main mode vehicle/vessel time).

This requirement is more important for travellers on business or commuter trips, compared to those on leisure trips.

➢ **Accessibility**: Users require:

- Transport terminals that are fully accessible by all feeder transport modes, as well as the vehicles that they are required to use for the main mode components of the full journey.

This aspect is of greatest importance for all mobility-impaired groups.

➢ **Employees -** Users require (or expect):

- Transport employees at interchanges and on-board vehicles/vessels to be able to assist them (if required), provide the correct information to them, are smartly dressed and courteous, etc.

For mobility-impaired travellers it is important for employees to have sufficient training and awareness of disability-issues.

➢ **Effort -** Users require:

- That the total effort (physical, cognitive and affective) they need to expend to undertake a journey is reasonable (i.e. is acceptable for them, not uncomfortable for them etc.).

For mobility-restricted travellers minimal effort is a key requirement for them to safely and comfortably use transport services.

➢ **In-vehicle facilities -** Users require (expect):

- Services to be provided, or be available for them such as catering facilities (see Comfort), communication facilities (wireless access, plug sockets) and entertainment facilities (newspapers, TV/films, games etc.).

For business travellers (and some commuters) wireless access etc. will be more important, compared to those travelling for leisure purposes.

➢ **Environmental concerns -** Users have:

- Expectations that transport companies and operators are taking actions to minimise the environmental impact of service vehicles (i.e. using low emission vehicles, fuel etc.);

➢ **Promotion of intermodality** - Users need:

- To be aware of intermodal services that are available to them and these need to be marketed in a way that is attractive to them.

There is also considerable evidence that if ‘certain’ user needs are unmet, this can prevent people from making certain journeys. However, the relationship between user requirements and modal choice decisions is complex and also dependent of the personal factors of travellers as well as their trip purpose, and prevailing conditions (service provision, costs) according to location. To fully understand this complexity, further research is needed.

## REFERENCES - KEY TRENDS


CO_0001 Schafer A., Victor D. G., 2000. The future mobility of the world population. Transportation Research Part A 34 (2000) 171 - 205

CO_0003 Riahi K., Grübler A., Nakicenovic N., 2007. Scenarios of long-term socio-economic and environmental development under climate stabilization. Technological Forecasting & Social Change 74 (2007) 887ï 935.

CO_0004 Rosenberg M., Weiste H., 2007. Public transport city of the future.

CO_0005 Glockner H., Rodenhäuser B., 2008. The Future of Mobility.

CO_0006 IFP Innovation Energy Environment, 2008. Trends and challenges in passenger mobility.

CO_0007 Moriarty P., Honnery D., 2008. Low-mobility: The future of transport. Futures 40 (2008) 865 ï 872.

CO_0009 Debbah F., 2009. User Aspects. Transport Research Knowledge Centre. Thematic Research Summary.

CO_0010 Dobbs L., 2009. Wedded to the car: women, employment and the importance of private transport.

CO_0013 Frye A., 2011. Mobility: Rights Obligations and Equity in and Ageing Society. International Transport Forum.

CO_0015 EC, 2009. A sustainable future for transport: Towards an integrated, technology-led and user friendly system.

CO_0016 EC, 2008. Regions 2020. An Assessment of Future Challenges for EU Regions. Commission Staff Working Document.

CO_0017 Petersen R., Hook W., Zimmer W., 2008. Discussion Paper - Symposium "Future Challenges of Transport and Environment".

CO_0018 EC, 2003. Hydrogen Energy and Fuel Cells ï A vision of our future.

CO_0019 World Economic Forum, 2011. Repowering Transport.

CO_0021 EC, 2011. White Paper-Roadmap to a Single European Transport Area ï Towards a competitive and resource efficient transport system.

CO_0023 European Travel Commission, 2006. Tourism trends for Europe.

CO_0024 World Economic Forum, 2011. Global Risks 2011 - Sixth Edition: An initiative of the Risk Response Network.

CO_0025 EC, 2010. Critical raw materials for the EU. Report of the Ad-hoc Working Group on defining critical raw materials.

CO_0026 Schade W., Fiorello D., Beckmann R., Fermi F., Köhler J., Martino A., Schade B., Walz R., Wiesenthal T. , 2008. High Oil Prices: Quantification of direct and indirect impacts for the EU. Deliverable 3 of HOP! (Macro-economic impact of high oil price in Europe). Funded by EC.

CO_0028 European Environment Agency (EEA), 2006. Urban sprawl in Europe - The ignored challenge EEA Report N° 10.

CO_0030 Hakamies-Blomqvist L., 2003. Ageing Europe: the challenges and opportunities for transport safety.

CO_0031 OECD, 2001. Ageing and Transport. Mobility Needs and Safety Issues.

CO_0032 Stantchev D., Merat N., 2010. Equity and Accessibility. Transport Research Knowledge Centre. Thematic Research Summary.

CO_0034 Sessa C., Enei R., 2010. EU Transport GHG: Routes to 2050? EU transport demand: Trends and drivers.

CO_0036 Borsdorf A., 2004. On the way to post-suburbia? Changing structures in the outskirts of European cities. COST Action C10.

CO_0039 Dado M., Spalek J., Aleġ Janota A., 2009. Present and Future Challenges of ICT for Intelligent Transportation. Technologies and Services. Wireless Communication, Vehicular Technology, Information Theory and Aerospace & Electronic Systems Technology, 2009.

CO_0042 Steg L., Gifford R., 2005. Sustainable transportation and quality of life. Journal of Transport Geography, Vol. 13 (2005), pp. 59ï 69.

CO_0049 World Energy Council, 2007. Transport Technologies and Policy Scenarios to 2050.

CO_0050 EC, 2011. The 2012 Ageing Report: Underlying Assumptions and Projection Methodologies.

CO_0054 May T., Crass M., 2007. Sustainability in Transport. Implications for Policy Makers. Transportation Research Record, 2007, pp. 1ï 9.

CO_0058 Wismans J., Malmek E.M., Karlsson C., Depner N., Funcke M., Ickert L., Lesemann M., Bayer B., Schindler W., Monfrino G., Petiot M., Ntchouzou C., 2011. Societal scenarios and available technologies for electric vehicle architectures in 2020 (Deliverable D1.1). ELVA Project (7FP).

CO_0059 Schäfer A., 2006. Long-Term Trends in Global Passenger Mobility. The Bridge - Winter 2006 pag. 24-35.

CO_0066 Eurostat, 2011. Migrants in Europe: A statistical portrait of the first and second generation.

CO_0069 EC, 2010. Commission Staff Working Document Demography Report 2010.

CO_0073 EC, 2009. Dealing with the impact of an ageing population in the EU (2009 Ageing Report). Communication From The Commission To The European Parliament, The Council, The European Economic And Social Committee And The Committee Of The Regions.

CO_0077 European Road Transport Research Advisory Council (ERTRAC), 2009. ERTRAC Road Transport Scenario 2030+ - ĩRoad to Implementationò

CO_0079 Eurocities, 2008. Demographic change & urban mobility and public space.

CO_0081 Weihong Guo A., Brake J.F., Edwards S.J., Blythe P.T., Fairchild R.G., 2010. The application of in-vehicle systems for elderly drivers. Eur. Transp. Res. Rev. (2010) 2:165ï 174.

CO_0083 Letablier M.T, Pennec S., 2003. Changing Family Structure in Europe: New Challenges for Public Policy. Cross-National Research Papers.

CO_0084 Eurostat, 2010. Household structure in the EU.

CO_0085 Eurostat, 2012. Migration and migrant population statistics: tables and figures Year Book 2012.

