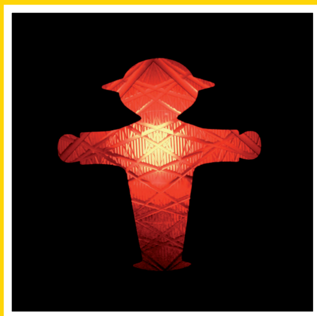
EEA Report | No 34/2016

Transitions towards a more sustainable mobility system

TERM 2016: Transport indicators tracking progress towards environmental targets in Europe

ISSN 1977-8449



European Environment Agency

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Luxembourg: Publications Office of the European Union, 2016

ISBN 978-92-9213-839-4
ISSN 1977-8449
doi:10.2800/895670

European Environment Agency
Kongens Nytorv 6
1050 Copenhagen K
Denmark

Tel.: +45 33 36 71 00
Web: eea.europa.eu
Enquiries: eea.europa.eu/enquiries

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Acknowledgements

The Transport and Environment Reporting Mechanism (TERM) process is steered jointly by the European Environment Agency (EEA) and the European Commission (Eurostat, Directorate-General for Environment, Directorate-General for Mobility and Transport, Directorate-General for Climate Action).

This report was prepared by the EEA, based upon a draft assessment from the European Topic Centre on Air Pollution and Climate Change Mitigation (ETC/ACM).The ETC/ACM partners involved in its preparation were Inge Mayeres (Flemish Institute for Technological Research (VITO), Belgium), as task leader, with Laurent Franckx (VITO, Belgium), Hans Hilbers and Hans Nijland (Netherlands Environmental Assessment Agency (PBL), Netherlands).

The Chapter 3 case study illustrating future mobility and accessibility patterns in the Greater Helsinki area was prepared by Maria Salonen, guest scientist at EEA. Contributions to this study came from Maria Salonen, Henrikki Tenkanen, Vuokko Heikinheimo and Tuuli Toivonen, Accessibility Research Group, Department of Geosciences and Geography, University of Helsinki. Their input is gratefully acknowledged.

The EEA project manager was Alfredo Sánchez Vicente. Diana Vedlugaite, Martin Adams, Paul McAleavy, Mike Asquith, Colin Nugent, Patrick McMullan, Andy Martin and Pia Schmidt (all EEA) are thanked for their input to this year's report.

Comments on the draft version of this report received from EEA member countries and the European Commission are gratefully acknowledged.

Executive summary

In March 2015 the European Environment Agency (EEA) released its five-yearly report *European environment — state and outlook report 2015* (SOER 2015). The report concluded that Europe will need to fundamentally transform its systems of production and consumption if it is to achieve its 2050 vision of 'living well, within the limits of our planet'. This vision was specified in the European Union's (EU) Seventh Environment Action Programme (7EAP). SOER 2015 stated: '*While progress has been made in meeting certain policy objectives, including efficiency and short-term GHG-reduction targets, major challenges remain toward meeting longer-term objectives. The European Commission's target of a 60 % reduction in transport GHG emissions by 2050 will require significant additional measures'* (EEA, 2015a).

This year's 'Transport and Environment Reporting Mechanism (TERM)' report (released on an annual basis since 2000) reflects on the prospects for significant future 'systemic' changes towards sustainability for the mobility system. Technological developments will largely determine the future environmental performance of the transport sector. However, many past technological advances in the transport sector have historically been offset by the ever increasing demand for transport. Previous TERM reports have addressed this issue and have concluded that technical solutions alone are not enough to ensure that environmental impacts from transport will be reduced. Other measures, such as demand optimisation in the form of better vehicle utilisation, avoidance of unnecessary trips and modal shift, will therefore be indispensable. '*Ultimately, we should not be afraid of asking whether we actually need all this transport… …and reconsider our consumption patterns and lifestyle choices*' (EEA, 2016a).

The understanding of 'long-term sustainability' in this context is largely based on the aims of the 7EAP and the 2011 Transport White Paper's quantitative target of a 60 % reduction in transport greenhouse gas (GHG) emissions by 2050.

The need for a systemic change

Two recent European Commission documents — the *European strategy for low-emissions mobility* (EC, 2016a) and the Commission's 2016 'Reference Scenario' (EC, 2016b) — suggest that, if no additional measures are taken beyond those currently planned, it will be difficult to reconcile high levels of human development (living well) with environmental sustainability i.e. living within environmental limits. Transport is responsible for a quarter of the EU's present-day GHG emissions and is also the only major economic sector in Europe where GHG emissions are higher than their 1990 levels. GHG emissions from transport increased slightly in 2014, following a period of decreasing emissions between 2008 and 2013.

Looking toward the future, EU transport activity is expected to continue growing under current trends and adopted policies. From 2010 to 2050, passenger transport is estimated to grow by about 40 %, with aviation as the fastest growing sector (more than doubling 2010 levels), while freight transport would grow by 58 %.

Current policies in the transport sector are expected to reduce GHG emissions until 2030, but will not deliver the 2011 Transport White Paper's indicative goal for 2030 (20 % reduction in GHGs compared to 2008 levels, or an increase of 8 % compared to 1990) in the absence of greater efforts. Transport GHG emissions under current policies are forecast to slightly increase between 2030 and 2050 to 15 % above 1990 levels, and therefore significantly higher than the 60 % reduction target by 2050.

Beyond reducing transport GHG emissions, other transport related environmental pressures, such as air pollution, biodiversity fragmentation, traffic congestion, inefficient use of urban space and noise, also require more ambitious actions to reach the 7EAP's 'living well, within the limits of our planet' vision. A transition to sustainable mobility implies an understanding that small incremental steps are not enough to reach the necessary reduction in transport related pressures on the environment.

New societal developments and technological advances have gained in pace in recent years, such as car-sharing schemes, innovative mobile applications to access mobility services, etc. These developments are likely to help shape future changes in the way society uses transport, especially in the urban areas. Significant business opportunities (including new mobility services and web applications, fuel and vehicle technologies) are also foreseen.

Links between mobility and other societal systems

Europe's transport sector caters for the mobility needs of many stakeholders by offering a variety of services, with different characteristics in terms of their costs, speed, reliability, etc. A well-functioning mobility system is essential for our society. On the other hand, the mobility system itself can also be shaped by changing practices in society.

The mobility system has close linkages with other societal systems. Three such systems, land use, the food system and tourism, were selected as case studies for this report as each provides a clear illustration of the very close links that exist between them and the mobility system. Because of these links, actions designed to improve the environmental performance of transport can become more complex, as the outcomes also depend on factors that are external to the mobility system. These links also offer opportunities for integrated solutions that address the environmental performance of transport via the other societal systems.

Land use and transport

Financial and technological developments have changed land use patterns in recent decades. The relatively low costs of car transport, coupled with improved transport infrastructure have allowed longer distances to be covered when commuting. This has generated problems in terms of increasing congestion and pollution. Measures such as urban planning for higher urban densities, varied land use mixes, removal of financial incentives that encourage commuting, improved public transport connectivity and better accessibility can help reduce commuting distances travelled.

A comprehensive package of land-use and mobility measures covering all modes of transport in a metropolitan area can create more liveable cities and reduce the amount we travel, while ensuring its continued social and economic development. This, in return, can increase the attractiveness of the metropolitan area.

Transport and the globalisation of food production and consumption systems

The EU's food consumption-production system has become increasingly global over time. Whether this is positive or negative from an environmental point of view depends on both the production process and the corresponding transport flows for each particular trade flow.

Consumers attach a strong value to purchasing food regardless of season and diversified access to food products. This access is made possible by the current global organisation of the food system, supported by the relatively low transport prices, and the variety of existing transport options. A transition to a more sustainable consumption and production pattern would be more fully supported if the externalities created by the system, be it in transport or in the rest of the supply chain, were reflected in the final price paid by consumers.

Aviation and tourism

The tourism sector depends heavily on transport. The increasing demand from this sector contributes to the growth in the transport activity. Although the aviation and cruise modes are growing, the largest share of trips made by tourists is by car. However, air transport accounts for the largest share of tourism-related GHG emissions, and this is expected to grow significantly. More ambitious environmental policies would be required in order to mitigate the environmental impacts of the growing air transport activity. These may consist of more efficient and quieter aircraft, the uptake of alternative fuels, the improvement of air traffic management and operations, environmental measures taken by airports and the inclusion of market based instruments. Tourists themselves can also help reduce the environmental impacts associated with trips by switching to more environmentally friendly modes, travelling to closer destinations and/or staying a longer time at each destination instead of making frequent short trips.

Lock-ins and barriers towards future changes

Even when opportunities for sustainable mobility are identified, it may not be straightforward to fully exploit them, as specific factors may exert strong incentives for avoiding the fundamental changes that are required. Depending on specific circumstances, different barriers and lock-ins may occur on different pathways towards sustainable mobility.

Examples of possible barriers include the incumbent interests of the automotive industry and other stakeholders, the long lifetime of ships and aircraft or slow decision-making processes in the international transport sector. Furthermore, improvements in efficiency tend to make products or services cheaper, which can in itself lead to increased consumption, that is, a 'rebound effect'.

One example of a lock-in is the investment in certain transport infrastructures. Due to our car-dependency, most infrastructure investments are in roads. During previous decades, transport investment policies focused on extending infrastructure capacity, particularly roads, as a response to increasing traffic demand. However, there is strong evidence that new transport infrastructure, which tends to be roads, generates new demand for travel, and often serves simply to shift congestion problems from one place or point in time to another. This not only reinforces car-dependency but also reduces potential investments in more sustainable modes of transport.

Niches and policies that can boost the changes needed

In the transition to sustainable mobility, 'niches' have an important role in catalysing changes in established systems. Niches are examples of novel innovations that can develop without immediate or direct pressure from the current dominant practices. Recent times have seen a number of innovations with a potential to change travel behaviour in a fundamental way, while still meeting the need for mobility. These innovations consist not only of technological breakthroughs, such as electric vehicles and self-driving vehicles, but also new business and ownership models, fuelled by information technology (IT) developments. These new opportunities include shared mobility and 'Mobility as a Service', which allows consumers to buy mobility services that are provided by the same or different operators by using just one platform and a single payment. Shared mobility could also help in overcoming the main competitive disadvantage of public transport in comparison to private cars, its longer door-to-door travel times, which is mainly due to the first and the last mile in the transport chain.

Looking forward, public authorities have a key responsibility in ensuring that different transport services are connected and inter-operable, that the required infrastructure is in place and that price signals are consistent. Through their regulatory and funding power, public authorities also have the possibility to shape the mobility system of the future. These authorities must also create the necessary regulatory and operating frameworks to ensure that innovative technologies and business models can be fully exploited and contribute to improved sustainability of the mobility system.

1 Introduction

The Transport and Environment Reporting Mechanism (TERM) report has been monitoring progress in integrating environmental objectives in transport since 2000, and since that year it has been providing information to European Environment Agency (EEA) member countries, the European Union (EU) and the public. The TERM reporting mechanism includes indicators used for tracking the environmental performance of the transport sector and measuring progress in meeting key transport-related policy targets. Part A of TERM contains the necessary information to ascertain whether developments and latest data are in line with existing policy targets, presenting the relevant TERM indicators.

The EU has set itself ambitious future targets for the long-term decarbonisation of its economy. However, according to its own estimations, the transport's decarbonisation targets will not be met unless more ambitious measures are implemented. Part B of this report provides knowledge on what is needed to understand and support the more fundamental transitions towards long-term sustainability in the transport system.

1.1 Key recent policy developments

A number of EU policy documents, including the *Roadmap for moving to a competitive low carbon economy in 2050* (EC, 2011a), *the roadmap to a single European transport area —Towards a competitive and resource efficient transport system* (EC, 2011b) (referred to as the 2011 Transport White Paper) and more recently, the *European strategy for low-emissions mobility* (EC, 2016a) have presented the aims and actions for the future of Europe's transport sector. They clearly identify the challenges the transport sector faces: to develop a competitive transport system, to reduce Europe's dependence on imported oil and to reduce carbon emissions from transport by 60 % by 2050 (compared to 1990 levels), while supporting growth and employment.

The European Union's (EU's) Seventh Environment Action Programme (7EAP) put forward a clear vision 'In 2050, we live well within the planet's ecological limits. Our prosperity and healthy environment stem from an innovative, circular economy where nothing is wasted and where natural resources are managed sustainably, and biodiversity is protected, valued and restored in ways that enhance our society's resilience' (EU, 2013a). In order to achieve this vision, greenhouse gas (GHG) and air pollutant emissions should be significantly reduced. In the case of GHGs, meeting the 2050 transport target implies a reduction of two-thirds from current levels.

These ambitions were reconfirmed during the December 2015 United Nations Climate Change Conference (COP21) held in Paris. They are reflected in the EU's goals concerning climate change mitigation and in its efforts to exploit technological innovations contributing to emission reductions, as well as the development of renewable energy sources such as wind and solar. Making use of innovation in the sector also helps to attain the EU's ambition to maintain and strengthen the competitiveness of its economies.

Finally, together with the recent publication of the European strategy for low-emissions mobility, the European Commission proposed in July 2016 a binding GHG emission reduction for Member States for the non-Emission Trading Scheme (non-ETS) sectors (i.e. including transport, as well as buildings, agriculture, small industry and waste) to be achieved in a 2021–2030 timeframe. Therefore, according to this proposal known as the 'Effort Sharing Regulation', transport will need to contribute towards the 30 % reduction by 2030 compared to 2005 emissions.

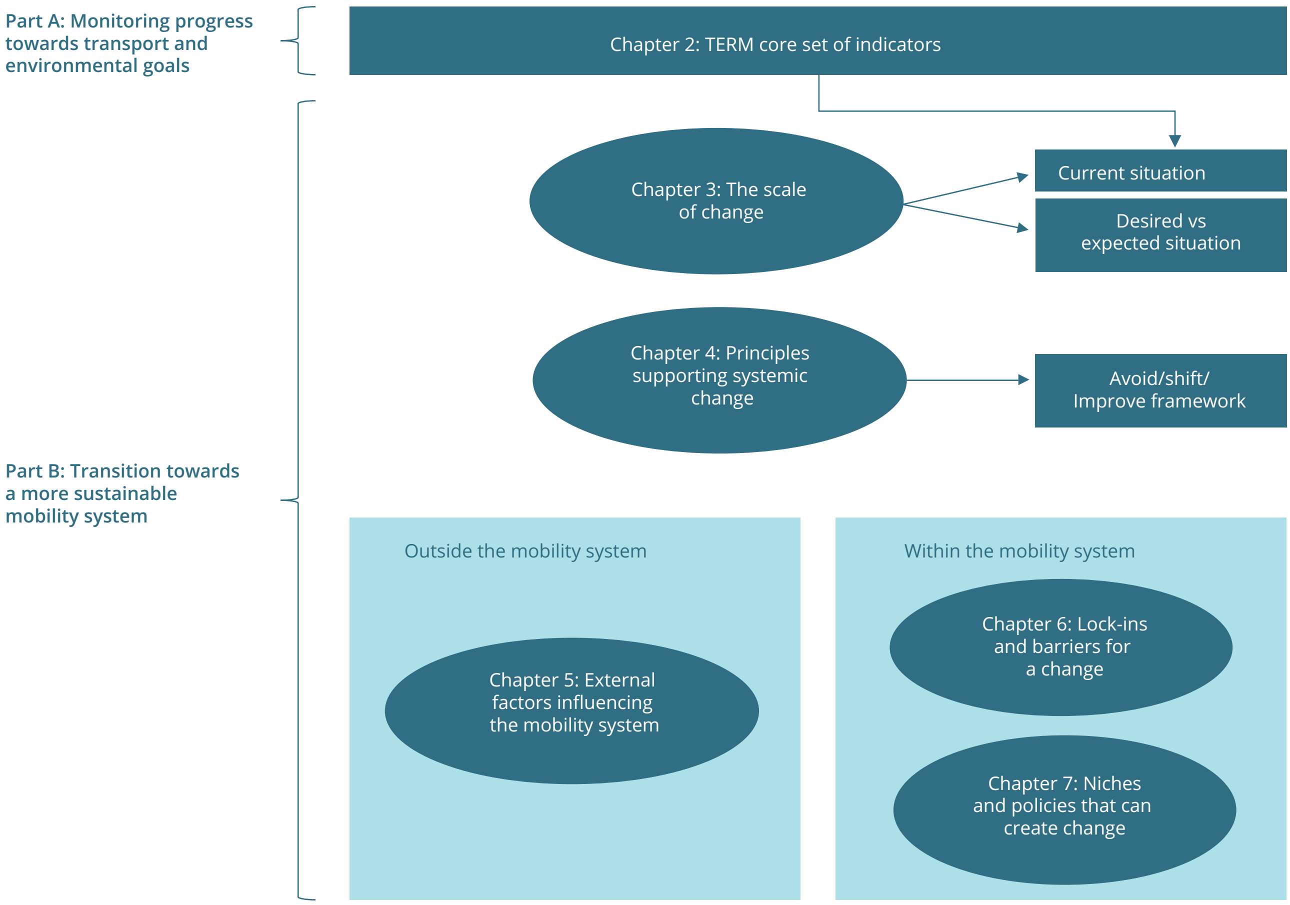
In the international arena, the International Civil Aviation Organisation (ICAO), meeting in Montreal in October 2016, adopted the first global plan to offset emissions from airlines and cap them at 2020 levels. The plan will work at a global level and will be largely voluntary from 2021 but will then become mandatory in a second phase from 2027 to 2035, with certain exemptions for a number of developing countries.