CO_0086 EC, 2011. Annual Report on Immigration and Asylum (2010). Communication From The Commission To The European Parliament And The Council.

CO_0087 B. Cohen, 2006. Urbanization in developing countries: Current trends, future projections, and key challenges for sustainability. Technology in Society 28 (2006) 63ï 80.

CO_0088 Gallotti M., 2009. The Gender Dimension of Domestic Work in Western Europe. International Migration Papers N° 96.

CO_0089 EC, 2011. Accompanying the White Paper - Roadmap to a Single European Transport Area ï Towards a competitive and resource efficient transport system.

CO_0091 United Nations Environment Programme (UNEP), 2008. Kick the habit - An UN guide to climate neutrality. Kirby A.

CO_0092 Gheasi M., Nijkamp P., Rietveld P., 2009. Migration and tourist flows. Research Memorandum 2009-59.

CO_0094 Tsang F., Rohr C., 2011. The impact of migration on transport and congestion. RAND Corporation technical report prepared for the Migration Advisory Committee.

CO_0095 Nguyen C. V., Van den Berg M., Lensin R., 2011. The impact of work and non-work migration on household welfare, poverty and inequality. Economics of Transition Volume 19, Issue 4, pages 771ï 799, October 2011.

CO_0096 EC, 2004. Towards a thematic strategy on the urban environment. COM(2004)60.

CO_0097 A. Piorr, J. Ravetz, I. Tosics, 2011. Peri-Urbanisation in Europe: Towards a European Policy to Sustain Urban-Rural Futures. PLUREL Project - Synthesis Report.

CO_0098 University of Copenhagen - Danish Centre for Forest, Landscape and Planning, 2008. PLUREL Project Newsletter No. 3 April 2008.

CO_0101 S. Bührmann, F. Wefering, S. Rupprecht, 2011. Guidelines - Developing and Implementing a Sustainable Urban Mobility Plan. ELTIS PLUS project.

CO_0102 EC, 2007. Sustainable Urban Transport Plans - Preparatory Document in relation to the follow-up of the Thematic Strategy on the Urban Environment. Technical Report - 2007/018.

CO_0103 Hymel K., 2009. Does traffic congestion reduce employment growth? Elsevier.

CO_0104 Sanchez T. W., 1999. The connection between public transit and employment. Routledge.

CO_0105 Price l., Laurie M., Worrell E., Khrushch M., 1998. Sector trend and driving forces of global energy use and greenhouse gas emissions. Kluwer.

CO_0109 International Transport Forum, 2011. Statistics Brief Infrastructure Investment. OECD.

CO_0110 International Transport Forum, 2011. Investment in inland transport infrastructure. OECD.

CO_0111 European Environment Agency (EEA), 2011. Transport infrastructure investments (TERM 019). EEA Management Plan.

CO_0112 European Environment Agency (EEA), 2010. Percentage of GDP used for transport infrastructure investment by mode. European Environment Agency.

CO_0113 OECD, 2002. Impact of transport infrastructure investment on regional development.

CO_0115 Hall J. C., Russell S. S., 2005. Institutions, entrepreneurship and regional differences in economic growth. Southern Journal of Entrepreneurship.

CO_0116 Rice P., Venebles T., 2004. Productivity: understanding the regional differences. Centre Piece.

CO_0117 Cambridge Econometrics, University of Cambridge, ECORYS, 2003. A study on the factors of regional competitiveness. European Commission DG Policy.

CO_0118 Brundtland G. H., Ehrlich P., Goldemberg J., Hansen J., Lovins A., Likens G., Lovelock J., Manabe S., May B., Mooney H., Robert K-H., Salim E., Sato G., Solomon S., Stern N., Swaminathan M., Watson B., 2012. Environment and development challenges: The imperative to act.

CO_0119 Xiaomei Tan, 2006. Environment, governance and GDP: discovering their connections. International Journal of Sustainable Development.

CO_0120 EC, 2008. Climate change and international security. Paper from the High Representative and the European Commission to the European Council.

CO_0125 EC, 2008. Environment and Ageing. Directorate-General for Environment.

CO_0126 Slingenberg A., Rademaekers K., Sincer E., van der Aa R., 2008. Environment and labour force skills. Directorate-General for Environment.

CO_0127 EC, 2011. On the implementation of the Environmental Noise Directive in accordance with Article 11 of Directive 2002/49/EC. Report from the Commission to the European Parliament and the Council.

CO_0128 European Environment Agency (EEA), 2010. Good practice guide on noise exposure and potential health effects. EEA Technical report N° 11/2010.

CO_0129 European Environment Agency (EEA), 2011. Air quality in Europe ð 2011 report. EEA Technical report N°12/2011.

CO_0131 European Environment Agency (EEA), 2011. Greenhouse gas emission trends and projections in Europe 2011. EEA Report N° 4/2011.

CO_0132 European Environment Agency (EEA), 2010. The European environment state and outlook 2010 ï Land use. Thematic assessment.

CO_0134 European Environment Agency (EEA), 2010. The European environment state and outlook 2010 ï Air pollution. Thematic assessment.

CO_0135 European Environment Agency (EEA), 2010. The European environment state and outlook 2010 ï Material resources and waste. Thematic assessment.

CO_0136 European Environment Agency (EEA), 2010. The European environment state and outlook 2010 ï Water resources: quantity and flows. Thematic assessment.

CO_0137 European Environment Agency (EEA), 2010. The European environment state and outlook 2010 ï Consumption and the environment. Thematic assessment.

CO_0140 European Environment Agency (EEA), 2010. The European environment state and outlook 2010 ï Mitigating Climate Change. Thematic assessment.

CO_0141 European Environment Agency (EEA), 2010. The European environment state and outlook 2010 ï Synthesis. Thematic assessment.

CO_0143 RPA, 2010. Review of the Implementation of Directive 2002/49/EC on Environmental Noise. Final Report on Task 1.

CO_0144 RPA, 2010. Inventory of Potential Measures for a Better Control of Environmental Noise. Final Report on Task 2.

CO_0146 Metz B., Davidson O.R., Bosch P.R., Dave R., Meyer L.A., 2007. IPCC 2007: Summary for Policymakers. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.

CO_0147 UN HABITAT, 2011. Cities and climate change: Policy directions - Global report on human settlements 2011. Abridged edition.

CO_0148 Lutsey N., Sperling D., 2008. Transportation and greenhouse gas mitigation. Institute of Transportation Studies, University of California.

CO_0149 Burbank C. J., 2009. Greenhouse Gas (GHG) and Energy Mitigation for the Transportation Sector Recommended Research and Evaluation Program. Paper prepared for the Transportation Research Board.

CO_0150 Bertoni D., Dutilleux G., Nielsen H. L., Penn-Bressel G., Popp C., Serve C., 2003. Guidelines for Road Traffic Noise Abatement.

CO_0151 den Boer E., Schroten A., 2007. Traffic noise reduction in Europe. CE Delft.

CO_0152 International Energy Agency (IEA), 2011. World Energy Outlook 2011. Executive Summary.

CO_0153 International Energy Agency (IEA), 2010. Energy Technology Perspectives Scenarios - (Part 1) - Scenarios & Strategies to 2050.

CO_0154 International Energy Agency (IEA), 2010. Energy Technology Perspectives Scenarios - (Part 2) - The transition from present to 2050.

CO_0155 Torun H., 2007. Innovation: is the engine for economic growth?. EGE University.

CO_0156 Ulku H., 2004. R&D Innovation and Economic Growth: An Empirical Analysis. International Monetary Fund.

CO_0157 OECD, 2011. Growing Income Inequality in OECD Countries: What Drives it and How Can Policy Tackle it?.

CO_0159 World Energy Council, 2011. Global Transport Scenarios 2050.

CO_0160 ITF - OECD, 2012. Transport Outlook 2012: Seamless Transport for Greener Growth.

CO_0161 World Bank, 2011. Gender Equality and Development - World development report 2012. The International Bank for Reconstruction and Development.

CO_0162 European Parliament, 2006. Women and Transport. Provisional version.

CO_0163 Kunieda M., Gauthier A., 2007. Gender and Urban Transport: Smart and Affordable. Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung (BMZ).

CO_0165 University of Copenhagen, 2006. Gender Mainstreaming European Transport Research and Policies. TRANSGEN Co-ordination for Gender Studies University of Copenhagen 2007.

CO_0166 World Travel & Tourism Council, 2011. Travel & Tourism Economic Impact 2012 Europe.

CO_0167 European Travel Commission, 2012. European Tourism: Trends & Prospects Quarterly Report - Q4/2011.

CO_0168 European Travel Commission, 2011. European Tourism Insights 2009-10.

CO_0170 Commission of European Communities, 2005. Commission Staff Working Document on the links between employment policies and environmental policies.

CO_0172 Boshma R. A., Weterings A. B. R., 2005. The Effect of Regional Differences on the Performance of Software Firms in Netherlands. Utrecht University Urban and Regional Research Centre.

CO_0173 Bialas-Motyl A., 2010. Significant Differences between Regions in the Stock of Passenger Cars and Freight Vehicles. Transport General and Regional Statistics.

CO_0174 Van Rossum M., van de Grift M., 2009. Regional Analysis: Differences in Emission-Intensity Due to Differences in Economic Structure of Environmental Efficiency? Journal of Sustainable Development Vol. 2, N° 3.

CO_0176 Office of the Deputy Prime Minister, 2010. The Drivers of Social Exclusion. Social Exclusion Unit.

CO_0178 Pfeffenzeller S., 2008. Economic Growth: What Macroeconomic Factors Lead to Economic Growth? Jet-to-Let Magazine Issue 4.

CO_0179 Department for Business innovation and Skills, 2011. Sources of Economic Growth. Trade and Investment analytical Paper.

CO_0180 International Monetary Fund, 2011. World Economic Outlook. World Economic and Financial Surveys.

CO_0183 International Energy Agency (IEA), 2008. Worldwide Trends in Energy Use and Efficiency.

CO_0184 Koeste M.J., Rietveld P., 2008. The impact of climate change and weather on transport: an overview of empirical findings. Transportation Research Part D 14 (2009) 205-221.

CO_0185 International Energy Agency (IEA), 2012. Tracking Clean Energy Progress - Energy Technology Perspectives 2012. Excerpt as IEA input to the Clean Energy Ministerial.

CO_0186 Peeters P., Szimba E., Duijnisveld M., 2005. European Tourism Transport and Environment. ETC European Transport Conference - Association for European Transport and contributors 2005.

CO_0187 Peeters P., Landré M., 2011. The Emerging Global Tourism Geography - An Environmental Sustainability Perspective. Sustainability 2012, 4, 42-71; ISSN 2071-1050.

CO_0188 Gali J., 1996. Technology, Employment and the Business Cycle: Do the Technology Shocks Explain Aggregate Fluctuations? New York University Faculty of Arts and Science Department of Economics.

CO_0190 Antio E., Parhankagas A., 1998. Employment generation potential of new-technology based firms during the recessionary period: the case of Finland. Small Business Economics 11, 113-123.

CO_0192 Ganco M., 2009. The Influence of Technological Interdependence on Employee Entrepreneurship and Mobility: Evidence from the Semiconductor Industry. Paper presented at the Summer Conference 2009 on Copenhagen Business School.

CO_0193 Handel M. J., 2003. Complex picture of information technology and employment emerges. SRI International.

CO_0194 EC, 2011. A Roadmap for moving to a competitive low carbon economy in 2050. COM(2011) 112 final.

CO_0195 EC, 2011. A resource-efficient Europe ï Flagship initiative under the Europe 2020 Strategy. COM(2011) 21.

CO_0196 Kitamura R., 2010. Life-style and travel demand. Transportation (2009) 36:679ï 710 DOI 10.1007/s11116-009-9244-6

CO_0197 Eurostat, 2011. Sustainable development in the European Union.

CO_0198 EC, 2012. Energy Efficiency Plan 2011. COM(2011) 109 final.

CO_0199 CIVITAS Initiative, 2010. Promoting a new mobility culture in cities.

CO_0200 European Environment Agency (EEA), 2011. Greenhouse gas emissions in Europe: a retrospective trend analysis for the period 1990ï 2008. EEA Report N° 6/2011.

CO_0201 EC, 2010. Analysis of options to move beyond 20% greenhouse gas emission reductions and assessing the risk of carbon leakage. COM(2010) 265 final.

CO_0202 EC, 2009. EU action against climate change - The EU Emissions Trading Scheme.

CO_0203 EC, 2002. Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 relating to the assessment and management of environmental noise.

CO_0204 UNESCAP, 2006. Enhancing Regional Cooperation in Infrastructure Development including that Related to Disaster Management.

CO_0206 Transportation Research Board, 2002. Environmental benefits of transport investment. National Cooperative Highway Research Program.

CO_0207 American Public Transportation Association, 2009. Job impacts of spending on public transportation: An update. Economic Development Research Group.

CO_0209 Price Waterhouse Coopers, 2012. Investing in transport. Doing more with less. Transport Investment Framework.

CO_0210 United Nations (UN), 2011. Investing in Energy and Resource Efficiency. Environment Programme.

CO_0211 Sakamoto K., Dalkmann H., Palmer D., 2010. A paradigm shift towards sustainable low-cost transport. Institute for Transportation and Development Policy.

CO_0212 Timilsina G.R., Dulal H.B., 2008. Fiscal policy instruments for reducing congestion and atmospheric emissions in the transport sector.

CO_0213 The Economist, 2011. Life is a slow lane. America's transport infrastructure.

CO_0214 Bose N., Haque M. E., 2005. Causality between public investment in transport and communication and economic growth. Journal of Economic Development.

CO_0215 World Health Organisation, 2012. Environmental health inequalities in Europe.

CO_0216 OECD, 2011. Extended regional typology: the economic performance of remote rural regions. OECD Publishing.

CO_0217 Barrios S., Strobl E., 2005. The dynamics of regional inequalities.

CO_0220 European Environment Agency (EEA), 2012. Air pollution by ozone across Europe during summer 2011.

CO_0223 Cheshire C., Magrini S., 2009. Urban growth drivers and spatial inequalities: Europe, a case with geographically sticky people. London School of Economics Discussion Paper.

CO_0224 European Environment Agency (EEA), 2011. NEC Directive status report 2010. EEA Technical report N° 3/2011.

CO_0225 EC, 2005. Thematic Strategy on air pollution. COM(2005) 446 final.

CO_0226 European Environment Agency (EEA), 2010. Impact of selected policy measures on Europe's air quality. EEA Report N° 8/2010.

CO_0227 European Environment Agency (EEA), 2004. Air pollution and climate change policies in Europe: exploring linkages and the added value of an integrated approach. EEA Technical report N° 5/2004.

CO_0229 European Environment Agency (EEA), 2005. Air pollution at street level in European cities. EEA Technical report N° 1/2005.

CO_0230 European Environment Agency (EEA), 2011. Air pollution impacts from carbon capture and storage (CCS). EEA Technical report N° 14/2011.