1.2 Contents of this report

The report is structured as shown in Figure 1.1 and detailed below.

- Chapter 2 provides an assessment of the progress made in the environmental performance of Europe's transport system as a whole, based on the EEA's TERM indicators. Descriptions of the relevant targets and an assessment of the key identified trends are provided.
- Chapter 3 describes the scale of the change required in the transport system, in terms of its environmental performance, in order to meet the targets for 2050.
- Chapter 4 contains a description of the 'Avoid, Shift, Improve' framework that can help support systemic change in the mobility system.
  - How can transport demand be optimised and intelligently managed to avoid unnecessary trips? (avoid)
  - Can journeys be shifted to a more environment-friendly transport mode, such as opting for train travel instead of flying or driving? (shift)
  - Can the efficiency of the different transport modes be improved? (improve)
- Chapter 5 examines three case studies, each of which provide a good example of the way in which mobility is interwoven with other societal systems, and how practices and policy changes undertaken within such systems can affect the environmental performance of transport, and vice-versa. The selected case studies address:
  - land use and transport;
  - transport and the globalisation of food production and consumption systems;
  - aviation and tourism.
- Chapter 6 presents examples of various barriers and lock-ins that can hamper or delay the future attainment of improved sustainability in the mobility system. The chapter describes the mechanisms through which sustainability is affected, the expected impacts and the possibilities to cope with lock-ins and barriers.
  - Barriers may, for example, occur due to:
    - existing interests of incumbents in the transport sector
    - the fact that the decision making for some environmental policies takes place in an international and not national or local context,
    - the presence of rebound effects.
  - Lock-ins can be caused by, for example,
    - the current dominance of fossil-fuelled road transport; or
    - the investments in particular types of energy.
- Chapter 7 highlights three important developments or 'niches' that may, in the next decades, significantly contribute to significant behavioural change and practices in the mobility system. Such niches have an important role in catalysing changes in established systems. The chapter also describes the enabling conditions for increased sustainability, as well as the policies that are required to boost positive changes. The selected 'niches' described are:
  - shared mobility;
  - driverless cars;
  - alternative fuel vehicles.
- Finally, Chapter 8 of the report summarises the main conclusions.

Figure 1.1 Structure of this report



Part A: Monitoring progress towards transport and environmental goals

2 TERM core set of indicators

Key messages

In 2014, the environmental performance of European transport improved for most monitored goals, with the exception of the evolution of transport GHG emissions. Reaching the long term environmental targets will still require substantial efforts.

Transport GHG emissions (including aviation but excluding international maritime shipping) have increased by 0.7 % in 2014. Emissions are 20.1 % higher than in 1990.

The average CO_2 emissions of new passenger cars and vans in 2015 are below their respective 2015 and 2017 targets. Substantial reductions still need to be realised to meet the future targets. The EU is undertaking actions to tackle the divergence between results from official testing and real-world fuel consumption and CO_2 emissions, so that the official results may in the future better represent actual vehicle performance.

The EU's share of renewable energy in transport rose to 5.9 % in 2014, which is lower than what is required according to the target path.

2.1 Overview of progress towards transport and environmental goals

The annual TERM report provides an assessment of the progress made in the environmental performance of the transport system in the EEA member countries. It makes use of a core set of 12 of the 40 TERM indicators (called core set of indicators, or TERM-CSI, see Box 2.1); these indicators have been selected based on their links to key transitional processes in transport, association to on-going European policy targets and data availability and reliability.

Transport relevant European policy targets are identified in Annex 1.

Targets are set out in:

- the Transport White Paper (EC, 2011b) and its impact assessment (EC, 2011c);
- the Renewable Energy Directive (EU, 2009a);
- the Fuel Quality Directive (EU, 2009b);
- the regulations on CO_2 emissions from cars and vans (EU, 2009c; EU, 2011).

The information provided by the relevant TERM-CSI is presented in this chapter, including a description of the relevant targets and an assessment of the key trends identified through the indicators. For each TERM-CSI a visual summary is given of its trends and the various targets.

Table 2.1 summarises the progress made for those goals that can be monitored. It contains only a selection of the goals as not all of them can be fully monitored yet, due to a lack of data and/or the complicated nature of the evaluation.

The approach for assessing progress was described in detail in the TERM 2012 report (EEA, 2012). Annex 2 to this report provides a more thorough explanation of the comparison between the observations and the target path. To summarise, for each transport goal, a base year and corresponding value are determined, which serve as a starting point for the target trajectory. For transport GHG emissions, the 2011 Transport White Paper (EC, 2011b) formulated the preferred policy option to reach the objective. This forms the basis of the trajectory for the transport GHG emission reductions. For the other objectives, a linear trend is assumed towards the target, starting from the base year.

2.1.1 Transport GHG emissions to be reduced by 20 % from 2008 levels by 2030, and by at least 60 % from 1990 levels by 2050

Between 2008 and 2013, a reduction was observed in transport GHG emissions, including aviation but

Box 2.1 Country groupings

The report covers all 33 EEA member countries, whenever information is available. Where data are not complete, this is generally noted. For some indicators, EU-28 data have been prioritised, as policy targets and goals are specifically developed for these countries, but a reflection based on the available EEA data has been included as far as possible.

When Croatia joined the EU in July 2013, it also became the 33rd member country of the EEA. Where it has not been possible to include data from Croatia in this year's TERM report, data for the EU-28 excluding Croatia are referred to as EU-27.

Where appropriate, a comparison between EU-13 (countries joining the EU after 2003) and EU-15 (EU Member States prior to 2003) is provided.

The following abbreviations are used to refer to specific country groupings:

- EU-15: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden and the United Kingdom.
- EU-13: Bulgaria, Cyprus, Croatia, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovakia and Slovenia.
- EFTA-4: Iceland, Liechtenstein, Norway and Switzerland.
- EU-28: EU-15 and EU-13.
- EU-27: EU-28 excluding Croatia.
- EEA-33: EEA member countries (EU-28, EFTA-4 and Turkey).

excluding international maritime shipping. In 2014, this downward evolution was stopped and transport GHG emissions slightly increased again, by 0.7 %. Road transport, which accounts for more than 82 % of the emissions excluding international maritime shipping, emitted 0.8 % more than in 2013, whereas international aviation, accounting for the second largest share, had 1.6 % higher emissions.

In spite of the 2014 increase, transport GHG emissions were still below the target path. However, they were 20.1 % above 1990 levels, implying that they will need to fall by 67 % by 2050 in order to meet the Transport White Paper target.

While emissions are clearly linked to economic activity and transport demand, various other factors have also contributed to the changes in GHG emissions seen in recent years, including (EEA, 2015b):

- efficiency improvements as a result of legislation;
- changes in consumer behaviour and preferences.

Previous TERM reports raised the concern that keeping the values in line with or below the target path may become more difficult if transport activity (due to the economy recovery) picks up. The 2014 rise in transport GHG emissions coincides with a higher economic growth in the EU in 2014. Therefore this concern remains valid. It implies that 'avoid', 'shift' and 'improve' policies will have an important role to play ([1]).

2.1.2 Average CO_2 emission targets for passenger cars and vans

Between 2010 and 2015, CO_2 emissions from official testing reported by national authorities ([2]) show that new passenger cars sold in the EU have fallen by almost 15 %. In 2015 the reported average emission rate decreased compared to 2014, from 123.4 g to 119.6 g CO_2/km. The 130 g CO_2/km target for 2015 for cars was met in 2013, two years early. However, in order to meet the 95 g CO_2/km target by 2021, the emission rate needs to reduce further by 21 %.

The average emissions of new vans registered in the EU in 2015 were 168.2 g CO_2/km, well below the 2017 target of 175 g CO_2/km. They need to fall by another 13 % in order to meet the 2020 target of 147 g CO_2/km.

The divergence between the results from official testing and real-world CO_2 emissions is a point of major concern. More background on this issue is given in the

([1]) The Avoid, Shift and Improve (ASI) framework relies on a set of policies aiming at minimising environment pressures from transport via a reduction of transport demand ('Avoid'), a shift to low-carbon or zero-carbon modes ('Shift'), and an improvement in vehicles and fuels technology ('Improve').

([2]) http://www.eea.europa.eu/highlights/reported-CO_2-emissions-from-new.

Table 2.1 Transport goals that can be monitored — overview in the EU-28

	Source	Target	Unit	Where we were: Base year Year	Where we were: Base year Value	Where we want to be: Target Year	Where we want to be: Target Value	Where we are (current trends vs. target paths): 2000 Observed	2010 Target path	2010 Observed	2011 Target path	2011 Observed	2012 Target path	2012 Observed	2013 Target path	2013 Observed	2014 Target path	2014 Observed	2015 Target path	2015 Observed	Latest annual trend
Key target	European Commission's 2011 Transport White Paper (EC, 2011)	Transport GHG (including international aviation, excluding international maritime shipping)	Mt CO_2	1990	854	2030 2050	920 (+ 8 %) 334 (– 60 %)	1034	1 069	1 069	1 112	1 061	1 114	1 024	1 117	1 019	1 118	*1 026*	*1 121*	*n.a.*	*0.7 %*
Key target	European Commission's 2011 Transport White Paper (EC, 2011)	EU CO_2 emissions of maritime bunker fuels	Mt CO_2	2005	161		96 (– 40 %)	134	159	159	152	160	151	148	149	139	148	135	146	n.a.	– 3.2 %
Indicative goals	Passenger car CO_2 EC regulation 443/2009	Target average type-approval emissions for new passenger cars ([a])([b])	g CO_2/km	2010	140	2015 2021	130 95	172	140	140	138	136	136	132	134	127	132	123	130	120	– 3.8 %
Indicative goals	Van CO_2 EC regulation 510/2011	Target average type-approval emissions for new passenger vans ([a])([b])	g CO_2/km	2012	180	2017 2020	175 147						180	180	179	173	178	169	177	168	– 1.0 %
Indicative goals	Impact assessment accompanying document to the 2011 Transport White Paper	Reduction of transport oil consumption ([b])	million TJ	2008	17.3	2050	5.2 (– 70 %)	15.9	16.4	16.4	16.5	16.3	16.2	15.6	15.9	15.4	15.6	*15.5*	*15.3*	*15.4*	*– 0.8 %*
Indicative goals	Renewable Energy Directive 2009/28/EC	10 % share of renewable energy in the transport sector final energy consumption for each Member State (here EU-28 as a proxy) ([c])	%	2010	4.8 %	2020	10.0 %		4.8 %	4.8 %	5.3 %	3.4 %	5.8 %	5.0 %	6.3 %	5.4 %	6.9 %	*5.9 %*	*7.4 %*	*n.a.*	*11.0 %*

Notes: For explanation fo colours please refer to Annex 2.

([a]) EU-28 excl. Croatia until 2013. EU-28 from 2014 onwards; provisional data for 2015.

([b]) Preliminary data for 2015 (transport oil consumption).

([c]) In the case of the Renewable Energy Directive (EU, 2009a) target, the share of biofuels in transport energy use which meet the sustainability criteria of the Directive is only available from 2011. The huge increase between 2011 and 2012 (increase by 49.8 %) is explained by the fact that in previous years the new sustainability criteria were not fully applied. The system for certifying sustainable biofuels is increasingly operational across all Member States.

recent EEA publication *Explaining road transport emissions — A non-technical guide* (EEA, 2016b). The European Commission has proposed to switch to a new procedure known as the 'Worldwide harmonized Light vehicles Test Procedure' (WLTP) in order for laboratory results to better represent actual vehicle performance on the road. The new WLTP test should become mandatory for all new vehicle types from September 2017 and for all new vehicles from September 2018.

2.1.3 All EU Member States to achieve a 10 % share in renewable energy by 2020 for all transport options

In order for EU Member States to meet this target, it is expected that biofuels will play a major role. Only biofuels complying with the sustainability criteria under the Renewable Energy Directive and the Fuel Quality Directive are to be taken into account for this target. To combat indirect land use change, new rules came into force in 2015 which amend the legislation on biofuels — specifically the Renewable Energy Directive and the Fuel Quality Directive (EU, 2015a; EU, 2015b). The new rules limit the share of biofuels from crops grown on agricultural land that can be counted towards the 2020 renewable energy targets to 7 %, following concerns that crop-based fuels can have a larger net environmental impact than conventional fuels.

The average EU-28 share of renewable energy consumed in transport rose between 2013 and 2014, from 5.4 % to 5.9 %, with biodiesel being the most widely used type of renewable energy. In eight Member States the share is larger than 6 %; Finland and Sweden achieved a large share of respectively 21.6 % and 19.2 %. The overall share of 5.9 % in the EU-28 is still less than that required in the target path.

About 27 % of the 64.1 kilotonnes per oil equivalent (ktoe) of electricity in road transport corresponds to renewable electricity, which is very small compared to the amount of biofuels consumed in transport (13 120 ktoe in 2014). Renewable electricity in rail and other transport modes of transport has increased by 4.1 % relative to 2013.

2.1.4 Transport oil consumption to be reduced by 70 % by 2050 from 2008 levels

Transport remains extremely dependent on oil. Oil derived fuels account for around 95 % of final energy demand by transport (including maritime bunker fuels ([3])). Transport oil consumption rose by 0.7 % in 2014 and fell by 0.9 % in 2015, according to the estimations. The additional efforts required to meet the 2050 target are very challenging, as they correspond with a reduction by approximately two thirds compared to the 2014 level. The majority of the projected reduction in oil consumption is a direct consequence of the EU's commitment to reduce CO_2 emissions.

2.1.5 Maritime bunker greenhouse gas emissions to be reduced by at least 40 % ([4]) from 2005 levels by 2050

Since 2007 the EU CO_2 emissions of maritime bunker fuels have known a downward evolution. This continued in 2014, when they were 3.1 % less than in 2013. Compared to 2005 levels, which form the basis for the 2050 target, the 2014 emissions were lower than the derived target path. It is important that the lower emissions since 2007 are sustained with higher economic growth rates and the corresponding increase in freight demand. The system for monitoring, reporting and verification of CO_2 emissions from maritime transport, established by Regulation (EU) 2015/757, is expected to deliver more reliable data on maritime GHG emissions from 2018 onwards.

2.2 Overview of the TERM core set of indicators

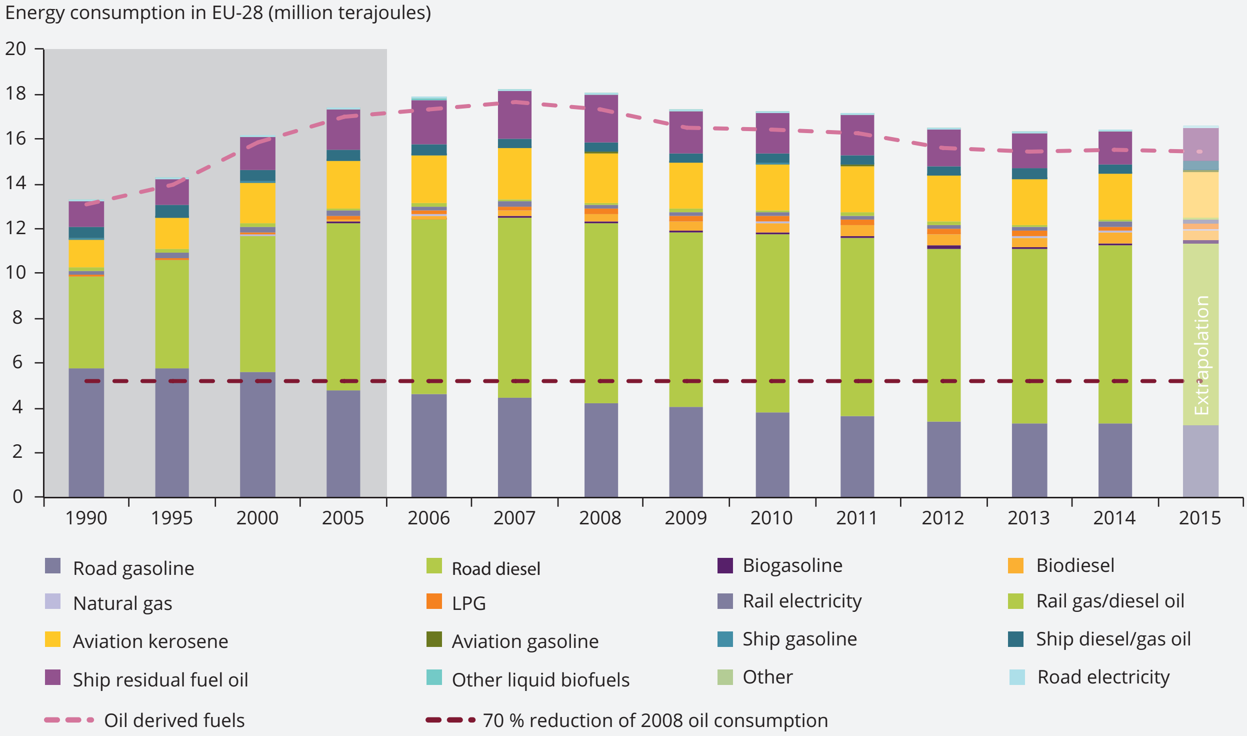
Box 2.1 TERM core set of indicators (TERM-CSIs)

- TERM 01: Transport final energy consumption by mode
- TERM 02: Transport emissions of greenhouse gases
- TERM 03: Transport emissions of air pollutants
- TERM 04: Exceedances of air quality objectives due to traffic
- TERM 05: Exposure to, and annoyance by, traffic noise
- TERM 12: Passenger transport volume and modal split
- TERM 13: Freight transport volume and modal split
- TERM 20: Real change in transport prices by mode
- TERM 21: Fuel tax rates
- TERM 27: Energy efficiency and specific CO_2 emissions
- TERM 31: Share of renewable energy in the transport sector
- TERM 34: Proportion of vehicle fleet by alternative fuel type

([3]) The fuel used in maritime transport is often referred to as marine bunker fuel oil. The term covers all types of shipping fuel such as marine heavy fuel oil, marine diesel oil, marine gasoline oil, and, recently, liquefied natural gas.
([4]) By 50 %, if feasible.