CO_0233 European Environment Agency (EEA), 2011. European Union emission inventory report 1990ï 2009 under the UNECE Convention on Long-range Transboundary Air Pollution (LRTAP). EEA Technical report N° 9/2011.

CO_0234 Enei R., Schoemaker J., Scholtz A., 2012. Towards low carbon transport in Europe. Transport Research and Innovation Portal (TRIP).

CO_0235 FES - Friedrich-Ebert-Stiftung, 2012. Social Growth Model of a Progressive Economic Policy. Friedrich-Ebert-Stiftung International Policy Analysis.

CO_0236 Sardoni C., 2009. The sustainability of fiscal policy: An old answer to an old question. International Economic Policy Institute.

CO_0237 Enei R., Fluhrer T., Szimba E., 2012. Innovating for a competitive and resource-efficient transport system. Transport Research and Innovation Portal (TRIP).

CO_0238 European Environment Agency (EEA), 2010. Towards a resource-efficient transport system TERM 2009: indicators tracking transport and environment in the European Union. EEA Report N° 2/2010.

CO_0239 EC, 2011. European Competitiveness Report 2011. Enterprise and Industry.

CO_0240 European Environment Agency (EEA), 2012. Towards efficient use of water resources in Europe. EEA Report N° 1/2012.

CO_0241 Ha-Joon C., 2007. Bad Samaritans The myth of free trade and the secret history of capitalism. Bloomsury Press.

CO_0243 EC, 2011. Resource efficiency ï A business imperative. Directorate-General for Environment.

CO_0244 EC, 2011. Roadmap to a Resource Efficient Europe. COM(2011) 571 final.

CO_0245 EC, 2012. Energy roadmap 2050.

CO_0246 International Energy Agency (IEA), 2011. Technology Roadmap - Electric and plug-in hybrid electric vehicles.

CO_0247 International Energy Agency (IEA), 2010. Transport Energy Efficiency - Implementation of IEA Recommendations since 2009 and next steps. Energy Efficiency Series.

CO_0248 International Energy Agency (IEA), 2009. Transport, Energy and CO2 - Moving toward sustainability.

CO_0250 EC, 2010. Progress report on implementation of the Communityφs integrated approach to reduce CO2 emissions from light-duty vehicles. Report from the Commission to the European Parliament, the Council, and the European Economic and Social Committee.

CO_0253 EC - Directorate-General for Mobility and Transport, 2011. The European Electronic Toll Service (EETS). Directorate-General for Mobility and Transport.

CO_0254 Brackstone M., Debbah F., Winder A., 2010. Transport Management. Transport Research Knowledge Centre. Thematic Research Summary.

CO_0255 Hájek M., Ġitavancová Z., 2010. Intelligent Transport Systems. Transport Research Knowledge Centre. Thematic Research Summary.

CO_0257 EC, 2010. Energy 2020 - A strategy for competitive, sustainable and secure energy. COM(2010) 639 final.

CO_0258 EC - Directorate-General for Research and Innovation, 2012. Innovation for our future mobility.

CO_0260 EU - Directorate-General for Research Transport, 2010. Keeping Europeœs cities on the move.

CO_0261 EU - Directorate-General for Research Transport, 2010. Intelligent transport systems - EU-funded research for efficient, clean and safe road transport.

CO_0266 EC, 2010. EU at the steering wheel of Road Safety.

CO_0267 IEE, 2012. Energy efficiency & renewables - Making a future together.

CO_0269 EC - Directorate General for Energy, 2011. Saving energy - Time to step up our efforts.

CO_0270 EC - Directorate General for Energy, 2011. Renewables make the difference.

CO_0272 Jolley A., 2006. Transport Technologies. Climate Change Working Paper N°. 5 - Victoria University.

CO_0274 European Environment Agency (EEA), 2011. The European Environment State And Outlook 2010 - Assessment of global megatrends.

CO_0275 OECD, 2008. CO2 Capture and Storage - A Key Carbon Abatement Option. International Energy Agency.

CO_0276 Oxley T., Kwiatkowski L., Castillo A., Scarbrough T., ApSimon H., 2012. Pollution Abatement from Road Transport: Cross-sectional Implications, Climate co-Benefits and Behavioural Change. Environmental Science and Policy 19-20 (16-32).

CO_0278 Tarleton J., 2009. Using Intelligent Transportation System Technology to Monitor Transportation Pollution, Collect Accurate, Real□Time Data and Take Action. Vaisala, Inc.

CO_0279 ISIS, University of Natural Resources and Applied Life Sciences (BOKU), Vienna, 2010. Information Technology Services for traffic control and visualisation. CIVITAS II - Policy advice notes N° 12.

CO_0280 EC - Directorate General for Energy and Transport, 2009. Intelligent Transport Systems - A smart move for Europe.

CO_0281 UNECE, 2012. Intelligent Transport Systems (ITS) for sustainable mobility.

CO_0283 Bonsall, P. 2011. An analysis of potential solutions for improving interconnectivity of passenger networks. INTERCONNECT Deliverable D3.1.

CO_0284 OECD/ITF, 2010. Transport & Innovation - Unleashing the Potential.

CO_0285 ISIS, University of Natural Resources and Applied Life Sciences (BOKU), Vienna, 2010. Innovative ticketing systems for public transport. CIVITAS II - Policy advice notes N° 10.

CO_0286 ISIS, University of Natural Resources and Applied Life Sciences (BOKU), Vienna, 2010. Innovative information systems for public transport. CIVITAS II - Policy advice notes N° 9.

CO_0287 TRCP, 2011. Use and Deployment of Mobile Device Technology for Real-Time Transit Information.

CO_0288 EC - Directorate General for Energy and Transport, 2009. Traffic management for land transport. Transport Research Knowledge Centre. Thematic Research Summary.

CO_0289 EC, 2011. Intelligent Transport Systems - Results from the transport research programme.

CO_0290 EC - Directorate General for Energy and Transport, 2006. Urban pricing - From theory to reality.

CO_0292 TTF, 2010. Tourism & Transport Forum (TTF) Smartcard ticketing on public transport. Position Paper.

CO_0293 ITF - OECD, 2010. Innovation and Visions for the Future of Transport. Summary of Experts Session Forum 21 - Paris, 26 January 2010.

CO_0294 ERTRAC, 2011. ERTRAC Research and Innovation Roadmaps.

CO_0298 EC - Directorate General for Energy and Transport, 2005. The annual energy and transport review for 2004.

CO_0299 Pasinetti L. L., 1999. Economic Theory and Technical Progress. Royal Economic Society Annual Conference.

CO_0300 Cesaratto S., Stirati A., 2011. Germany and the European and Global Crises. University of Siena

CO_0301 Cesaratto S., 2012. Controversial and novel features of the Eurozone crisis as a balance of payment crisis. University of Siena

CO_0302 De Grauwe P., 2011. Balanced budget fundamentalism. CEPS Commentary

CO_0303 Palma J. G., 2009. The Revenge of the market on the rentiers. Cambridge Journal of Economics.

CO_1002 EC, 2006. Globalisation: Trends, Issues and Macro Implications for the EU. EC Economic papers.

CO_1004 EC, 2006. The long-term sustainability of public finances in the European Union.

CO_1009 World Business Council on Sustainable Development (WBCSD), 2006. Pathways to 2050: Energy and Climate Change.

CO_1010 de Mooij, R., Tang, P., 2003. Four Futures of Europe.

CO_1014 Miola, A., 2008. Backcasting approach for sustainable mobility. JRC publication.

CO_1015 United Nations (UN), 2007. World Urbanization Prospects- The 2007 Revision.