Box 2.2 TERM 01 — transport final energy consumption by fuel

Figure 2.1 Transport energy consumption



Notes: This graph covers the EU-28. Oil derived fuels are all fuels excluding biodiesel, biogas, biogasoline, electrical energy, natural gas and solid biofuels. Biogasoline is almost all road, with a small share of domestic navigation from 2008. Biodiesel is mostly road, some rail from 2004 and a small share of domestic navigation from 2009. Natural gas is all road. Liquefied petroleum gas (LPG) is all road except negligible amounts in domestic navigation for a few years (scattered).

Estimates for the year 2015 are based on the Eurostat indicator nrg_102m using the categories 'gross inland deliveries observed' and 'international maritime bunkers' for a limited range of fuels. These include gasoline, road diesel, jet fuel and fuel oil. The proportionate change observed for these fuels between 2014 and 2015 is then used to estimate 2015 consumption figures for all oil-based road petrol and diesel, rail diesel, aviation kerosene and shipping fuels. Electricity, aviation gasoline, LPG, natural gas and biofuels are estimated by extrapolating the consumption trends of the previous years.

Latest available data: 2014; extrapolation for 2015.

Source: Eurostat, 2016.

Related targets and monitoring

The impact assessment which accompanied the EC's Transport White Paper (EC, 2011b) suggests that a 70 % reduction of transport oil consumption from 2008 levels should be achieved by 2050.

Key messages

Between 1990 and 2007, transport energy consumption in the EU-28 grew by 37 %. With the onset of the recession, this trend reversed. Between 2007 and 2013, total energy demand in the transport sector declined by 10.5 % in the EU28. However, between 2013 and 2014 it has risen again, by 0.9 % in the EU-28. Using current fuel sales as a proxy for energy consumption, it appears that transport energy consumption may have also increased in 2015, by about 0.8 % in the EU-28.

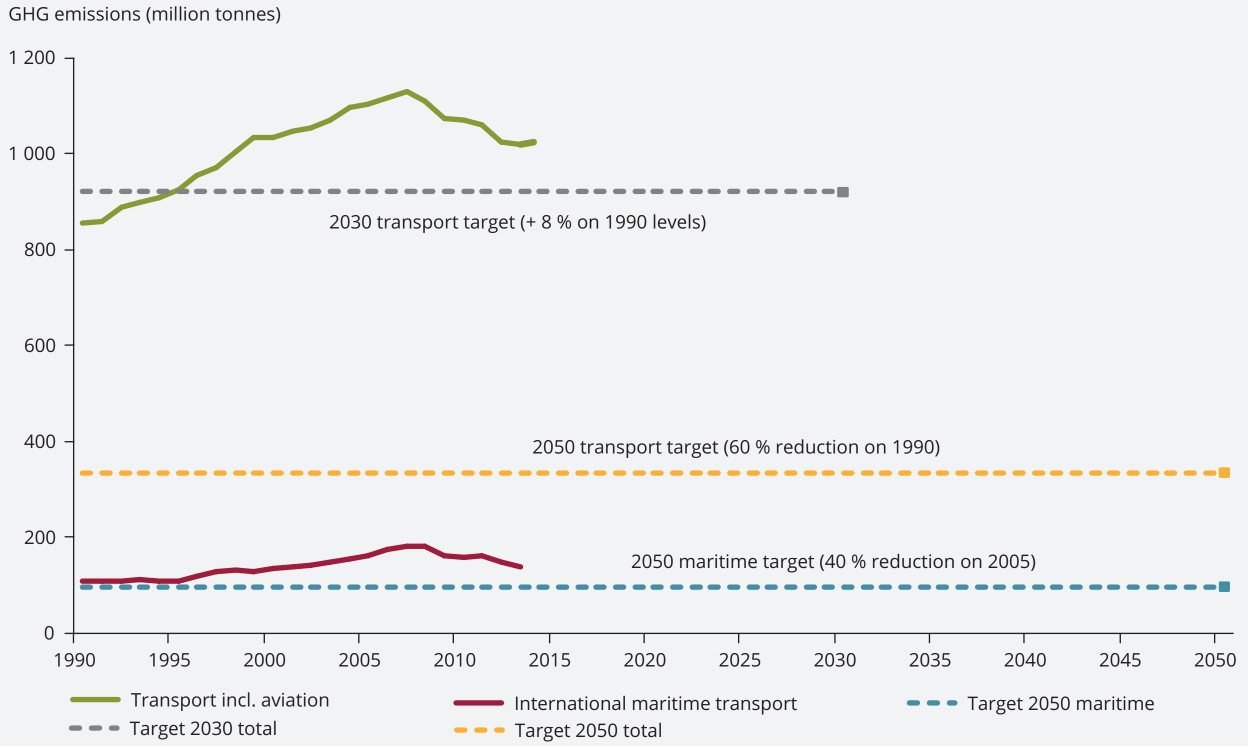
In the EU-28, road transport accounts for the largest amount of transport energy consumption (including international shipping), accounting for 73 % of total demand in 2014. Despite the reduction between 2007 and 2013, total transport energy consumption in 2014 was still 24 % higher than in 1990. The proportion of diesel in the total consumption of petroleum products by road transport has increased substantially from 51 % in 2000 to 69 % in 2014.

Between 1990 and 2007, annual transport energy consumption grew by 37 % in the EEA-33 The EEA-33 countries consumed approximately 17.6 million terajoules (TJ) for transport in 2014. The vast majority, 82 %, is consumed by the original EU-15 Member States, with 11 % consumed by the new EU-13, and the remaining 7 % by other EEA countries. According to current fuel sales, it is estimated that transport energy consumption may have also increased by 1.6 % in the EEA-33.

Further information: Box 2.10: Box 2.12.

Box 2.3 TERM 02 — transport emissions of greenhouse gases

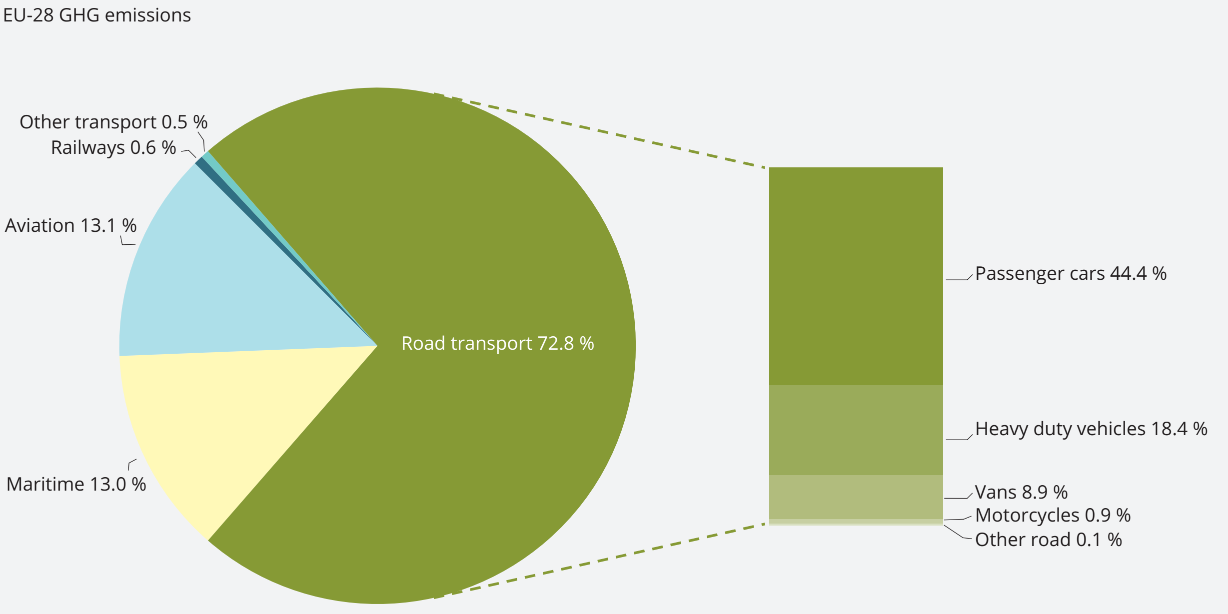
Figure 2.2 EU-28 transport emissions of GHG



Notes: Latest available data: 2014.

Source: EEA, 2016.

Figure 2.3 Share of EU-28 transport GHG emissions by mode, 2014



Source: EEA, 2016.

Box 2.3 TERM 02 — transport emissions of greenhouse gases (cont.)

Related targets and monitoring

The EU has the overall goal of achieving a 60 % reduction in transport GHG emissions (including international aviation but not maritime bunkers) from 1990 levels by 2050 with an intermediate goal of reducing 20 % transport GHG emissions from 2008 levels by 2030 (+ 8 % against 1990 levels). Similarly, shipping emissions (international maritime bunkers) are to be reduced by 40 % from 2005 levels by 2050. These overall transport targets are monitored annually and are in line with the total GHG emissions reduction of 20 % reduction by 2020 (from 1990 levels). Other transport policies supporting the achievement of these targets, such as the various regulations setting CO_2 emission targets for new passenger cars and vans are also monitored in TERM.

Key messages

The reduction trend seen between 2008 until 2013 did not continue in 2014 as transport emissions, including aviation, increased by 0.7 %. The relative increase was stronger for aviation (1.3 %) than for road transport (0.8 %). In 2014 transport emissions were 20.1 % above 1990 levels. Emissions will, therefore, need to fall by 67.4 % by 2050 in order to meet the Transport White Paper target.

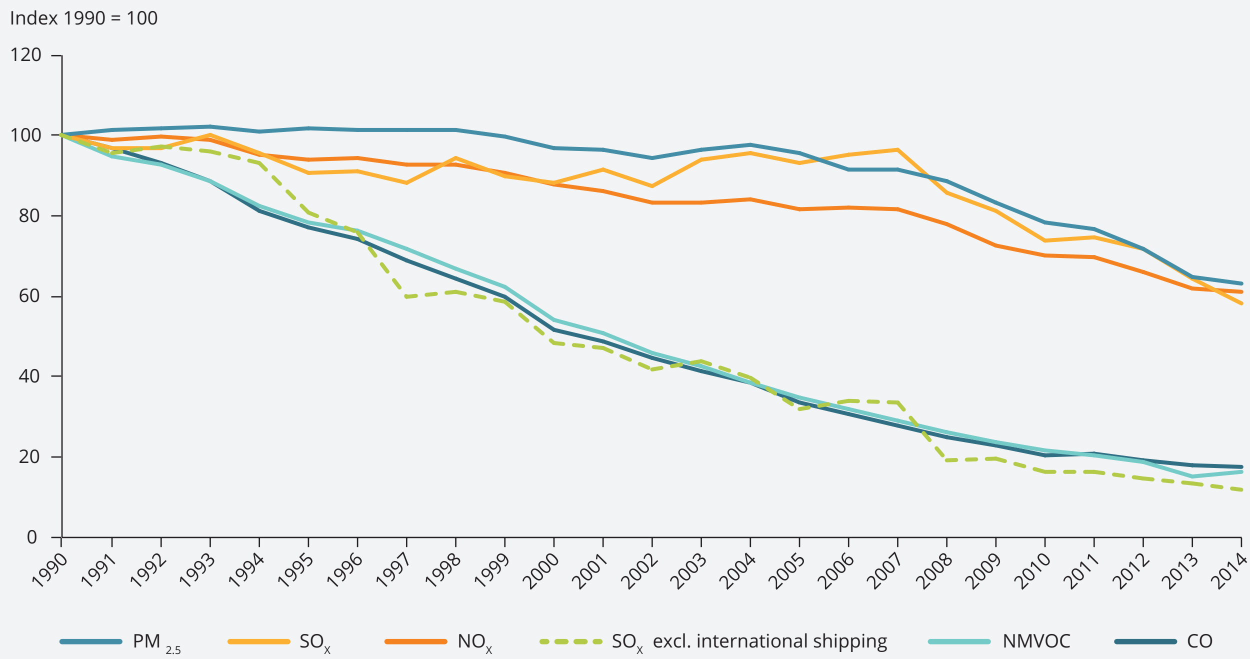
Due to the notable increase in air passenger kilometres compared to the values seen in 1990, international aviation experienced the largest percentage increase in GHG emissions from 1990 levels (97 %), followed by international shipping (26 %) and road transportation (17 %). In 2014, transport (including shipping and aviation) contributed 27.1 % of the total of GHG emissions in the EU-28, 22.2 % if bunkers are excluded from the overall value.

EU GHG emissions from international shipping have fallen in 2014 (by 3.2 %). Emissions will need to fall by another 28.5 % by 2050 in order to meet its reduction target (40 % reduction from 2005 levels by 2050).

Further information: EEA, 2016c; EEA, 2016d**;** see also Box 2.11.

Box 2.4 TERM 03 — transport emissions of air pollutants

Figure 2.4 Trend in emissions of air pollutants from transport in EEA-33



Source: EEA, 2016.

Related targets and monitoring

The introduction of progressively stricter Euro emission standards and fuel quality standards has led to substantial reductions in air pollutant emissions. Policies aimed at reducing fuel consumption in the transport sector to cut GHG emissions (see Boxes 2.3 and 2.11) may also help further reduce air pollutant emissions. In addition to this, policies regulating fuel tax rates (i.e. how much diesel fuel is taxed compared with other — cleaner road fuels) and alternative energy sources also reduce the emission of pollutants (Boxes 2.10, 2.12 and 2.13). Directive 2001/81/EC on national emission ceilings for certain atmospheric pollutants (known as the National Emissions Ceilings Directive (NECD)) (EU, 2001) has recently been revised.

The latest emission standards have been introduced from 2014 for passenger cars, and from 2014/2015 for light commercial vehicles (referred to as Euro 6). The latest standards for heavy-duty engines used in Heavy Goods Vehicles (HGVs), buses and coaches (referred to as Euro VI) have been introduced from 2013.

Iceland, Liechtenstein, Norway, Switzerland and Turkey are not members of the European Union and hence have no emission ceilings set under the NECD. Norway and Switzerland have ratified the 1999 United Nations Economic Commission for Europe Convention on Long-range Transboundary Air Pollution (UNECE LRTAP) Gothenburg Protocol, which required them to reduce their emissions to the agreed ceiling specified in the protocol by 2010.

Key messages

Overall transport emissions of all air pollutants except non-methane volatile organic compound (NMVOC) have decreased between 2013 and 2014 (by 1 % in the case of nitrogen oxides (NO_X), 10 % for sulphur oxides (SO_X) and 2 % and 3 % in the case of airborne particulate matter (PM_{10} and $PM_{2.5}$) respectively), which is a continuation of the general decreasing trend over the past years. However, due to an increase in transport activity and the effect of dieselisation, passenger cars emissions of NO_X have increased by 2.9 % in 2014, being the first annual increase since 1990.

The transport emissions of NMVOC have also risen by 8 % due to an increase in the exhaust emissions by road transport. In 2014, non-exhaust emissions are 50 % of the road transport emissions of primary PM_{10} and 34 % of the road transport emissions of primary $PM_{2.5}$.

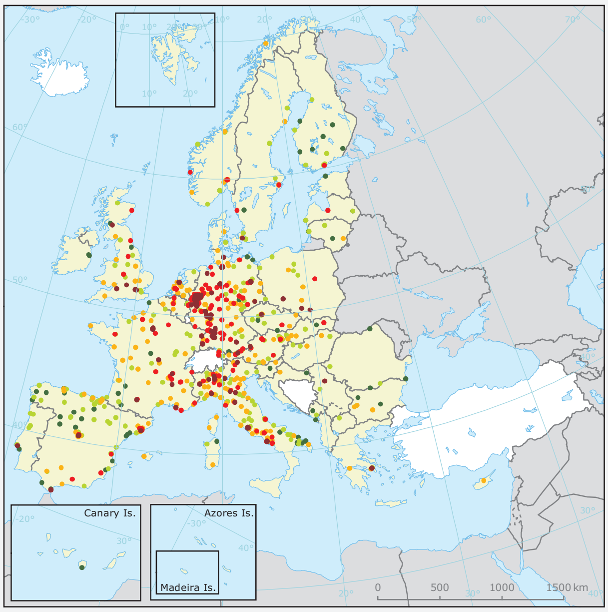
In aviation emissions of all pollutants except NH_3 and NMVOC have risen between 2013 and 2014, by up to 9 % in the case of SO_X emissions. For shipping, air pollutant emissions either fell between 2013 and 2014 (in the case of carbon monoxide (CO), ammonia (NH_3), NMVOC and SO_X), or remained more or less constant (in the case of NO_X and PM).

Overall, the transport sector has achieved important pollutant emission reductions in the period 1990-2014, led by NMVOC and CO reductions (– 84 % and – 83 %), but also NO_X (– 39 %), SO_X (– 42 %) and particulates (– 37 % for $PM_{2.5}$ and – 31 % for PM_{10}).

Further information: Box 2.5 and EEA, 2016e.

Box 2.5 TERM 04 — exceedances of air quality objectives due to traffic

Figure 2.5 Annual mean NO_2 concentrations observed at traffic stations, 2014 (left) and annual mean PM_{10} concentration observed at traffic stations, 2014 (right)



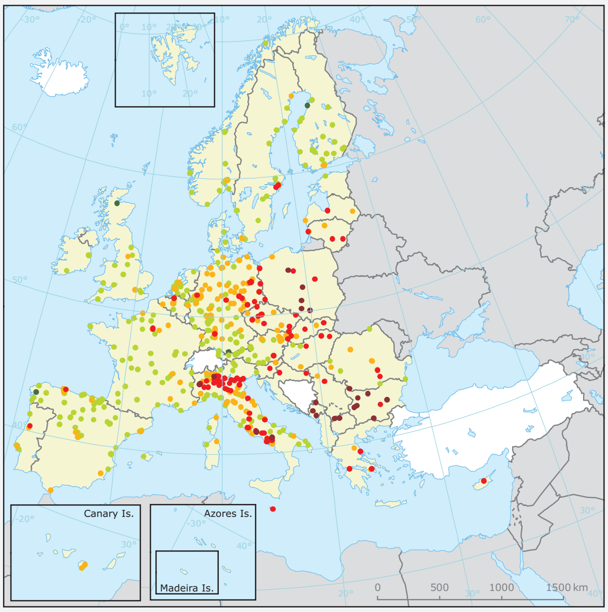
Annual mean NO_2 concentrations observed at traffic stations, 2014

µg/m³ • ≤ 20 • 20–30 • 30–40 • 40–50 • > 50

No data   Outside coverage

Note: Observed concentrations of NO_2 in 2014 at traffic stations. Red and dark dots correspond to values above the EU annual limit value and the WHO Air Quality Guidelines (40 µg/m3). Only stations with more than 75% of valid data have been included in the map.

Source: EEA, 2016.



90.4 percentile of PM_{10} daily mean concentrations observed at traffic stations, 2014

µg/m³ • ≤ 20 • 20–40 • 40–50 • 50–75 • > 75

No data   Outside coverage

Notes: The observed concentrations of PM_{10} in 2014 map shows the 90.4 percentile of the PM_{10} daily mean concentrations, representing the 36th highest value in a complete series. It is related to the PM_{10} daily limit value, allowing 35 exceedances of the 50 µg/m³ threshold over 1 year. The red and dark red dots indicate stations with concentrations above this daily limit value. Only stations with more than 75 % of valid data have been included in the map.

Source: EEA, 2016.

Related targets and monitoring

Directive 2008/50/EC (EU, 2008) sets limit values for the atmospheric concentrations of main pollutants, including sulphur dioxide (SO_2), nitrogen dioxide (NO_2), PM_{10}, $PM_{2.5}$, lead, CO, benzene, and ozone (O_3). These limits are related to transport as it contributes significantly to the emissions of many air pollutants and the resulting poor air quality, particularly in urban areas with high traffic volume.

EU limit values on concentrations of NO_2 in ambient air (limit values had to be met by 1 January 2010):

- An annual mean limit value for NO_2 of 40 µg NO_2/m^3 has been set for the protection of human health.
- An hourly limit value of 200 µg NO_2/m^3 not to be exceeded more than 18 times in a calendar year has also been set.

EU limit values on concentrations of PM_{10} in ambient air (limit values had to be met by 1 January 2005):

- A limit value for PM_{10} of 50 µg/m³ (24-hour average, i.e. daily) has been set, not to be exceeded more than 35 times in a calendar year.
- A limit value of 40 µg/m³ as an annual average has also been set.

Box 2.5 TERM 04 — exceedances of air quality objectives due to traffic (cont.)

Key messages

Air quality levels in cities remain a fundamental challenge for public health, particularly for NO_2. The European Commission adopted a new clean air policy package in December 2013, including a Clean Air Programme for Europe, with targets for 2030 (EC, 2013). Road transport is largely responsible for the most significant air quality problems in cities. In addition to direct NO_2 emissions, NO_X is also contributing to tropospheric O_3 formation. Road transport in cities is also a substantial source of airborne particulate matter.

Air quality in urban areas is significantly influenced by local traffic. While considerable progress has been made over the past twenty years in improving urban air quality, a number of issues remain. Despite considerable improvements, air pollution is still responsible for more than 400 000 premature deaths in Europe each year. It also continues to damage vegetation and ecosystems. Since the late 1990s, concentrations of NO_2 and PM_{10} in urban areas have not been declining in line with emissions trends. Although emissions from transport have been declining, there are still many areas where limit values for NO_2 and PM_{10} are exceeded across Europe, mainly due to road traffic.

For example, the annual EU limit value for NO_2, one of the main air quality pollutants of concern and typically associated with vehicle emissions, was widely exceeded across Europe in 2014, with 94 % of all exceedances occurring at road-side monitoring locations. Also, in 2014, about 16 % of the EU-28 urban population was exposed to PM_{10} above the EU daily limit value.

Further information: Box 2.4; EEA, 2016e.

Box 2.6 TERM 05 — exposure to and annoyance by traffic noise

Related targets and monitoring

This indicator shows progress towards a reduction in the number of people exposed to and annoyed by traffic noise levels that endanger human health and degrade quality of life.

Exposure to noise at night is particularly damaging to human health. The World Health Organization (WHO) recommends a night-time noise guideline for Europe of not more than 40 decibels (dB) $L_{night\text{-}outside}$ (night noise level outside the façade of buildings), and an interim target level of not more than 55 dB $L_{night\text{-}outside}$ where the guideline cannot be achieved in the short term.

The main legislative instrument for assessing exposure to noise in the EU is Directive 2002/49/EC relating to the assessment and management of environmental noise (known as the Environmental Noise Directive — END). Exposure to outdoor noise is monitored under the END against two thresholds, an indicator for day, evening and night periods (L_{den}) measuring annoyance and an indicator for night periods (L_{night}) designed to assess sleep disturbance.

The indicators introduced by the END are: > 55 dB L_{den} (weighted average day, evening and night level) and > 50 dB L_{night} (average night level). These data for 2012 are presented above.

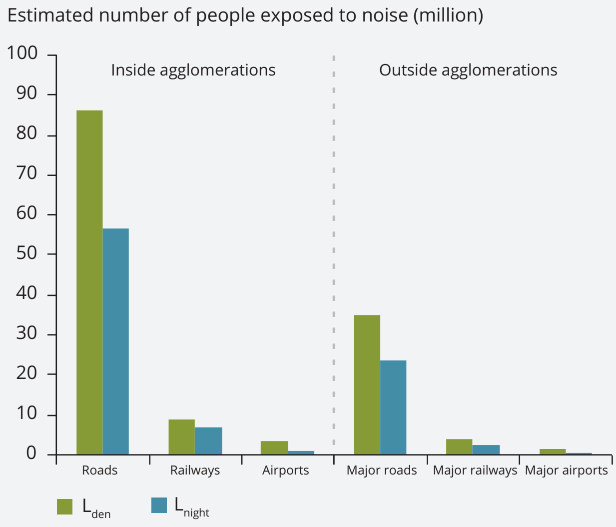
The 7th EAP includes an objective to significantly decrease noise pollution in the EU by 2020, moving closer to WHO recommended levels.

Key messages

Noise exposure from transport sources and industry can lead to annoyance, stress reactions, sleep disturbance, and related increases in the risk of hypertension and cardiovascular disease.

The figure above provides an overview of the number of people exposed to environmental noise in Europe above the noise indicators set by the END within and outside urban agglomerations. The major source of noise pollution (measured in terms of the number of affected people), both inside and outside urban areas, is road traffic. Noise from trains and aircraft has a much lower impact in terms of overall population exposure to noise, but remains an important source of localised noise pollution.

Figure 2.6 Number of people exposed to noise L_{den} above 55 dB and L_{night} above 50 dB in EU Member States, excluding Croatia, 2012



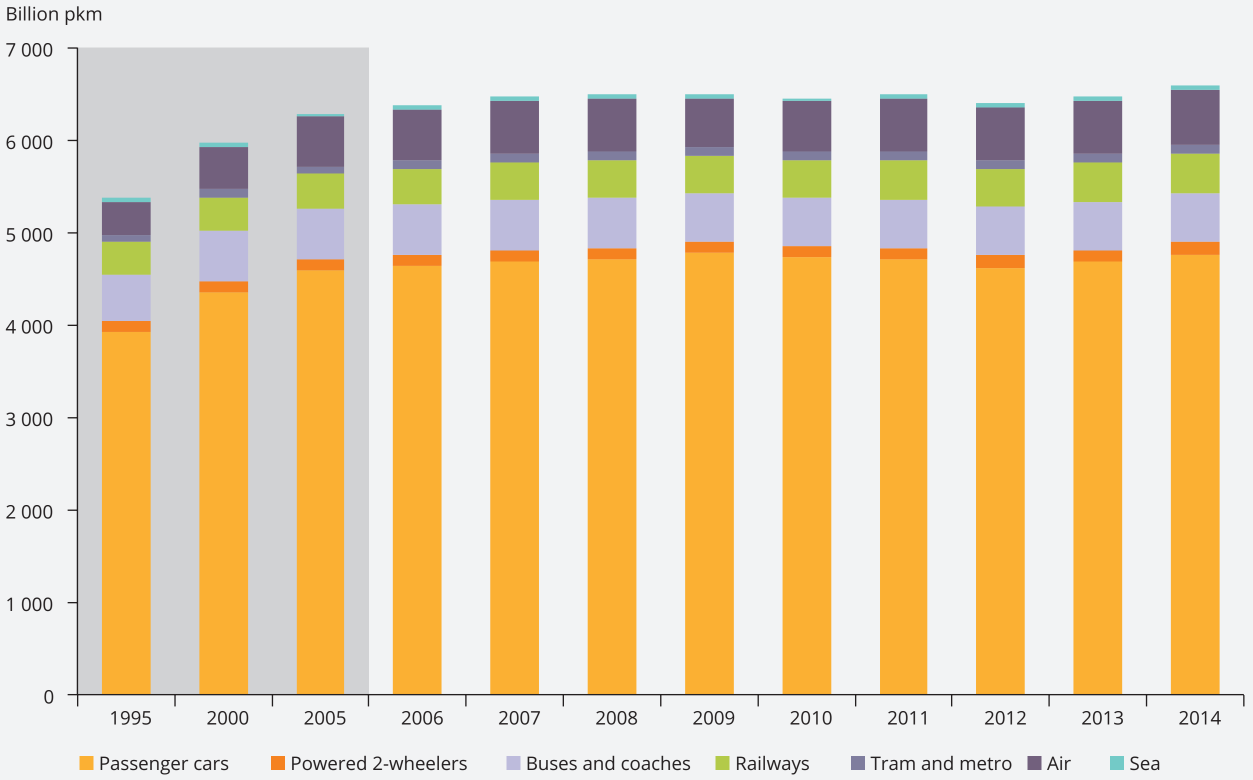
Source: EEA.

Distance to targets: Data reported under the END shows that noise remains a major environmental health problem in Europe. In 2012, at least 125 million people, or one in four Europeans, were exposed to daily road traffic noise levels exceeding the assessment threshold specified in the END. During the more sensitive night time period eight million people suffer sleep disturbance due to noise that exceeds the Directive's night noise threshold. As a result, at least 10 000 cases of premature deaths from noise exposure occur each year, with road traffic as the dominant source. Where comparable, reported data suggests that noise exposure remained relatively stable between 2007 and 2012. Efforts to reduce noise of individual sources are being offset by continuing growth of urban areas and increases in traffic. This is likely to continue in the future with transport demand set to increase, including road transport and forecasted increases in aircraft noise. It is therefore unlikely that noise pollution will significantly decrease by 2020.

Further information: Noise Observation & Information Service for Europe (http://NOISE.eionet.europa.eu).

Box 2.7 TERM 12 — passenger transport volume and modal split

Figure 2.7 Passenger transport volume in the EU-28



Note: Figures on passenger-kilometres travelled by air are only available as a EU-28 aggregate. Air passenger-kilometres are a provisional estimate for domestic and intra-EU-28 flights. Figures for car, bus and rail are available, separately, for all EU-28 Member States. The sources used by EC DGMOVE (2016) include national statistics, estimates, the International Transport Forum and Eurostat.

Source: EC DGMOVE, 2016.

Related targets and monitoring

In the EU, the majority of medium-distance passenger transport (50 % passenger-km between 300 and 1000 km) should be by rail by 2050 (EC, 2011b).

Key messages

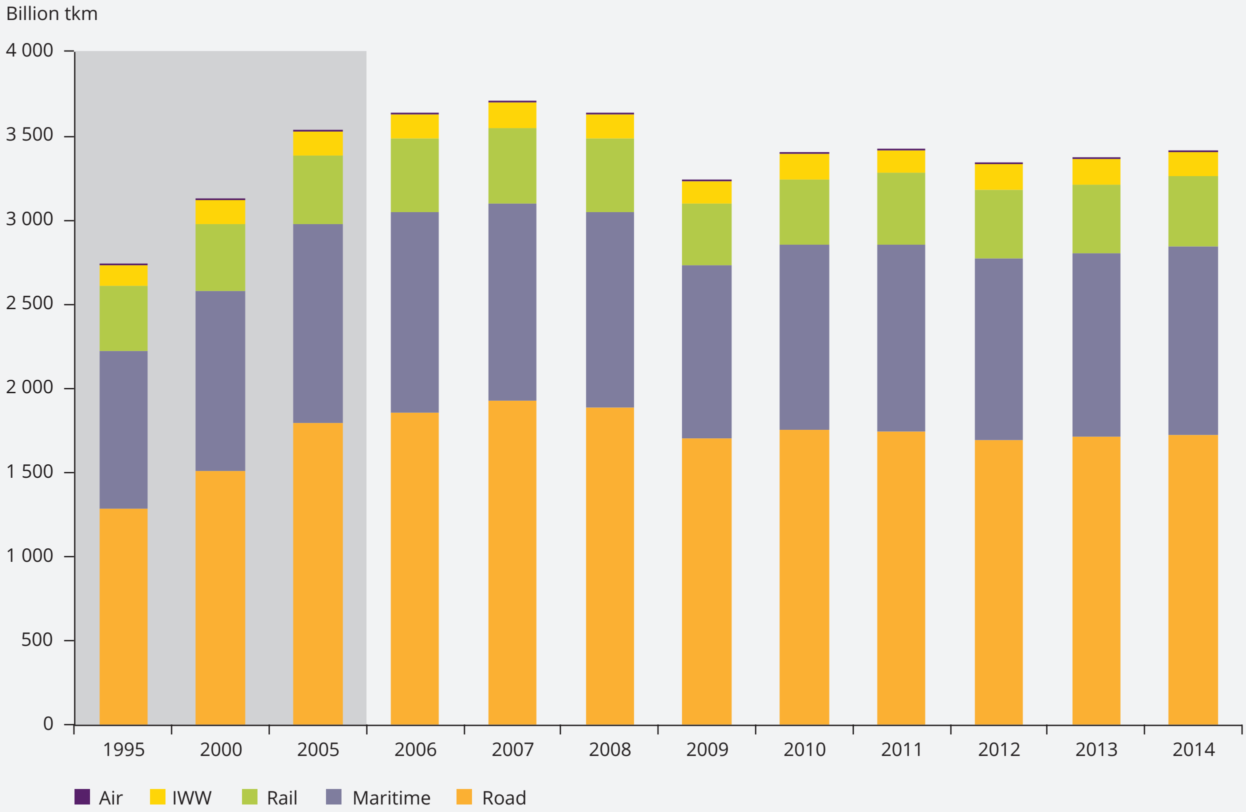
Passenger transport demand in the EU-28, measured in passenger-kilometres, experienced a sustained period of robust growth until 2005. Following its peak in 2009 (9 % higher than in 2000), it has known only a slight overall reduction as a result of the economic recession followed by a moderate increase since 2012. In 2014, total passenger demand was 10.5 % higher than in 2000, exceeding the level of the 2009 peak by 1.5 %.