CO_1016 IPCC, 2007. Climate Change 2007: Synthesis Report.

CO_1023 ESPON, 2007. Scenarios on the territorial future of Europe.

CO_1027 European Environment Agency (EEA), 2005. Climate change and a European low-carbon energy system. Executive summary.

CO_1029 EC, 2007. European Energy and Transport trends to 2030 - Update 2007. Executive summary.

CO_1030 World Business Council on Sustainable Development (WBCSD), 2004. Mobility 2030: meeting the challenges to sustainability. Executive summary.

CO_2013 Barton J., 2007. New Trends in Technology Transfer. International Centre for Trade and Sustainable Development.

CO_2014 Zero Emissions Platform, 2011. The Cost of CO2 Capture, Transport and Storage.

CO_2015 European Science and Technology Observatory (ESTO), 2003. Trends in vehicle and fuel technologies. Scenarios for future trends. Joint Research Centre (JRC).

CO_2017 United Nations Environment Programme (UNEP), 2009. Hybrid Electric Vehicles.

CO_2018 EC, 2010. Study of Social Impact of ICT.

CO_2019 World Bank, 2006. The Road to 2050.

CO_2023 World Health Organization, JRC, European Environment Agency, 2008. Impacts of Europe's changing climate - 2008 indicator-based assessment.

CO_2024 Stern N., 2005. Stern Review Report on the Economics of Climate Change.

CO_2025 Carnegie. Endowment for International Peace, 2010. The World Order in 2050.

CO_2026 HSBC, 2011. The world in 2050. Quantifying the shift in the global economy.

CO_2027 JRC, 2009. Climate change impacts in Europe. Final report of the PESETA Project. Joint Research Centre (JRC).

CO_2028 EC, 2009. EU Energy Trends 2030. EC publication.

CO_2030 EC, 2006. Changing professions in 2015 and beyond.

CO_2037 Mitchell W., Casalegno F., 2005. Smart Mobility. Rethinking the Paris Bus Line.

CO_2038 Dargay J., Gately D., Sommer M., 2007. Vehicle Ownership and Income Growth, Worldwide: 1960-2030.

CO_2041 ICCR (A) et al., 2004. A foresight exercise to help forward thinking in transport and sectoral integration.

CO_2042 Eurocontrol, 2007. Long-Term Forecast. Flight Movements 2008 - 2030.

CO_2043 European Personalities, 2001. European Aeronautics: a vision for 2020.

CO_2046 Bleijenberg A., 2002. The Driving forces behind transport growth and their implications for policy. European Conference of Ministers of transport.

CO_2050 EC, 2009. 2009 Ageing Report: Economic and budgetary projections for the EU-27 Member States (2008 - 2060).

CO_2057 Geyer A., Scapolo F., Boden M., Döry T., Ducatel K., 2003. The Future of Manufacturing in Europe 2015-2020. The Challenge for Sustainability. Joint Research Centre (JRC).

CO_4006 Gilhooly M. L. M., Hamilton K., O'Neill M., Gow J., Webster N., Pike F., Bainbridge D., 2002. Transport and ageing: Extending quality of life for older people via public and private transport. Brunel Institute for Ageing Studies.

CO_4010 Yeomana I., Lennonb J.J., Blakec A., Galtd M., Greenwooda C., McMahon-Beattiee U., 2007. Oil depletion: What does this mean for Scottish tourism? Tourism Management Volume 28, Issue 5, October 2007, Pages 1354-1365.

CO_4012 US Environment Protection Agency, 2006. Greenhouse Gas Emissions from the U.S. Transportation Sector 1990ï 2003.

CO_4013 Greene D. L., Baker H.H. Jr., Plotkin S. E., 2011. Reducing Greenhouse Gas Emissions from U.S. Transportation.

CO_4014 Hitoshi I. (Ed.), 2010. Sustainable Urban Transport in an Asian Context. Springer.

CO_4015 Brueckner J. K., 2005. Transport subsidies, system choice, and urban sprawl. Regional Science and Urban Economics Volume 35, Issue 6, November 2005, Pages 715-733.

CO_4016 ITF-OECD, 2010. Reducing Transport Greenhouse Gas Emissions: Trends and Data.

CO_4017 David Banister, 2000. Sustainable urban development and transport-A Eurovision for 2020. Transport Reviews Volume 20, Issue 1, 2000.

CO_4024 ITF - OECD, 2011. Transport Outlook 2011. Meeting the Needs of 9 Billion People.

CO_4033 Assum T. et al., 2011. Immigrants in Europe, their travel behaviour and possibilities for energy efficient travel. ñTogether on the moveò Project Deliverable D2.1. IEE/009/735/S12.577622.

CO_5003 Holden E., Linnerud K./European Parliament, 2010. The future of sustainable passenger transport.

CO_5004 European Parliament, 2010. The future of the EUôs transport infrastructure.

CO_5005 European Parliament, 2010. The future of transport in urban areas.

CO_5006 Institute for Social-Ecological Research/European Parliament, 2010. The future of mobility in the EU.

CO_5008 TRT/Directorate General Internal Policies of the Union, 2007. Energy and environmental aspects of the transport policy.

CO_5009 OECD, 2008. OECD Environmental Outlook to 2030.

CO_5011 Bleischwitz R. et al./European Parliament, 2009. Eco-innovation - Putting the EU on the path to a resource and energy efficient economy.

CO_5012 Argiolu R., van der Heijden R., Marchau V., 2007. ITS-Based Transport Concepts and Location. Preference: Will ITS change ôBusiness as Usualö? Essays on Transport Economics. Contributions to Economics, 2007, Part V, 293-315.

CO_5017 Fraga F., 2011. Car Fleet Renewal Schemes: Environmental and Safety Impacts France, Germany and the United States. OECD/ITF.

CO_5018 Gazibara I., Goodman J., Madden P., 2010. Megacities on the Move. EMBARQ.

CO_5019 ITF-OECD, 2011. Transport for Society, Highlights 2011 Annual Summit.

CO_5024 Kageson P., 2009. Making International Transport Pay Its Climate Bill. OECD/ITF.

CO_5026 EC, 2010. Why socio-economic inequalities increase? Facts and policy responses in Europe.

CO_5027 EC, 2010. World and European Sustainable Cities - Insights from EU research. EC EUR 24353 EN.

CO_5028 World Bank, 2009. World Development Report 2009 Reshaping Economic Geography.

CO_5029 IMO, 2011. World Migration Report 2011 Communicating Effectively about Migration. IMO.

CO_5030 European Environment Agency (EEA), 2011. Laying the foundations for greener transport. TERM 2011: transport indicators tracking progress towards environmental targets in Europe.

CO_5031 European Environment Agency (EEA), 2008. Beyond transport policy - Exploring and managing the external drivers of transport demand Illustrative case studies from Europe.

CO_5032 International Energy Agency (IEA), 2011. Technology Roadmap Biofuels for Transport. OECD/IEA.

CO_5033 European Green Cars Initiative (EGCI), 2010. European Green Cars Initiative PPP. Multi-annual roadmap and long-term strategy. European Green Cars Initiative (EGCI).

CO_5034 European Road Transport Research Advisory Council (ERTRAC), 2011. ERTRAC Research and Innovation Roadmaps. Implementation of the ERTRAC Strategic Research Agenda 2010.

CO_5036 Conseil C.O.C/European Parliament, 2007. Tourism and immigration policy in the EU. DG for Internal Policies of the Union. Policy Department Structural and Cohesion Policies.

CO_5037 CESUR & TPR University of Antwerp, 2007. The consequences of the growing European low-cost airline sector. DG for Internal Policies of the Union. Policy Department Structural and Cohesion Policies.