Car passenger travel remains the dominant mode, with a share well above 70 %. Air transport grew by 4.5 % in 2014 and has a share of 9.2 % of the total passenger-kilometres. Rail passengers' share has slightly diminished in 2014 and accounts for 6.5 % in 2014.

Land passenger transport demand in non EU-28 countries kept growing in 2014, with a 5.1 % growth in Iceland, 1.8 % in Switzerland, 3.2 % in Norway and 3.1 % in Turkey. In Turkey car transport grew by 5.1 % at the expense of bus transport which fell by 1 %. Turkey has known a substantial growth in air traffic, with an average annual growth rate of 7 % over the past five years (Eurocontrol, 2016).

Box 2.8 TERM 13 — freight transport volume and modal split

Figure 2.8 Freight transport volume in the EU-28



Note: Figures in tonne-kilometres for air and maritime are only available as a EU-28 aggregate. Air and maritime tonne-kilometres are provisional estimates for domestic and intra-EU-28 transport. Figures for road, inland waterways and rail are available separately for all EU-28 Member States. The sources used by EC DG MOVE (2016) include national statistics, estimates, the International Transport Forum and Eurostat.

Source: EC DGMOVE, 2016.

Related targets and monitoring

In the EU, a total of 30 % of road freight over 300 km should shift to other modes such as rail or waterborne transport by 2030, and more than 50 % by 2050, facilitated by efficient and green freight corridors (EC, 2011b).

Key messages

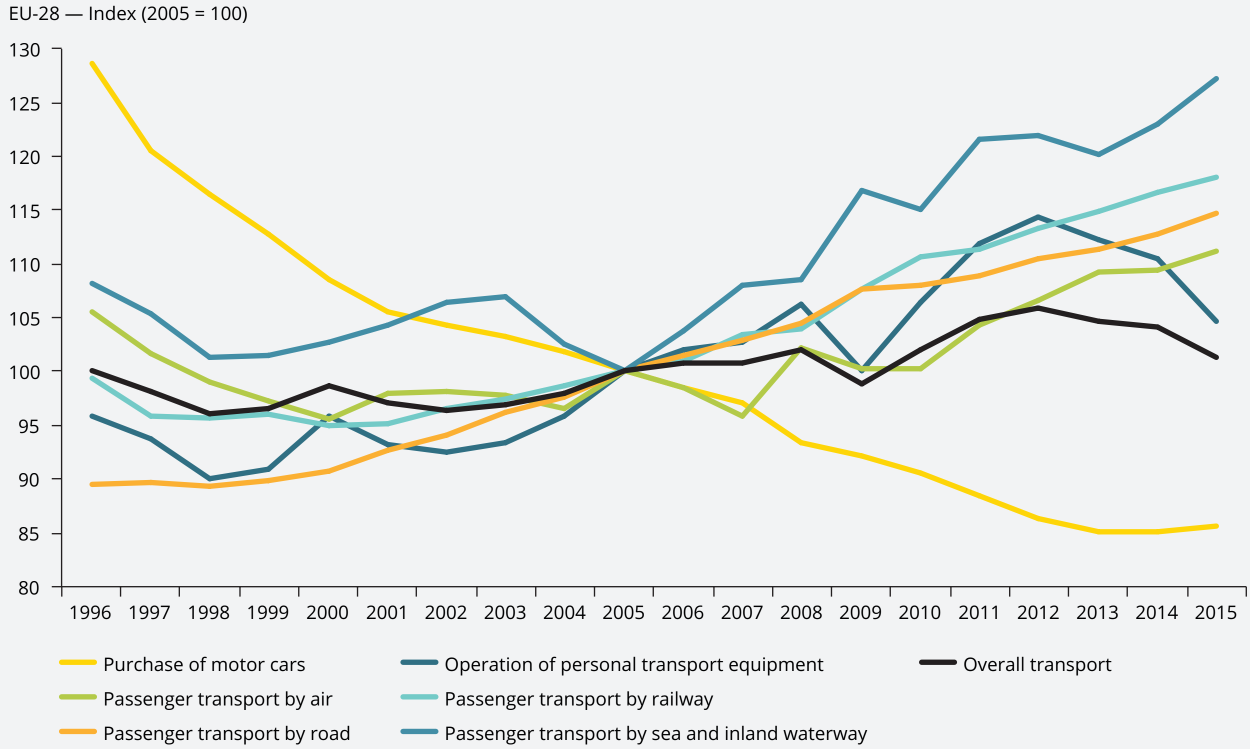
Freight transport volumes in the EU-28 (excluding oil pipeline transport) have increased by 1.5 % between 2013 and 2014. All modes except inland navigation — which fell by 1.3 % — have grown. The highest increase is recorded for shipping (+ 3.8 %). In overall terms, total freight transport volumes in the EU-28 are still 7.7 % below the peak volumes experienced in 2007. In 2014, the majority of EU freight was transported by road (50.6 %) and sea (32.9 %), followed by rail (12 %) and inland waterways (4.4 %). The contribution of air transport within the EU remained very small throughout the whole period (0.1 %). Over time the modal shares have been quite stable.

If the evolution of the intensity of freight transport in the EU-28 economy (tonne-km per unit of GDP in constant prices of 2010) is compared with the year 2000, freight intensity was lower from 2001 to 2003, but subsequently increased from 2004 to 2008. Since 2009, the intensity of freight transport in the economy has been around 5 % lower than in 2000, and it is 6 % lower in 2014. This lower intensity coincides with the period of lower or negative economic growth in Europe following the economic recession.

Land freight transport increased between 2013 and 2014 in the non-EU-28 members of the EEA: by 1.8 % in Norway, 3 % in Switzerland, 4.8 % in Turkey and 5 % in Iceland.

Box 2.9 TERM 20 — real change in transport prices by mode

Figure 2.9 Real change in transport prices by mode in the EU-28



Note: Real change in passenger transport prices by mode, relative to average consumer prices based on the United Nations Classification of individual consumption by purpose (COICOP). Passenger transport by road includes exclusively transport of individuals and groups of persons and luggage by bus, coach, taxi and hired car with driver.

Source: Eurostat, 2016.

Related targets and monitoring

Passenger transport in Europe is predicted to grow by 40 % by 2050 under current trends and adopted policies (EC, 2016b). With this significant growth in transport use, it is important that prices are monitored to see if users are given appropriate incentives to use more environmentally-friendly modes of transport. Changes in transport prices drive individual and business transport decisions; fair and efficient price signals are required. To encourage this, one of the aims of the 2011 Transport White Paper is to achieve full internalisation of external costs in all modes.

The cost of transport reflects market changes such as vehicle technology developments and international energy price evolutions, as well as state interventions through regulation, subsidies, and taxation (see Box 2.10). Government actions can internalise the environmental externalities of different transport modes through economic incentives, which can lead to users shifting between modes. The economic incentives for modal shifts can be partly monitored through the indicator of transport prices by mode.

Key messages

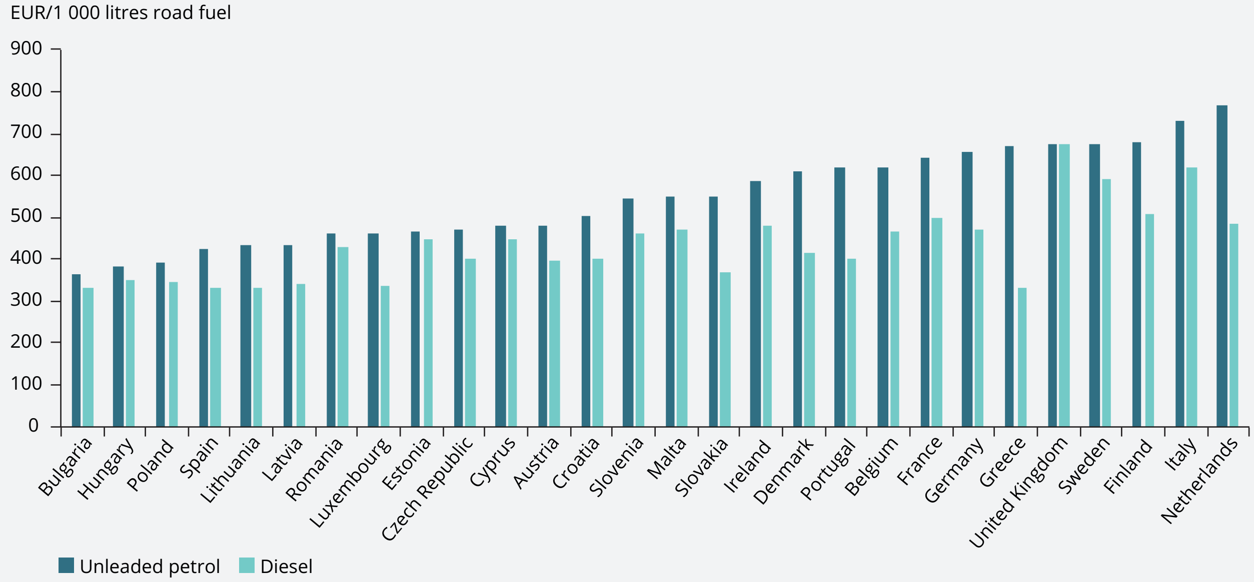
If 2015 is taken as the reference point, the cost of purchasing motor cars has decreased significantly since 1996, in comparison to average consumer prices. In contrast, the cost of passenger services and the operation cost of personal transport equipment has generally increased.

The volatility of the transport market can be seen in 2009, for example, when overall transport prices fell at a faster rate than average consumer prices, primarily due to a significant drop in the average crude oil price between 2008 and 2009, and subsequent reductions in fuel prices. Rail transport prices are less closely tied to the fuel costs as most services operate under 'public service obligations' and an increasing proportion of passenger rail is electric-powered.

Further information: Box 2.10.

Box 2.10 TERM 21 — fuel tax rates

Figure 2.10 Road fuel excise duties in the EU-28 (situation as of June 2016)



Note: Some Member States have higher tax rates for fuels with sulphur content > 10 parts per million (ppm) or biofuel shares below a given threshold.

Source: DG TAXUD ([5]).

Related targets and monitoring

The White Paper on Transport (EC, 2011b) suggests that EU road fuel taxation should be revised to incorporate the energy and CO_2 components. In 2011, the European Commission put forward a proposal (COM/2011/169) for a revised Energy Taxation Directive along these lines, aiming at a more rational and targeted energy taxation that would contribute in a technology-neutral manner to cleaner and more efficient consumption of energy. This is a particular issue for diesel, where freight vehicles travel further to buy fuel in countries where the fuel tax is lowest (fuel tourism). The proposal was however withdrawn in 2015 ([6]).

Key messages

The internalisation of external environmental costs, through methods such as fuel taxation, means that the externalities are taken into account by transport users when making travel decisions. Fuel consumption is a good proxy for GHG emissions produced by the use of transport, and so fuel taxes are a good instrument for this internalisation.

Higher fuel prices act as incentives to reduce fuel consumption, such as through the purchase and use of more fuel efficient vehicles, a shift to non-motorised or public transport modes, fewer trips, and less motorised transport-orientated patterns of settlements. Differentiated fuel taxes can also stimulate a shift towards alternative fuels.

Apart from the United Kingdom, where the same tax per litre applies for diesel and petrol, all other Member States tax diesel less than petrol. In June 2016, the weighted average share of taxes and duties on fuel prices in the EU-15 was 65 % for unleaded petrol and 60 % for diesel. In the EU-13 shares were 58 % and 55 %, respectively. The largest differences are found in Greece (where diesel is taxed approximately 50 % less than petrol) and in Denmark, the Netherlands, Portugal and the Slovakia (where diesel taxes are more than 30 % lower).

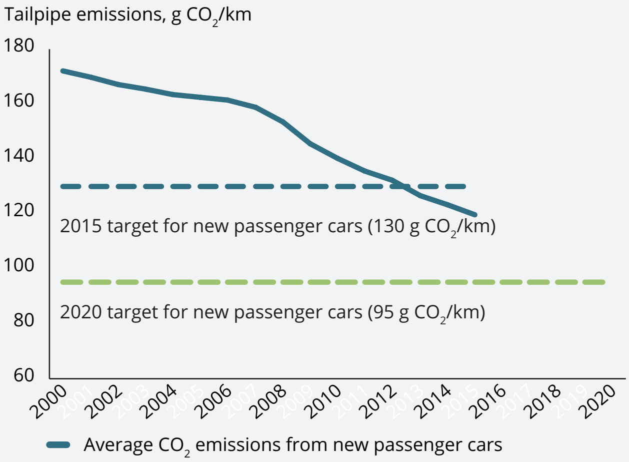
Policies favouring the uptake of diesel fuel have led to an increase in diesel consumption over petrol for use in road transport. Some of these policies were put in place in Europe because of the improved fuel efficiency (and reduced CO_2 emissions) that are attributed to diesel fuels. As recognised in the document *Tax Reforms in EU Member States 2014. Tax policy challenges for economic growth and fiscal sustainability* (EC, 2014), specific measures could be introduced adjusting the level and structure of fossil fuel excise duties so as to reflect the carbon and energy content of the fuels, and indexing environmental taxes to inflation.

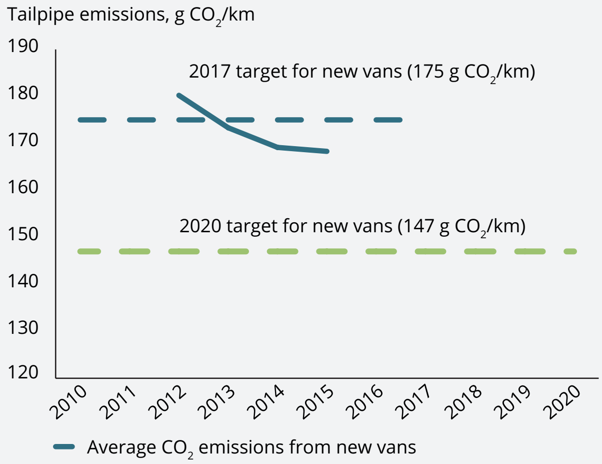
Further information: Box 2.9.

([5]) http://ec.europa.eu/taxation_customs/taxation/excise_duties/energy_products/rates/index_en.htm.
([6]) Commission Work Programme 2015, Annex 2, COM(2014) 910 final.

Box 2.11 TERM 27 — energy efficiency and specific CO_2 emissions

Figure 2.11 Average emissions (g CO_2/km) for new passenger cars (left) and vans (right) in the EU-27





Note: Latest available data: 2015 (provisional).

Source: EEA, 2016.

Related targets and monitoring

The EU target for average passenger car emissions is 130 g CO_2/km for the new car fleet by 2015 (phased in from 2012), and 95 g CO_2/km from 2021 onwards (phased in from 2020) (Regulation (EC) No 443/2009). The target for vans is 175 g CO_2/km by 2017 (phased in from 2014) and 147 g CO_2/km by 2020 (Regulation (EC) No 510/2011). Average emissions of CO_2 for the new car fleet have been monitored annually by the European Commission for over a decade, but such data are available for vans since 2012 only.

Member States report new vehicles' CO_2 emission levels, measured under standardised laboratory conditions, following the requirements of the New European Driving Cycle (NEDC) test procedure. This procedure is designed to allow a comparison of emissions for different manufacturers.

Recognising the shortcomings of the NEDC for representing real-world driving conditions and emissions, the European Commission has proposed a number of changes to the vehicle type-approval framework and the test cycle. A new procedure known as the 'Worldwide harmonized Light vehicles Test Procedure' (WLTP) will be introduced over the coming years so that laboratory results better represent actual vehicle performance on the road.

Key messages

Based on provisional data, CO_2 emissions from the new passenger car fleet in the EU-27 decreased by 3.8 g CO_2/km between 2014 and 2015, from 123.4 g/km to 119.6 g/km. The new passenger car fleet has already met the 130 g CO_2/km target for 2015 two years early, but additional effort is required to meet the 95 g CO_2/km target by 2021.

The highest emitting new cars were bought in Estonia and Latvia (137 g CO_2/km) followed by Bulgaria (130 g CO_2/km). For all remaining Member States, the average emission levels were below 130 g CO_2/km. As seen in 2014, the Netherlands (101.2 g CO_2/km) was the country that registered the lowest emitting new cars. Portugal and Denmark followed with new cars emitting on average 106 g CO_2/km.

Diesel cars remain the most sold vehicles in the EU, constituting 52 % of sales. As in past years, the countries with the highest proportions of diesel sales include Ireland and Luxembourg (71 %), Portugal (69 %), and Croatia, Greece and Spain (63 %).

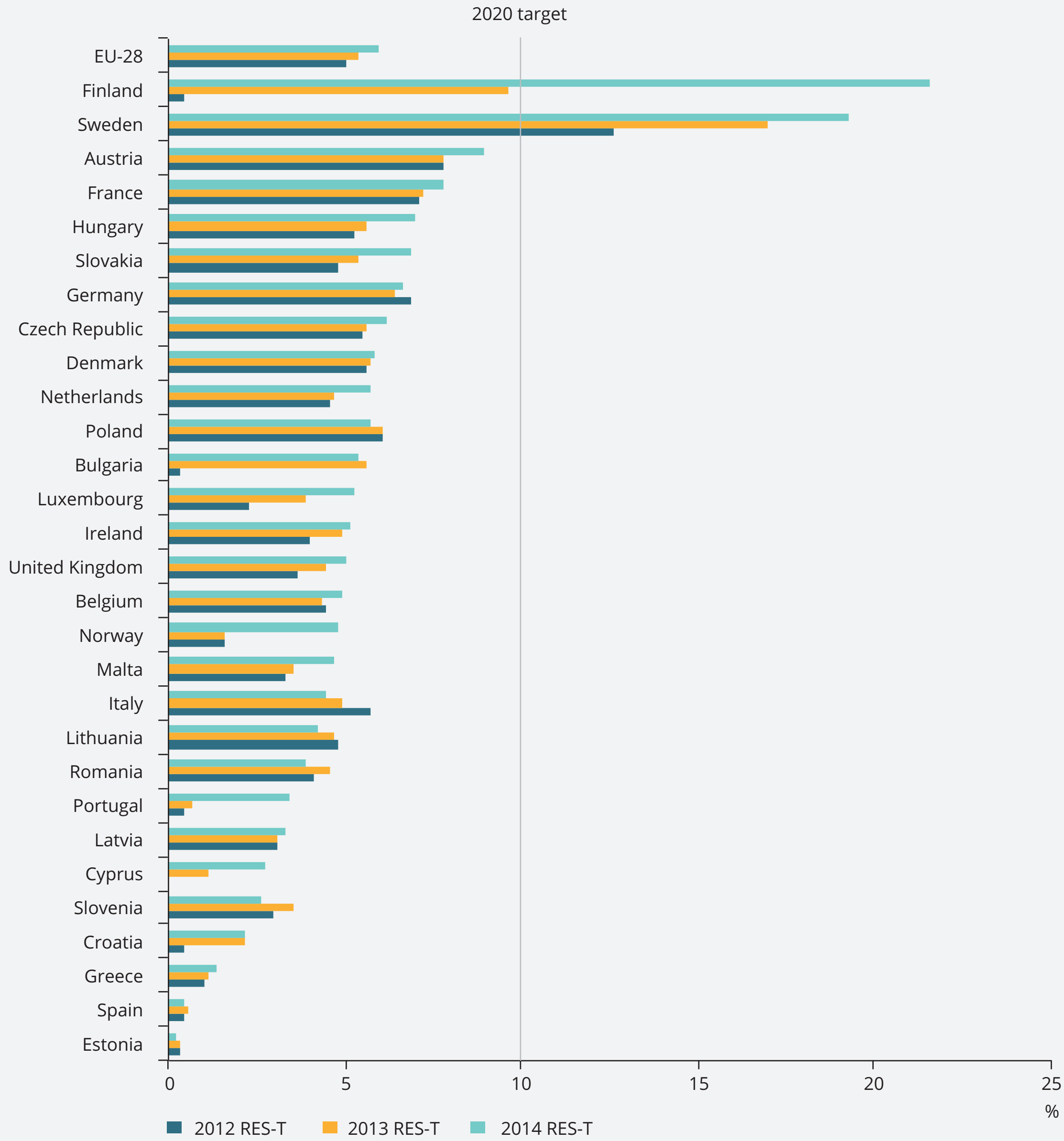
The average fuel efficiency of petrol cars (122.6 g CO_2/km) has been catching up with the fuel-efficiency of diesel cars (119.2 g CO_2/km) in recent years. In 2000, petrol cars still emitted 17.1 g CO_2/km more on average than diesel cars.

For vans, the required target for 2017 has also already been met. The average emissions of new vans registered in the EU in 2015 was 168.2 g CO_2/km, well below the 2017 target of 175 g CO_2/km. The average emissions in 2015, and the trend followed in terms of reductions in emissions (EC 2015b; EEA, 2016f) suggest that the implementation of the van CO_2 regulation has also significantly influenced manufacturers' efforts and technical developments to reduce emissions. Still, significant progress will have to be made in order to achieve the target of 147 g CO_2/km by 2020.

Further information: EEA, 2016b; EEA, 2016f.

Box 2.12 TERM 31 — share of renewable energy in the transport sector

Figure 2.12 Percentage share of renewable energy consumed in transport (RES-T) by country, including only those biofuels compliant with the Renewables Energy Directive (RED)



Note: According to the RED, renewable electricity in electric road vehicles was accounted for 2.5 times the energy content of the input of electricity from Renewable Energy Sources (RES) and the contribution of biofuels produced from wasted, residues, non-food cellulosic material, and lingo-cellulosic material was considered twice that of other biofuels. As of data year 2011, countries shall report as compliant only those biofuels and bioliquids for which compliance with Articles 17 as well as Article 18 can be fully demonstrated. This definition does not take into account the amendments introduced by the Directive to reduce indirect land use change for biofuels and bioliquids (known as the ILUC Directive)((EU) 2015/1513). The ILUC Directive amends the Renewables Energy Directive and the Fuel Quality Directive.

Source: EEA based on Eurostat, 2016.

Box 2.12 TERM 31 — share of renewable energy in the transport sector (cont.)

Related targets and monitoring

For each EU Member State, 10 % of the energy consumed in the transport sector must be renewable by 2020 (RED, 2009/28/EC) (EU, 2009a). Only biofuels complying with the sustainability criteria under the RED are to be counted towards this target and therefore proper monitoring is only possible from 2010. In addition, to stimulate the growth of certain shares of renewable energy sources in transport, when calculating the RES-T (%) of the complying biofuels, the renewable electricity in electric road vehicles is accounted for 2.5 times the energy content of the input of electricity from renewable energy sources, while the contribution of biofuels produced from wastes, residues, non-food cellulosic material, and ligno-cellulosic material is considered twice that of other biofuels. In 2015 new rules came into force, setting a 7 % cap on biofuels made from food crops for use in transport. The ILUC Directive also introduced an indicative sub-target for 'advanced' biofuels that is to be set by Member States by April 2017, and increased the contribution that renewable electricity in transport makes to the RES-T target.

Low carbon sustainable fuels in aviation are to reach 40 % by 2050 (EC, 2011b).

The renewable energy directive for the 2020-2030 (REDII) period is currently being drafted.

Key messages

Since 2011, Eurostat publishes the share of biofuels in transport energy use, which meet the sustainability criteria of the RED. The average EU-28 share of renewable energy consumed in transport increased between 2013 and 2014 from 5.4 % to 5.9 % including only those biofuels which met the sustainability criteria.

In 2014, Finland had the highest share of renewable sources in transport in the EU with a RES-T of 21.6 % that shows a 55.6 % increase from its share in 2013. Moreover, Sweden's RES-T in 2014 corresponds to 19.2 %. Both Finland and Sweden have already reached the 2020 target of 10 % share of renewable energy in transport as set by the RES Directive. Other EU Member States with high shares of RES-T (i.e. above 6 %) include Austria, Czech Republic, France, Germany, Hungary and Slovakia.

In general the proportion of renewable energy used by the transport sector is growing but remains small. Several reasons lie behind the slow uptake of renewable fuels across the EU, including:

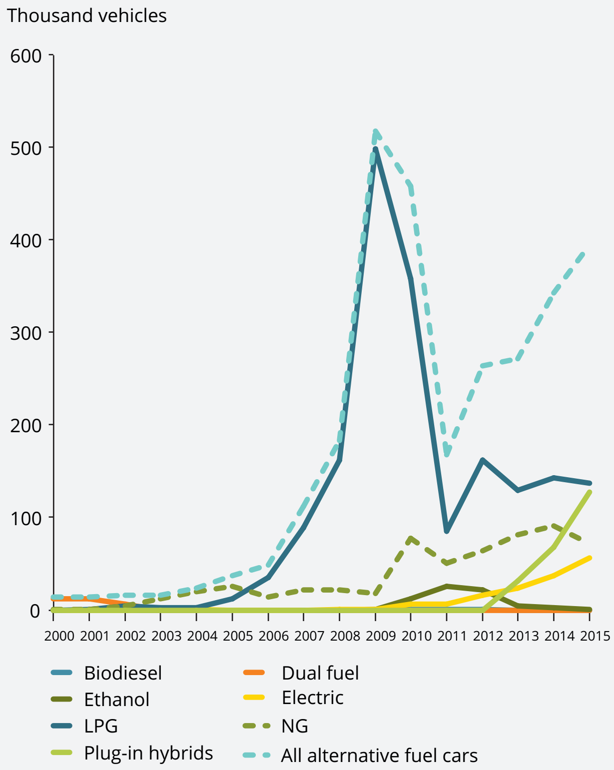
- low competitiveness of biofuels in terms of prices;
- slow progress in the deployment of second-generation biofuels.
- increasing awareness that certain biofuel production pathways may increase overall GHG emissions when emissions from ILUC are taken into account;

The use of electricity in road transport has increased by 18 % between 2013 and 2014 to 64.1 ktoe. About 27 % corresponds to renewable electricity consumed in road transport, which is very low compared to the amount of biofuels consumed in transport (13 120 ktoe in 2014). Renewable electricity in rail and other modes of transport has increased by 4 % to 1 532 ktoe.

Examining the non-EU countries in 2014, the share of renewables in transport was 4.75 % in Norway and 0.6 % in Iceland.

Box 2.13 TERM 34 — proportion of vehicle fleet by alternative fuel type

Figure 2.13 Number of car registrations by alternative fuel type in the EU-28



Note: Croatia has been included since 2013. All previous years refer to EU-27.

Plug-in hybrids (petrol and diesel) are reported separately from 2013 onwards. They were included under conventional petrol and diesel vehicles in the previous years.

LPG: Liquefied petroleum gas;
NG: Natural gas

Source: EEA, 2016.

Related targets and monitoring

There are no specific targets for the number or percentage of vehicles that use alternative fuels, but the European Commission aims for European cities to be free of conventionally fuelled cars by 2050 (EC, 2011b), to be measured by passenger-kilometres in urban areas.

Key messages

The share of alternative fuel passenger cars over the total fleet has remained constant at around 5 % over the last five years, with LPG cars playing a dominant role with a share of about 4.3 % of the overall passenger car fleet in the EEA-33. Poland and Italy are the leading LPG countries in the EU-28 with 2.6 million and 2.4 million cars respectively. In Turkey, more than 3.1 million cars ran on LPG in 2015.

Natural gas (NG) cars, whose number has almost tripled between 2005 and 2015, is nevertheless only a small fraction of the total fleet in the EEA-33 (1.3 %). The number of NG passenger cars is only significant in Italy and the United Kingdom (about one million); only small numbers (a few thousands) can be found in other EU countries. The registration of new NG cars shows an increasing trend over the years, however their share as a proportion of total new registrations remains low, at around 0.5 %.

Electric cars are slowly penetrating the EU market. These include battery electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs), and electric vehicles with range extenders (REEVs). Despite their small numbers (about 268 000) and their small share (about 0.11 %) of the total passenger car fleet, the number of electric cars new registrations in the EU has been increasing steadily over the last years reaching 0.4 % of the total new registrations in 2015. BEV sales increased by 49 % in 2015 compared to 2014, which follows the pattern of regular growth since 2008. France leads with 17 660 BEVs sold in 2015, followed by Germany with 12 375, a considerable increase compared to 2014 in both countries. There is also an increasing number of PHEVs and REEVs (112 365 petrol and 14 580 diesel) registered in the EU-28. A large number of EU Member States (Austria, Belgium, Czech Republic, Denmark, Estonia, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal, Romania, Spain, Sweden and the United Kingdom) are offering financial incentives for electrically chargeable vehicles. Such incentives include the exemption from one-off purchase taxes, purchase subsidies, the exemption from annual taxes, VAT exemption, and other incentives such as the permission to use of bus lanes. Outside the EU, around 18.7 % of all new cars sold in Norway during 2015 were electric (including PHEVs and BEVs). This makes Norway a leading market for electric vehicles in terms of market share among EEA member countries.

The percentage of alternative fuel light commercial vehicles (LCVs) and buses is lower compared to passenger cars, being about 1.7 % of the total fleet of LCVs and 2 % of buses respectively.

Further information: Box 2.11.

Part B: Transitions towards a more sustainable mobility system

3 The scale of change

Key messages

Transport is responsible for a quarter of the EU's GHG emissions, and causes air pollution, noise pollution and habitat fragmentation.

More concretely, transport is the only major economic sector in Europe where GHG emissions are still higher than their 1990 levels. Latest data show that GHG emissions from transport rose slightly in 2014, the first increase since 2007. Meeting the 2050 target requires a reduction of two thirds from current levels.

Current estimates suggest significant growth in future transport demand. From 2010 to 2050, passenger transport is estimated to grow by about 40 %, with aviation as the fastest growing sector. Freight transport is expected to grow by around 58 %, and road will carry 70 % of total freight.

It is estimated that ongoing climate policies in the transport sector would reduce GHG emissions from transport in 2050 to around 8 % below 2010 level. This still means almost three times more emissions that those corresponding with the aimed reduction of 60 % below the 1990 level.

High volumes of traffic still causes major air quality problems. Transport is also a key contributor of harmful noise levels. Both affect severely the quality of life of Europeans, especially in urban areas.

Significant efforts are needed to reach the necessary reduction which implies a transition towards an entire new mobility system.

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The European Commission aims for a reduction by 60 % in transport GHG emissions by 2050 as compared to 1990 levels and a phasing out of conventionally-fuelled cars in cities (EC, 2011b). This would mean a drastic reversal of the current trend. From 1990 until now, GHG emissions from transport have increased by 21 %. This makes transport the second largest CO_2 emitting sector (after the energy sector). Transport is the only major economic sector within the EU for which GHG emissions have risen since 1990. In relation to this, the reduction of oil consumption in the transport sector has been very slow, making the European economy more vulnerable towards fluctuations in global energy supplies and prices. A reversal of the trend requires a huge effort, given the expected growth of transport in the coming decades. This chapter explores the challenges ahead by taking a closer look at recent long-term transport projections and at the related CO_2 emissions.

3.1 Environmental pressures from transport

Fifteen years after the publication of the first TERM report, TERM 2015 (EEA, 2015b) took a retrospective look at the transport sector, highlighting the key developments in EU policies which have aimed to reduce the environmental impacts of transport. It also assessed the transport-related environmental trends and the progress towards transport policy goals. The headline messages in TERM 2015 provided an overview on the current levels of environmental pressures from transport, and how they have evolved in the last two decades. TERM 2015 key messages include the following ([7]):

- The 2050 target requires a reduction of two-thirds compared with current levels. While emissions are clearly linked to economic activity and transport demand, various other factors have also contributed to the changes in GHG emissions seen in recent years. This includes efficiency improvements as a result of legislation and changes in consumer behaviour and preferences. Latest data show that GHG emissions from transport rose slightly in 2014, the first increase since 2007.

- The transport oil consumption goal is to be reduced by 70 % by 2050 from 2008 levels. Oil-derived fuels account for around 94 % of energy demand by transport ([8]). Europe imports around 87 % of its crude oil and other oil products from abroad.

- Emissions of three important air pollutants —SO_X, NO_X and PM — from transport activities decreased in the period 2000 to 2014 in the EU. With the exception of international aviation, all modes of transport contributed to the decrease. However, due to an increase in transport activity and the effect of dieselisation, passenger cars emissions of NO_X have increased by 3.3 % (by 2.9 % in the EEA-33) in 2014, being the first annual increase since 1990.

- Despite these advances, achieving levels of good air quality in Europe is still a challenge, especially in urban areas with high volumes of traffic. For example, the annual EU limit value for NO_2, one of the main air quality pollutants of concern and typically associated with vehicle emissions, was widely exceeded across Europe in 2014, with 94 % of all exceedances occurring at road-side monitoring locations.

- Noise pollution has long been recognised as negatively affecting quality of life and well-being. Over previous decades it has also been increasingly recognised as an important public health issue. Road traffic is by far the dominant source of environmental noise in Europe. Noise from trains and aircraft remains the cause of many localised issues.

- Transport can cause important negative impacts on ecosystems and biodiversity in different ways, including the alteration of the quality and connectivity of habitats and the creation of physical barriers to the movement of plants and animals between habitat areas. Species can become isolated by habitat fragmentation. The development and use of transport infrastructure can also increase pollution levels in surrounding habitats and can lead to the spread of non-native and invasive species.

3.2 Transport volumes in 2050

Since the first edition in 2000, each TERM report has attempted to reflect upon the fact that growing transport demand negates many of the benefits of technology development. The reports have concluded that technical solutions alone are not enough. Beyond other non-environmental considerations, technological developments in transport essentially reduce GHG and other air pollutant emissions per kilometre travelled. However, technology developments do not always successfully addresses other transport related environmental pressures, such as biodiversity fragmentation, traffic congestion, inefficient use of urban space, and noise pollution.

According to the European Commission's July 2016 European strategy for low emissions mobility (EC, 2016a), the ambitious reduction in transport GHG emissions will have to take place despite the expected growth in traffic volumes. Transport volumes have grown over decades and current EU estimations for 2050 show a continuously growing demand for passenger transport (especially by air) and an even faster growing demand for freight transport.