CO_5038 Chorus C.G., Arentze T.A., Timmermans H.J.P., Molin E.J.E., Van Wee B., 2006. Travelers' Need for Information in Traffic and Transit: Results from a Web Survey. Journal of Intelligent Transportation Systems, 11:2,57 ð 67, 2007.

CO_5039 Toledo T., Beinhaker R., 2006. Evaluation of the Potential Benefits of Advanced Traveler Information Systems. Journal of Intelligent Transportation Systems, 10:4,173 ð 183, 2006.

CO_5040 Dekkers J., Rietveld P., 2007. Electronic Ticketing in Public Transport: A Field Study in a Rural Area. Journal of Intelligent Transportation Systems, 11:2,69 ð 78, 2007.

CO_5042 OECD, 2007. Infrastructure to 2030. Volume 2. Mapping policy for electricity, water and transport. Final Report on the OECD Futures project "Global Infrastructure needs: Prospects and Implications for Public and Private Actors".

CO_5044 Stillwater T., 2011. Comprehending Consumption: The Behavioral Basis and Implementation of Driver Feedback for Reducing Vehicle Energy Use. Research Report, University of California at Davis-Institute of Transportation Studies.

CO_5046 Ogden J., Anderson L., 2011. Sustainable Transportation Energy Pathways: A Research Summary for Decision Makers. University of California at Davis-Institute of Transportation Studies.

CO_5047 Litman T., 2011. The future isnõt what it used to be. Changing trends and their implications for transport planning. Report. Victoria Transport Policy Institute.

CO_5048 Petersen M.S., Sessa C., Enei R., Ulied A., Larrea E., Obiosca O., Timms P.M. , Hansen C.O., 2009. TRANSvisions. Report on Transport Scenarios with a 20 and 40 Year Horizon. Final report, project funded by the European Commission DG TREN.

CO_5049 EC, 2011. Intelligent transport systems in action. Action plan and legal framework for the deployment of intelligent transport systems (ITS) in Europe.

CO_5051 ESPON, 2010. New Evidence on Smart, Sustainable and Inclusive Territories. The ESPON 2013 Programme. First ESPON 2013 Synthesis Report.

CO_5052 Monti M., 2010. A new strategy for the single market. Report to the President of the European Commission José Manuel Barroso.

CO_5053 Wintjes R., Hollanders H., 2010. The regional impact of technological change in 2020. Synthesis report for Directorate-General Regional Policy on behalf of: The network for European Techno-Economic Policy Support ETEPS AISBL.

CO_5054 Bozeat N., Irving P., Ramos X., Vincze M. P., Juravle C., Jesuit D., 2010. Social Mobility and Intra-Regional Income Distribution Across EU Member States- Revised Final Report.

CO_5055 Pálfalvi J./European Parliament, 2010. Transport and globalisation. DG for Internal Policies. Policy Department B: Structural and Cohesion Policies.

CO_5059 Morrow K., Karner D., Francfort J., 2008. Plug-in Hybrid Electric Vehicle Charging Infrastructure Review. Final Report. U.S. Department of Energy Vehicle.

CO_5065 Burnewicz J., 2009. Innovative Perspective of Transport and Logistics.

CO_6000 Rainer Muenz, 2007. Aging and demographic change in European societies: main trends and policy options. World Bank.

CO_6004 Mantzos et al., 2003. European energy and transport trends to 2030. National Technological University of Athens.

CO_6006 European Monitoring Centre on Change, 2008. Trends and drivers of change in EU transport and logistics sector: Scenarios. EMCC.

CO_6014 Dorian et al., 2006. Global challenges in energy. Elsevier - Science direct.

CO_6018 Piecyk & McKinnin, 2010. Forecasting the carbon footprint of road freight transport in 2020. Elsevier - Science direct.

## REFERENCES - EMERGING TRAVELLER NEEDS


Alauzet, A., Dejoux, V., Simoes, A., Rocci, A., Suen, L., Rola, S., Wretstrand, A., Marin-Lamellet, C., Armoogum, J. and Madre, J-L- Access2All (2009) D1.1 User needs and preferences per user group.

Anable, J and Gatersleben, B.(2005) All Work and No Play: The role of instrumental and affective factors in work and leisure journeys by different travel modes. *Transportation Research Part A,* 39. 163-181

Apostolopulou, E., Nellas, G., Ganoudis, D. & Marinaki, A. (2000) Understanding quality needs and expectations of potential metro users in Athens. In Proceedings of European Transport Conference, Cambreidge, UK, September, 2000.

Assum, T., Panian, T., Plaffenbichler, P., Christiaens, J., Nordbakke, S., Davoody, H. & Wixey, S. (2011) Immigrants in Europe, their travel behaviour and possibilities for energy efficient travel. Deliverable D2.1: Together on the move.

Barrett, E., Heycock, M., Hick, D., Judge, E. (2003). Issues in access for disabled people: The case of the Leeds Transport Strategy. *Policy Studies*, 24 (4).

Ben-Akiva, M. and Morikawa, T. (2002) Comparing ridership attraction of rail and bus. *Transport Policy*, 9, 107-116.

Beirão, G. & Sarsfield, J.A. (2007) Understanding attitudes towards public transport and private car: A qualitative study. *Transport Policy*, 14, 478-489.

Bieger, T., Wittmer, A. and Laesser, C. (2007) What is driving the continued growth in demand for air travel? Customer value of air transport. *Journal of Air Transport Management*, 13, 31-36.

Brons, M., Givoni, M. and Reitveld, P. (2009) Access to railway stations and its potential for increasing rail use. *Transportation Research: Part A*, 43 (2), 136-149.

Carreno, M. and Stradling, S.G. (2007). *Which aspects are most important for elderly and mobility-impaired pedestrians?*. Proc. 11th International Conference on Mobility for Elderly and Disabled People (TRANSED), Montreal, Canada 18-22nd June, 2007.

Carreno, M. (2011) ‟User Needs" Deliverable 4.1 0f ORIGAMI, Co-funded by FP7. TRI, Edinburgh Napier University, Edinburgh, October, 2011.

CEC (2001) *European Transport Policy for 2010: Time to decide- White Paper*. Brussels.

CEC (2009) Directorate- General Energy and Transport, Evaluation of the common transport policy of the EU from 2000 to 2008 and analysis of the evolution and structure of the European transport sector on the context of the long-term development of the CTP- D3 Final Report- prepared by Steer Davies Gleave.

CEN/BT/WG 141 (2002) Working Group Intermodal and interoperable transport - Telematics of the European Committee for Standardisation.

CLOSER (2010) *Interconnections between short and long-distance travel networks: structure of interface and existing indicators*. Available at http://www.closer-project.eu/file/deliverable-d3-1/

Coffel, K., Parks, J., Sempler, C., Sampson, D.J., Calves, G, Kachadoorian, C,., Levinson, H.S. and Schofer, J.L. (2009) *Literature review for providing access to public transportation stations: TCRP Web-only Document 44*. http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_webdoc_44.pdf

Crime Concern & Transport and Travel Research (1997) *Perceptions of safety from crime on public transport*. Department of Transport, HMSO, London.

Crime Concern (2002) *People's perceptions of personal security and their concerns about crime on public transport*. Department for Transport, HMSO, London.

Crockett, J., Beecroft, M., McDonald, M., Whiteing, T., Whelan, G., Nash, C., Fowkes, T. and Wardman, M. (2004) *Rail user needs and deliver mechanisms*: Report RRUK/C2/02.