([7]) The numbers presented below have been updated with the latest available data, usually from 2014.
([8]) Including maritime bunkers.

Box 3.1 The European Commission 'Reference Scenario' 2016

The so-called 'Reference Scenario' is one of the European Commission's key analysis tools in the areas of energy, transport and climate action. It builds upon a set of assumptions related to future population growth, macroeconomic and oil price developments, technology improvements, and current EU policies. A number of projected key economic and environmental parameters to 2050 are provided, such as the share of renewable energy sources or levels of energy efficiency, on a five-year period for the EU as a whole and for each EU country. This is based on existing EU policies alongside current market trends. The scenario provides guidance to policymakers to support their drafting of new policy proposals using the forecasts provided as benchmarks.

In drafting this scenario document, the Commission has carried out analysis exploring where exactly market trends, coupled with the implementation of policies that were adopted at EU and Member State level by December 2014, are likely to lead. TERM 2016 uses the results from this Reference Scenario 2016 exercise (REF2016) to analyse how the current policy framework may affect the 2050 projections for transport activity and its energy and GHG emissions.

A description of the 'EU Reference Scenario 2016' (EC, 2016b) can be found at: https://ec.europa.eu/energy/sites/ener/files/documents/ref2016_report_final-web.pdf.

3.2.1 Passenger transport

Passenger transport volumes continue to grow. According to the REF2016 the growth rates will not be as high as in the past, but the number of passenger-kilometres will nevertheless increase between 2010 and 2050 by about 40 % (1 % per year until 2030 and 0.9 % per year until 2050).

Air transport is projected to be the highest growing of all passenger transport modes, more than doubling the number of passenger-kilometres between 2010 and 2050. This is mainly due to the large increase of international trips (e.g. to emerging economies in Asia). The highest potential for air traffic growth is expected in the EU-13 due to their faster growing GDP per capita and the available capacity at the airports. Overall, intra-EU air transport is expected to increase its modal share by about 5 percentage points, from 8 % in 2010 to 13 % in 2050. Other recent studies also suggest similar projections for air traffic. For example the European Aviation Safety Agency (EASA) expect an increase by 45 % of the number of flights in Europe by 2035 (EASA et al., 2016), compared to 2014 levels.

Passenger rail activity is growing quickly, driven in particular by the planned completion of the Trans-European Transport Network (TEN-T). It is projected to increase by 76 % during 2010–2050 and expand its modal share by 2 percentage points (from around 8 % in 2010 to 10 % in 2050). High-speed rail sees a significant increase in terms of volume and share as a result of the infrastructure build-up and the upgrade of existing railway lines. About 32 % of passenger rail traffic, expressed in passenger-kilometres, would be carried by high-speed rail by 2050, against 21 % in 2010 (EC, 2016b).

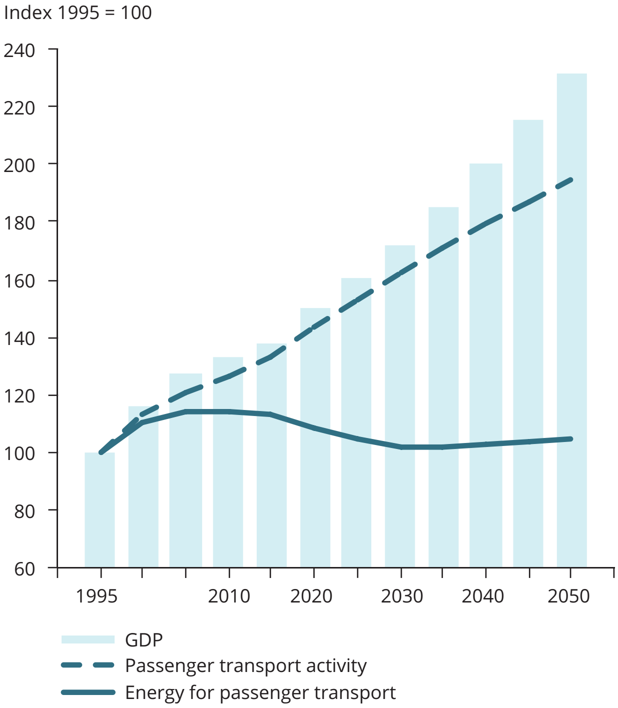
Partly due to a saturation of car ownership in the EU-2015, the REF2016 expects that private road transport (private cars and motorcycles) will grow less rapidly, i.e. by 30 % between 2010 and 2050. With its anticipated share of 69 % of all passenger-kilometres in 2050 (from 75 % in 2010) it remains the dominant mode.

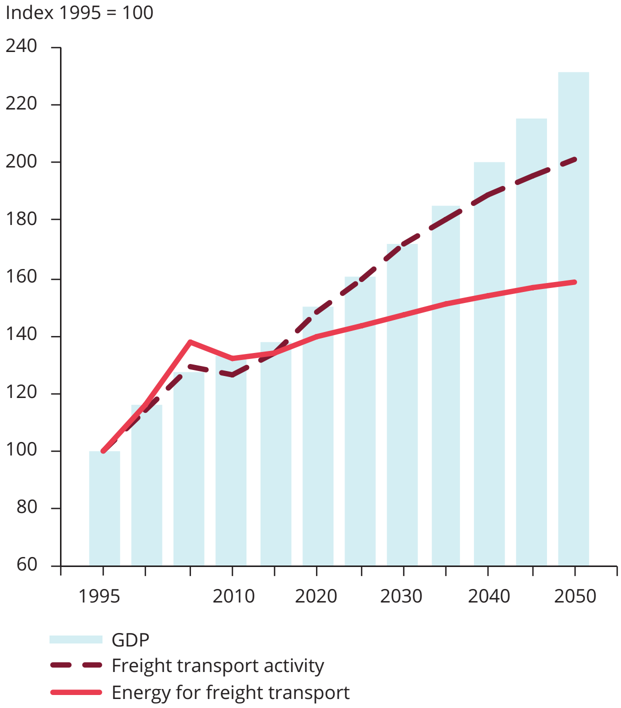
3.2.2 Freight transport

Freight transport is expected to grow faster than passenger transport. The REF2016 shows an increase in the total freight transport activity by about 58 % between 2010 and 2050. Until about 2030, the freight transport demand shows strong correlation to GDP growth. After 2030 the growth prospects of freight transport activity are weaker. This is due to lower GDP growth projections but also due to a change in the GDP composition (i.e. after 2030 the EU shifts its economic activities even more towards services) and limits to distant sourcing and offshoring.

Road freight traffic is projected to increase by about 57 % between 2010 and 2050, but growth is unevenly distributed between the EU-15 and the EU-13. The highest growth in road freight transport activity would take place in the EU-13 (almost doubling 2010 figures by 2050) where a strong correlation with GDP growth can be expected. By 2050, rail freight features the highest growth among the freight transport modes (84 %) and increases its modal share from 15 % in 2010 to 18 % in 2050. The expected significant increase in rail freight activity is mainly driven by the completion of the TEN-T core and comprehensive network, thus improving the competitiveness of the mode. Inland navigation traffic is projected to grow by 39 % between 2010 and 2050.

Figure 3.1 Trends in transport activities and energy consumption





Source: EC, 2016c.

3.3 Transport CO_2 emissions in 2050

A growth in transport volumes does not necessarily result in a similar growth in GHG emissions. A strong increase in efficiency and an important shift towards more sustainable modes and energy sources may reduce overall GHG emissions even if activity grows. The question is whether such a reduction can be expected and whether it will be enough to reach the 2011 White Paper GHG reduction target of 60 % by 2050 compared to 1990 levels.

Historically, final energy demand in the transport sector has grown in line with transport activity (Figure 3.1). However, the REF2016 shows that energy demand is decoupling from transport activity and, in addition to this, the share of electricity and biofuel in transport energy demand increases (reaching 4 and 6.6 % by 2050 respectively). As a result, the CO_2 emissions per passenger-km are expected to drop by 44 % between 2010 and 2050, and by 30 % per tonne-km.

Overall, by 2050 transport emissions ([9]) are more than 15 % above 1990 levels, still some way from the aspired 60 % reduction (compared to 1990 levels).

Passenger transport manages to reduce its emissions by 16 % between 2005 and 2030 in the REF2016. Freight transport manages to decouple its emissions from GDP growth. Emissions from freight transport stabilise around 2005 levels by 2030.

A number of key assumptions and developments underpin these figures:

- The main driver of the lower final energy demand from transport relative to transport activity is the policy-driven improvement in fuel efficiency, in particular for passenger cars and light commercial vehicles, and the uptake of more efficient technologies for other transport means.

- Aviation activity increases considerably throughout the projection period, leading to increased energy demand. Nonetheless, energy demand grows less than air transport demand as aviation experiences high efficiency gains due to the introduction of more energy efficient aircrafts and fleet renewal. Fossil fuels continue to dominate, and biofuels (biokerosene) slowly start penetrating the aviation

([9]) Including international aviation but excluding international maritime and other transportation.

fuel mix but only after 2035. The REF2016 projects a 31 % growth in CO_2 emissions in 2050 compared to 2010 levels.

- In the REF2016 biofuels constitute a significant share of transport fuels by 2020, driven by the legally binding target for this period of 10 % renewable energy in the transport sector (RES-T target) and by the Fuel Quality Directive (FQD) reduction target. Beyond 2020, with no further tightening of the RES-T target in the REF2016, biofuel quantities in EU28 remain relatively stable. Oil products would still represent about 90 % of the EU transport sector needs (including maritime bunker fuels) in 2030 and 86 % in 2050 (EC, 2016b).

- HGVs undergo improvements in specific fuel consumption driven in particular by the assumed increase in fossil fuel prices. Potential CO_2 emission standards for heavy duty vehicles (i.e. HGVs and buses) are not part of the REF2016 as such policies are not in place.

- Electricity consumption in transport increases steadily as a result of rail electrification and the penetration of alternative electric vehicles in road transport. Electric passenger cars and vans (i.e. battery electric, plug-in hybrid and fuel cell vehicles), in particular emerge in more significant numbers around 2020 as a result of EU and national policies as well as incentive schemes aiming to boost their penetration. Nevertheless, under current trends and adopted policies, the share of electric vehicles is projected to remain limited by 2050 (14 %).

Besides climate change, the impacts of traffic on noise, air quality and road safety are other concerns. European, national and regional regulations managed to reduce these problems to some extent, but the societal costs for health and quality of life remain substantial. The Organisation for Economic Cooperation and Development (OECD) estimates that the number of annual premature deaths due to outdoor air pollution (of which traffic is a major contributor) in the EU will decrease from 412 to 319–340 per million inhabitants in 2060 (OECD, 2016), but this improvement is clearly insufficient.

Making the move towards a competitive, low-emission transport sector requires more ambitious actions, both at the level of the EU and of the Member States themselves. Reducing unnecessary transport demand and achieving a more sustainable modal split, would need integrated actions to be undertaken by a number of different stakeholders, but also the development and introduction of cutting-edge technologies in the fields of non-fossil fuels (electricity and hydrogen). Realising the full potential of these technologies, which will significantly contribute to a competitive, low-emission transport sector, requires innovative action today (Hofhuis et al., 2016).

Box 3.2 Future mobility and accessibility — Greater Helsinki: a case study

Helsinki — a growing urban region

The Helsinki metropolitan area is an example of a rapidly growing urban region. It is also a region in which environmental sustainability issues are addressed in planning for the future mobility patterns of the city's inhabitants.

By 2050, the population within the metropolitan area is expected to increase by 45 % (i.e. from 1.4 to ca. 2 million inhabitants), with employment forecast to grow by a similar amount (HRT, 2014). Such growth will inevitably affect urban mobility. While travel demand is anticipated to grow in absolute terms as the population grows, in relative terms transport volumes are expected to decrease due to the region's plans to increase urban density.

Car travel is presently responsible for the largest share of transport related CO_2 emissions in the region, and ensuring access to more sustainable travel modes will be key in lowering the transport sector's future environmental impacts. The current public transport system within Greater Helsinki, the core area of the metropolitan area, consists of:

- a metro line covering the eastern suburbs;
- three commuter railway lines to the north, northwest and west of the city;
- a tram network of 13 lines in the extended city centre;
- a ferry line;
- an extensive bus network.

In 2012, the modal share of car for daily trips in within Greater Helsinki was 37 %; non-motorised transport accounted for 34 %, and public transport comprising the lowest share (27 %) (HRT, 2013). Previous studies have indicated that travelling by car is the fastest travel mode in the region (Jäppinen et al., 2013; Salonen & Toivonen, 2013), although public transport can compete with cars as a travel mode particularly in the city centre (Tenkanen et al., 2016a).

Box 3.2 Future mobility and accessibility — Greater Helsinki: a case study (cont.)

A 2050 urban vision

Helsinki's vision for the future is to become a 'polycentric' network city, with different compact and mixed-use urban centres. The daily mobility needs of inhabitants are largely foreseen to be addressed by more environmentally friendly ways of travelling than at present, with a particular focus on rail-based public transport (Helsinki City Planning Department, 2014; HRT, 2014).

In terms of the future changes to Helsinki's transport networks, two major developments are foreseen:

- increasing the rates of public transport by creating new and light rail-based infrastructure;
- modifying the existing motorways that lead into the city into 'urban boulevards', with less space being dedicated to cars, an increase in space dedicated for other travel modes, lower speed limits for vehicles, and new housing.

Assessing potential future levels of transport accessibility and CO_2 emissions

Good accessibility to transport is a key element of a successful mobility system. The Helsinki region is well-suited to analysing accessibility patterns and related transport emissions, as many essential datasets are freely available. In particular, the availability of planning documents describing future infrastructure plans, coupled with open spatial data such as public transport routes, schedules, and car networks, allows the testing of potential future transport developments. In the case study described here, two key questions were addressed:

- How may future changes to transport networks and population distribution affect accessibility patterns by car and by public transport? ([10])
- What changes in CO_2 emissions would result from the foreseen changes in transport networks, population patterns and assumed future vehicle emission levels?

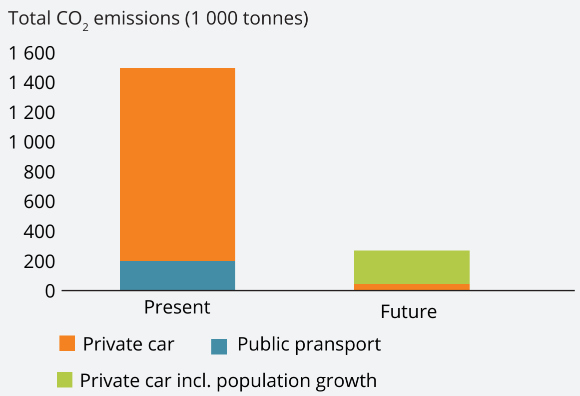
A basic description of the open accessibility modelling methodology and data sources employed is available (Tenkanen et al., 2016b; University of Helsinki (2016)).

Reduced CO_2 emissions, particularly in areas where buses are the main form of public transport

Significant reductions in CO_2 emissions could be achieved if the planned changes in infrastructure and population patterns, and the estimated future modal shares and assumed vehicle emission levels, were to become reality. Using an example in which every inhabitant makes one trip to the city centre, total estimated CO_2 emissions would decrease by more than 80 % (Figure 3.2).

The largest CO_2 savings would occur in areas where the current public transport connections rely on buses (Map 3.1). In contrast, higher CO_2 emissions would occur in areas where housing is not presently located but is assumed to do so in the future. Although the magnitude of hypothetical CO_2 savings is large, the overall impact, when considering the total travel demand within the region as well as uncertainties in future emission levels and modal shares, is likely to be less optimistic.

Figure 3.2 Potential future reduction of CO_2 emissions compared to present



More residents may reach the city centre in a shorter travel time

With these foreseen changes the city centre could be reached by more people within shorter travel times by both car and public transport travel modes (Figure 3.3 left). The increase in the level of accessibility is however greater for public transport. Assuming, for example, a travel time of 30 minutes, the increase in accessibility is 106 000 people for public transport and 42 000 people for car travel.

The level of accessibility by car decreases when the relative share of population able to reach the city centre is considered (Figure. 3.3 right). For example, there is an 11 % decrease in the level of accessibility for a 30 minute journey, whereas for public transport the level of accessibility is foreseen to increase by 4 %. Although the overall level of accessibility remains higher by car, the time gap between car travel and public transport travel is projected to decrease. In other words, public transport becomes more attractive, potentially supporting a modal shift from car to public transport.

([10]) The level of accessibility was determined as the number of residents that can reach the city centre within certain travel times.

Box 3.2 Future mobility and accessibility — Greater Helsinki: a case study (cont.)