Debbah, F. (2009) *User aspects: Thematic Research Summary*. Transport Research Knowledge Centre.

dell'Olio, L., Ibeas, A. and Cecin, P. Modelling user perception of bus transit quality *Transport Policy* 17 (6), 388-397 .

dell'Olio, L., Ibeas, A. and Cecin, P. (2011) The quality of service desired by public transport users. *Transport Policy*, 18, 217-227.

DETR (1998) *Older people: Their transport needs and requirements- summary report*, TSO, London.

DETR (2000) *Social exclusion and the provision of public transport* ï Main report. London, HMSO.

Department for Transport (DfT) (2003) *Attitudes for walking and cycling*. London, HMSO.

Department for Transport (2004) People's perceptions of personal security and their concerns about crime on public transport. London, HMSO.

Department for Transport (2009) Guideline no 1: Gender auditing an overview. Online available at http://assets.dft.gov.uk/publications/women-and-public-transport-the-checklist/checklist.pdf. Accessed 01/05/2012.

Diana, M. (2012) Measuring the satisfaction of multimodal travelers for local transit services in different urban contexts. Transportation Research part A, 46, 1-11.

Dickinson, J., Kingham, S., Copsey, S., Hougie, D. (2003) Employer travel plans, cycling and gender: will travel plan measures improve the outlook for cycling to work in the UK? *Transportation Research Part D*, 8. 53-67.

Disability Rights Commission (2003) *An overview of the literature on disability and transport*. London, DRC.

Dixon, L. (1996) Bicycle and pedestrian level of service performance measures and standards for congestion management systems. *Transportation Research Record,* 1538, 1-9.

Dobbie, F., McConville, S. & Ormston, R. (2010) Understanding why some people do not use buses. Edinburgh, Scottish Government.

Dobbs, L. (2005) Wedded to the car: Woman, employment and the importance of private transport. *Transport Policy*, 12 (3), 266-278.

Dowling, R., Flannery, A., Ryus, P., Petritisch, T. and Rouphail, N. (2010) *Field test results for multimodal level of service analysis for urban streets*. NCHRP Web-only Document 158. Available at http://www.trb.org/PedestriansAndBicyclists/Blurbs/Field_Test_Results_of_the_Multimodal_Level_of_Serv_163574.aspx.

DPTAC (2000) *The Design of Large Passenger Ships and Passenger Infrastructure: Guidance on Meeting the Needs of Disabled People*, London, DPTAC.

DPTAC (2002) *Attitudes of disabled people to public transport*. London, DPTAC.

DPTAC (2010) *Access to Sea Travel - Information for Disabled People and People with Reduced Mobility*. Available at http://dptac.independent.gov.uk/pubs/seatravel/pdf/accesstoseatravel.pdf

Dunbar, G., Holland, C.A. and Maylor, E.A. (2004) *Road Safety Research Report No. 37. Older Pedestrians: A Critical Review of the Literature*. London, HMSO.

Eboli, L. and Mazzulla, G. (2011) A methodology for evaluating transit service quality based on subjective and objective measures from the passenger's point of view. *Transport Policy*, 18, 172-181.

European Commission (EC) (2011) *Accompanying the White Paper- Roadmap to a single European transport area- Towards a competitive and resource efficient transport system*. Brussels.

European Commission (2001) *White Paper: Europe's Transport Policy for 2010: Time to decide*.

Federal Transit Administration (FTA). 2003. *Customer Preferences for Transit.* ATIS: Research Report. U.S. Department of Transportation, Battle Memorial Institute and Multisystems Inc., Washington.

Gaffron, P., Hine, J. P. & Mitchell, F. (2001) *The role of transport on social exclusion in urban Scotland – Literature Review*. Central Research unit, Scottish Executive.

Gallin, N. (2001) Quantifying pedestrian friendliness- guidelines for assessing pedestrian level of service. *Road and Transport Research* 10, 47-54.

Gilhooly, M. L. M. (2002) *Transport and ageing: Extending quality for life for older people via private and public transport*. Online available at www.esrc.ac.uk/my-esrc/.../7acf0892-9280-461e-9f6b-7c23857f8c4. Accessed 01.06.2012.

Gillam, T., Lyons, G. & McDonald, M. (1999) *Traveller information systems: What do end-users really want?* In Proceedings of European Transport Conference, Cambridge, UK, September, 1999.

Givoni, M. and Rietveld, P. (2007) The access journey to the station and its role in passenger satisfaction with rail travel. *Transport Policy*, 14, 357-365.

Granville, S. & Campbell-Jack, D. (2005) *Anti-social behaviour on buses*. Scottish Executive Social research, George Street Research Limited.

Gray, D. (2001) *Rural transport: an overview of key issues*. Prepared for the Commission for Integrated Transport.

Greico, M. (2007) *Gender, transport and mobility*. Presentation to TRANSGEN Advisory Board.

Grotenhuis, J. Wiegmans, B.W. and Rietveld, P. (2007) The desired quality of integrated multimodal travel information in public transport: Customer needs for time and effort savings. *Transport Policy*, 14 (1), 27-38.

GUIDE (200) *GUIDE- urban interchanges- a good practice guide*. Final Report.

Hamilton, K., Ryley Hoyle, S. & Jenkins, L. (2000) *Public transport and gender: Audit evidence*. London, Department for Transport.

Hensher, D.A., Stopher, P. and Bullock, P. (2003) Service quality- developing a service quality index in the provision of commercial bus contracts. *Transportation Research: Part A*, 37, 499-517.

Hine, J. & Mitchell, F. (2001) *The role of transport in social exclusion*. Edinburgh, Scottish Executive.

ILS (2004) Towards Passenger Intermodality in the EU. Available from: http://www.ils-forschung.de/down/towards-pass-1.pdf

Infopolis 2, 1999. *Needs of travellers: an analysis based on the study of their tasks and activities*. Advanced Passenger Information for European Citizens of 2000ð TR 4016; Deliverable 3 prepared for the Commission of European Communitiesð DG XIII 4th Framework Programme, Brussels.

Ipingbemi, O. (2010) Travel characteristics and mobility in Idaban, Nigeria. *Journal of Transport Geography,* 8, 46-53.

Jørgensen, F., Mathisen, T. A. and Solvoll, G. (2008). *Verdsetting av riksvegfergetilbudet i Norge* (Economic valuation of the highway ferry services in Norway). SIB report 4/2008, Bodø Graduate School of Business.

Kapros, S., Roumboutsos, A., Morfoulaki, M. & Papanikolaou, A. (2011) Promotion of passenger intermodality and user requirements for service performance at terminals and passengers interchange poles. In Proceedings of European Transport Conference, Glasgow, Scotland, 2011.

Kenyon, S. and Lyons, G. (2003) The value of integrated multimodal traveller information and its potential contribution to modal change. *Transportation Research: Part F*, 6, 1ï 21.

King, A. (2007) Health-related travel difficulties- Personal travel factsheet. National Centre for Social Research.

KITE (2007) Central issues in intermodality: Deliverable D1.

KITE (2008) Catalogue of best-practice implementation examples. D13.

KITE (2009a) Guidelines for seamless intermodal interchanges. D14.

KITE (2009b) Recommendations for a standardisation of intermodal information and ticketing service.

KITE (2009c) Report about results: user requirements and indicators about demand volumes. Deleiverable D8.

Krygsman, S., Dijst, M. and Arentze, T. (2004) Multimodal public transport: an analysis of travel time elements and the interconnectivity ratio. *Transport Policy*, 11, 255-265

Last, J. and Manz, W. (2003) *Unselected mode alternatives: what drives modal choice in long-distance passenger transport?* Paper presented at the 10th International Conference on Travel Behaviour Research, Lucerne, August, 2003.

Law, R. (1999) Beyond woman and transport: Towards new geographies of gender and daily mobility. *Progress in Human Geography*, 23 (4), 567-588.

Lekakou, M., Pallis, A. A., Vaggelas, G.K. & Vitsounis, T. K. (2011) Presented at The European Confernce on Shipping Intermodalism & Ports- ECONSHIP, Chios, Greece, June, 2011.

Limtankool, N., Dijst, M. and Schwanent, T. (2006) The influence of socioeconomic characteristics, land use and travel time considerations on mode choice for medium and long-distance trips. J*ournal of Transport Geography*, 14, 327-341.

LINK (2007) *LINK Working Groups: The user perspective*. Deliverable D21/31.

LINK (2010) *Recommendations and strategies for passenger intermodality in Europe*.

McDonald, M., Crockett, J., Beecroft, M., Menaz, C. and Fowkes, T. (2003) *The role of rail in integrated transport.* Rail Research UK Report: RRUK/C3/1.

McMillan, T. (2007) The relative influence of urban form on childô travel mode to school. *Transportation Research Part A*, 41, 69-79.

Mathisen, T.A. and Solvoll, G. (2010) Service quality aspects in ferry passenger transport: Examples from Norway. *European Journal of Transport and Infrastructure Research*, 10 (2), 142-157.

MIMIC (1999) MIMIC- Mobility, intermodality and interchanges. Final Report.

Mullan, E. (2003) Do you think that your local area is a good place for young people to grow up? Theeffects of traffic and car parking on young peoplesôviews. *Health and Place*, 9, 351-360.

Nathanail, E. (2008) Measuring the quality of service for passengers on the hellenic railways. *Transportation Research: Part A*, 42, 48-66

NICHES+ (2010a) Guidelines for implementers of passenger friendly interchanges.

NICHES+ (2010b) Guidelines for implementers of innovative cycling facilities at interchanges.

NICHES+ (2010c) Guidelines for implementers of tailored traveller information for users with reduced mobility.

Palmer, D., James, C., and Jones, M. (2011). *Door to Door Journeys*. Report produced by Transport Research Laboratory for Campaign for better Transport.

Pantouvakis, A.M. (2006) Port-service quality dimensions and passenger profiles: an exploratory examination and analysis. *Maritime Economics and Logistic*s, 8, 402-418.

Pantouvakis, A.M. (2007) Who pays the ferryman? an analysis of the ferry passenger's selection dilemma. *Maritime Policy and Management,* 34 (6), 591-612.

Pantouvakis, A.M., Chlomoudis, C. and Dimas, A. (2010) Testing the SERVQUAL scale in the passenger port industry: a confirmatory study. *Maritime Policy and Management*, 35 (5), 449-467

PIRATE (2001) *Promoting interchange rationale, accessibility and transfer efficiency*. Final Report.

Preston, J., Wall, G. and Whiteing, T (2006) Delivery of user needs: final report: Report RRUK/C2/06- available at http://portal.railresearch.org.uk/RRUK/Shared%20Documents/C2_06.pdf. Accessed 01/04/2012.

Porter, A. (2002). Compromise and constraint: Examining the nature of transport disability in the context of local travel, *World Transport Policy and Practice*, 8 (2), 9-16.

PROMPT: *New Means to PROMote Pedestrian Traffic in Cities (2003) Guidebook*. Available at http://virtual.vtt.fi/virtual/prompt/guidebook.pdf

Ravenscroft, N., Uzzell, D., Leach, R., Groeger, J. (2002) Danger ahead? The impact of fear of crime on people's recreational use of non-motorised shared routes'. *Environment and Planning, C,* 20. 741-756.

Reid-Howie Associates (2000) *Woman and Transport: Moving forward.* Edinburgh, Scottish Executive Central Research Unit.

Reid Howie Associates Ltd (2004). *Transport provision for disabled people in Scotland: Progress since 1998*. Edinburgh, Scottish Executive.

Royal National Institute for the Blind (1999) *Rights of way: transport and mobility for visually impaired people in the UK. London,* RNIB.

Smith, N., Beckhelling, J., Ivaldi, A., Kellard, K., Sandu, A. and Tarrant, C. (2006), *Evidence Base Review on Mobility: Choices and Barriers for Different Social Groups*. Loughborough: CRSP Working Paper 554.

Smith, M. J. (2008) Addressing the security needs of women passengers on public transport. *Security Journal*, 21, 117-133.

Soren, J. (2007) Pedestrian and bicyclist level of service on roadway segments. Transportation Research Record: *Journal of the Transportation Research Board*, 2031, 43-51.

Stradling, S.G. (2002) Transport user needs and marketing public transport. Proceedings of the Institution of Civil Engineers. *Municipal Engineer*, 151 (1), 23-28.

Stradling, S, G., Anable, J and Carreno, M. (2007) Performance, importance and user disgruntlement: a six-step method for measuring satisfaction with travel modes. *Transportation Research: Part A*, 41, (1), 98-106.

Stradling, S., Carreno, M., Rye, T. & Noble, A. (2007) Passenger perceptions and the ideal urban bus experience. Transport Policy, 14, 283-292.

Steg, L. (2005) Car use: lust and must: Instrumental, symbolic and affective motives for car use. *Transportation Research Part A*, 39, 147-162.

Stahl, A. and Wretstrand, A. (2008) *User needs and expectations relative to accessible transport*. EuroAccess WP2-Lund-Deliverable 2.

Su, F. & Bell, M. G. H. (2012) Travel differences by gender for older people in London. *Research in Transportation Economics*, 34, 35-38.

SWITCH (2001) FINAL REPORT. Deliverable 8.

Széchenyi István University (2008) *Consumer evaluation in the transit industry*. Széchenyi István University, Department of Marketing and Management, Hungary, 2008.

Thornton et al (2010). *Climate change and transport choices: segmentation study interim report.* London, Department for Transport.

Transport for London (2009a) *Interchange best practice guidelines 2009.* Transport for London, London. Available at http://www.tfl.gov.uk/microsites/interchange/

Transport for London (2009b) *Attitudes to rail*. London, Transport for London.

Transport Scotland (2011) Transport and travel in Scotland 2010. Online available at http://www.scotland.gov.uk/Publications/2011/08/31092528/0

Tyrinopoulos, Y. and Antoniou, C. (2008) Public transit user satisfaction: variability and policy implications. *Transport Policy*, 15 (4), 260-272.

Use Mobility (2012) ὁFactors influencing behavioural change towards eco-friendly multimodal mobilityô www.usemobility.eu

Verband deutscher Verkehrsunternehmen (VDV), TNS Infratest: Kundenbarometer ÖPNV Deutschland 2009, Der ÖPNV im Urteil der Bevölkerung 2009, Köln, 2009.

Wardman, M., Hine, J. and Stradling, S.G. (2001) *Interchange and travel choice*: Volume 1. Scottish Executive Research Unit, Edinburgh.

Wardman, M. and Whelan, G.A. (2001) Valuation of improved railway stock: a review of the literature and new evidence. *Transport Reviews*, 21 (4), 415-447.

Whitney, G., Keith, S. and Kolar, I. (2005) *Independent mobility for blind and partially sighted people traveling by large passenger ships*. International Congress Series, 1094-1098.

Wixey, S., Jones, P., Lucas, K. & Aldridge, M. (2005) *User needs literature review: Working Paper 1.* Available online at http://home.wmin.ac.uk/transport/download/SAMP_WP1_Literature_Review.pdf. Accessed 01/05/2012.