Map 3.1 Spatial distribution of potential future changes in CO_2 emissions compared to present

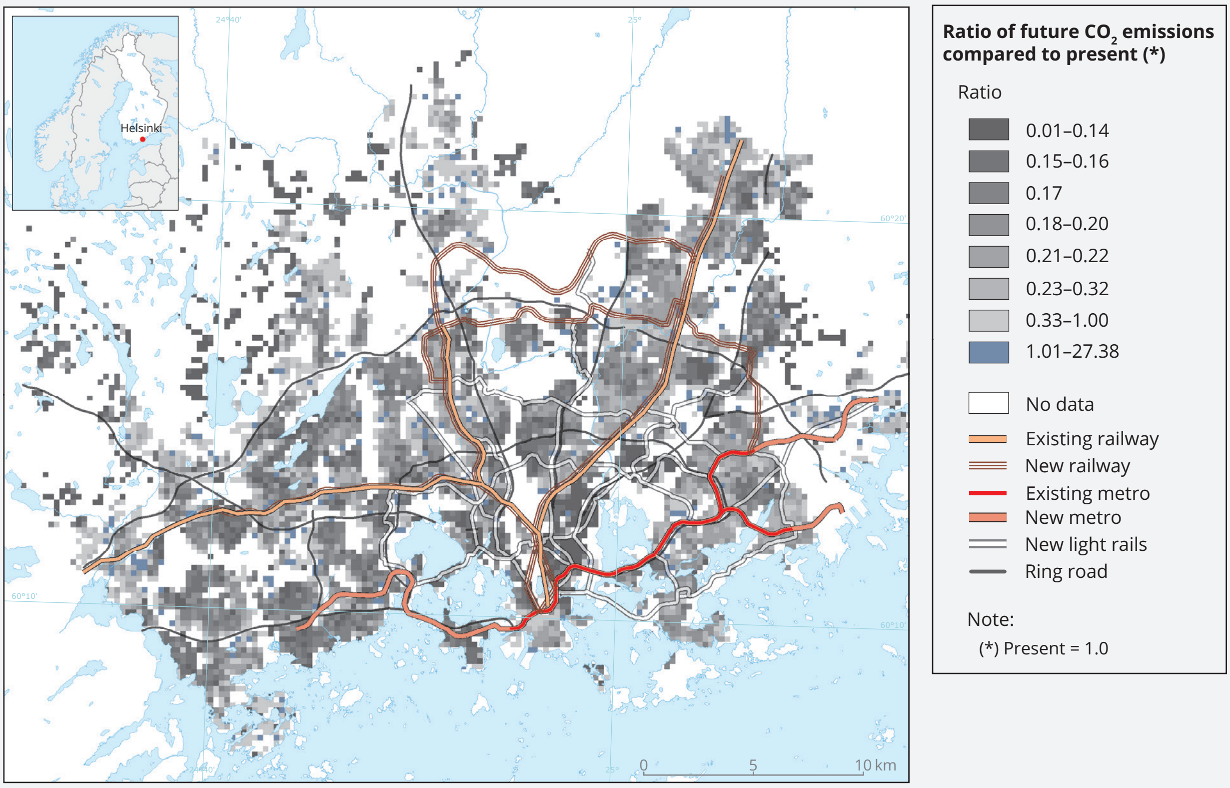
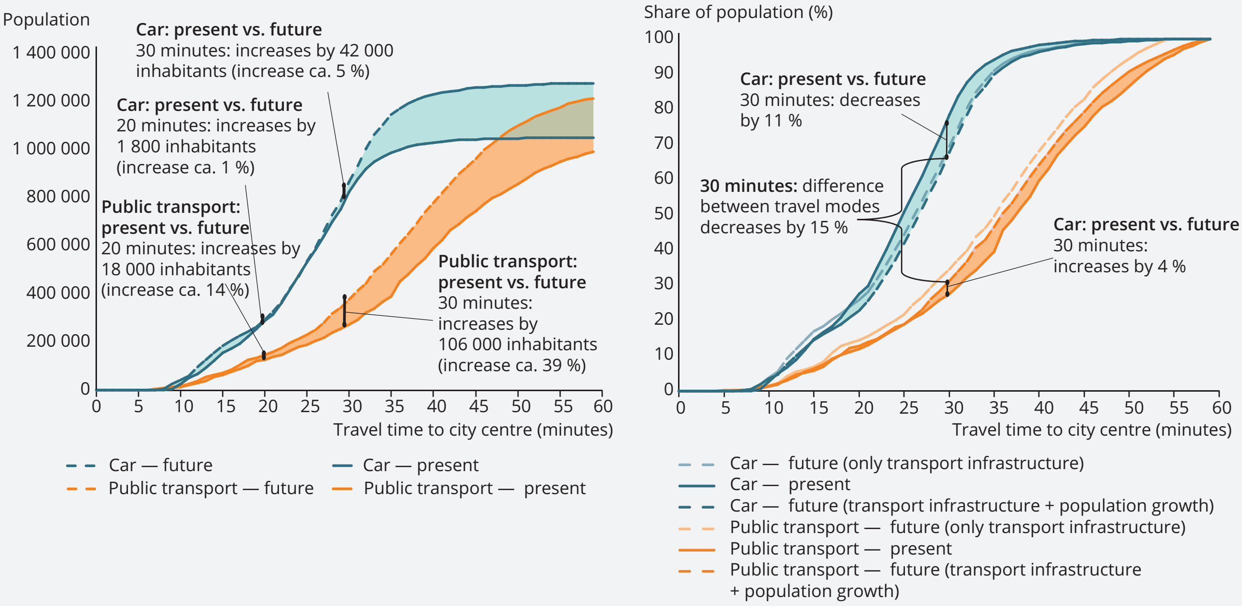


Figure 3.3 The absolute (left) and relative (right) share of population in Greater Helsinki able to reach the city centre within given travel times by car and by public transport, now and in the future



4 Principles supporting systemic change

Key messages

Addressing systemic change and dramatically reducing environmental pressures from transport requires all options to be explored and employed.

At the core of the discussion on systemic change is the fundamental question whether we actually need all the transport activity that has been estimated for the next decades. Is growth in transport activity a necessary condition to achieve the aim of 'living well, within the limits of the planet'?

A fundamental decarbonisation of the transport sector will require not just technological solutions but also policies that stimulate significant behavioural changes, including the inclusion of transport externalities in the consumer's final price and planning approaches that increase the use of sustainable modes of transport. Encouraging and nurturing innovation will also play a key role, as well as removing barriers that prevent sustainable options to develop.

While current emphasis is placed on policies towards the decarbonisation of the economy, other transport related environmental pressures such as air pollution, noise or habitat degradation should also be addressed.

It is clear that, with GHG levels as foreseen under current trends and adopted policies by 2050, a major effort is still needed to reach the desired GHG emission reduction. In addition to this, transport related pressures also include air pollution, noise or habitat degradation. Making internal combustion engines more efficient is unlikely to be sufficient on its own to achieve the EU's long-term goals of reducing emissions. Instead, an integrated approach is needed, covering vehicle efficiency, renewable fuels and modal shift as well as measures that help reduce transport demand itself.

The need for transitions or transformations in core systems such as the mobility system demands embracing the Avoid, Shift and Improve (ASI) framework from the very beginning: the need to move people and goods from one place to another in an easy, safe and efficient way. Firstly, there is a need to rethink whether we actually need all of this transport. There is a need to improve the efficiency of the transport system and intelligently manage transport demand, to avoid unnecessary trips and increase occupancy. Secondly, can the journey be shifted to a more environment-friendly transport mode, such as opting for train travel instead of flying, or for public transport or cycling instead of driving? Finally, can each of the transport modes be improved?

This complexity systems means that one solution on its own will not be adequate, rather a combination of actions using the ASI framework as guidance could lead to success. For example, replacing conventional vehicles with electric vehicles can help reduce emissions, although this depends significantly upon the source of the electricity used to charge vehicles: renewable sources, nuclear power or fossil fuel (EEA, 2016g) as well as potential savings from energy efficiency improvements in other sectors. However, simply replacing conventional vehicles will not solve other problems such as noise, land use and biodiversity degradation. It may even cause a rebound effect if no other actions are taken: urban sprawl may continue, growing congestion or increasing demand for road infrastructure and parking, affecting ecosystems and biodiversity as well as urban quality.

Box 4.1 The transitions terminology

Transitions or transformations in core systems are understood to be 'long-term, multi-dimensional and fundamental processes of change', based on 'profound changes in dominant practices, policies and thinking' (EEA, 2015a).

Transitions researchers have developed a variety of theories to explain how socio-technical systems ([11]) are structured, and the ways that these systems can be reorganised to deliver better outcomes (Markard et al., 2012). One of the most widely used approaches is the '**multi-level perspective**'.

The multi-level perspective characterises socio-technical systems as being structured and stabilised by a '**regime**' comprising factors such as knowledge, investments, policies, institutions, skills and cultural values (see Figure 4.1 below). Innovative technologies and practices are seen as holding the key to systemic change but they often struggle to have any impact because businesses and consumers are **locked into** established ways of producing and consuming.

For innovations to emerge and alter the dominant system, two things are needed. One is '**niches**': protected spaces below the regime level, where innovators can develop, nurture and experiment with new technologies or practices without immediate or direct pressure from the regime (Raven et al., 2010). There is an emphasis on social innovations: new practices and behaviours that enable society to meet its needs more sustainably. Such changes are sure to entail adjustments in policies, norms and values.

The second requirement looks at forces that can disrupt the regime, creating windows of opportunity for new innovations to establish themselves. Such forces come from the external '**landscape**' of long-lasting structures and large-scale socio-economic, demographic, political and international trends, which can both constrain and enable regime change (Raven et al., 2010). For example, global megatrends such as demographic and economic growth and associated demand for resources (e.g. fossil fuels) can create pressure on the energy system (EEA, 2015a).

Transitions cannot be managed. There is simply too much complexity and uncertainty (e.g. interplay of social and technological responses), but governments and other societal stakeholders can help catalyse and steer transitions, for example by creating niches in which experimentation and innovation can flourish.

Source: Based on *Sustainability transitions: Now for the long term* (EEA, 2016h).

4.1 Avoid

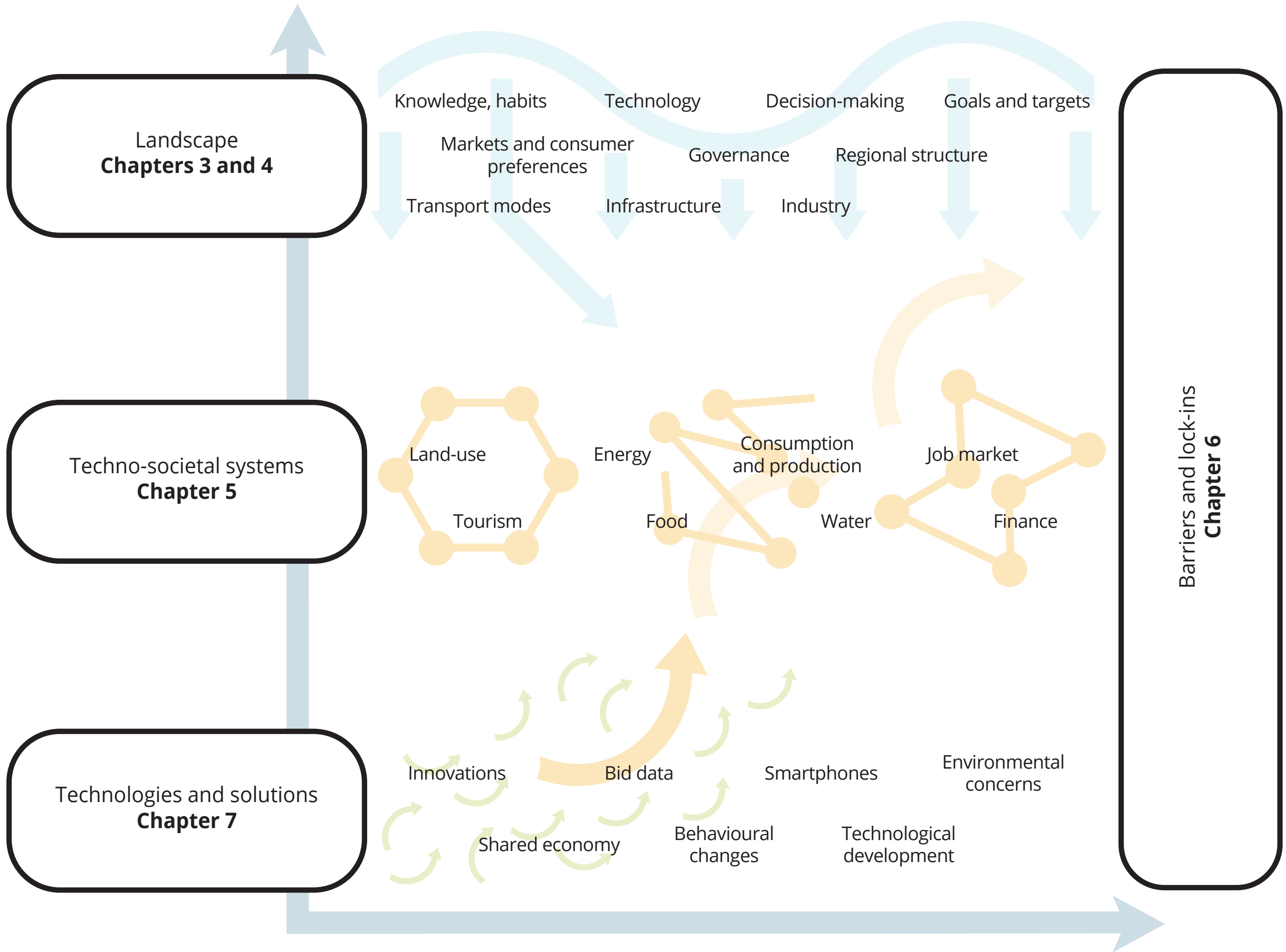
Reducing transport demand is perhaps the most difficult of these three options, or at least the one that has historically received less attention. However, it can be very cost effective and can also offer environmental co-benefits such as air quality improvements and noise reduction. Research has proven that there is great potential to reduce environmental pressures from transport through the avoidance of unnecessary trips, especially in the urban context (see, for instance, JRC (2013)), where new societal developments and behavioural changes are emerging. It will require changes in everyday practices, but not necessarily a change in current lifestyles (Givoni and Banister, 2013).

The use of information and communications technology (ICT) to reduce transport activity, whether reducing the number of trips or increasing occupancy applies for both passenger and freight transport. Beyond ICT-developments such as tele-working, tele-conferencing and tele-shopping, and their potential to replace existing travel (Sessa, and Enei, 2010), the use of real-time streams of data could significantly change the way mobility is carried out in our society (ITF, 2016). The increase, availability and complexity of communication services allows new business models to offer mobility as a service, by combining different modes (public transport, car-sharing, rental car service, taxi or bicycle) to cater for a given mobility need. It also makes possible to offer peer to peer mobility services in a rather individual way. Changing preferences away from car ownership is also gaining importance, especially for younger generations (see i.e. EEA, 2013), which hint at ICT playing a significant role in passenger transport.

Including the environmental cost of transport in the final purchase price is another key instrument. The 2011 Transport White Paper (EC, 2011b), announced a roadmap to gradually internalise external costs in the sector to move towards full internalisation of all

([11]) Socio-technical systems refer to the co-evolution of technological and social systems, i.e., the interaction between society's complex infrastructures and human behaviour.

Figure 4.1 Multi-level perspective in the mobility system



Source: Based on Geels, 2016.

costs in all modes by 2020 (EC, 2016c). When prices reflect the external costs caused by passenger and freight transport, consumers and producers will have to take these into account. If a transport mode causes environmental damage that is currently not included in price estimates then costs will rise and, as a result, the number of trips or distances covered may well drop. Secondly, a shift towards cheaper, more environmental friendly transport modes may occur. In order to give the correct incentives, the policy instruments can take various forms: differentiated taxes on vehicle purchase, ownership or use, fuel taxes, CO_2 taxes, the tax treatment of company cars, infrastructure charging, reconsiderations of various types of subsidies, etc. They will be most effective if they are closely linked to the type of external cost they are aiming to tackle.

4.2 Shift

An important contribution to meeting GHG targets and reducing environmental pressures from transport should come from a modal shift from aviation and road to rail and non-motorised passenger transport and from road to rail and waterborne freight transport.

Two targets are set out in the 2011 Transport White Paper (EC, 2011b): *'30 % of road freight over 300 km should shift to other modes such as rail or waterborne transport by 2030, and more than 50 % by 2050'*; and *'by 2050 the majority of medium-distance passenger transport should go by rail'*. These targets represent an ambitious modal shift from current levels, which are dominated by road transport.

Three-quarters of total freight transport (tonne-kilometres (tkm)) in the EU-28 is associated with distances greater than 300 km (EEA, 2014). Policies to encourage shifting road freight to rail and waterborne transport generally focus on reducing administrative barriers, investing in infrastructure, and confronting all transport modes with their full costs, including the costs of 'negative externalities' they cause (e.g. congestion, air pollution, GHG emissions) as well as fairer taxation policies. Other measures, such as more extensive use of information and communications technology, the development of better logistics that could improve the load factor of vehicles, and by making use of the appropriate mode at each link of the transport chain should also yield important results. Freight is likely to continue to rely on road haulage over short distances even if policies for modal shift are introduced, as other modes cannot compete in terms of speed, flexibility and reliability.

Rail is more competitive for long-distance freight, and the potential for rail to increase its market share is promising if problems concerning interoperability and national fragmentation are resolved. International rail freight is still impeded by several infrastructure and operational bottlenecks, in particular relating to crossing borders between Member States ([12]). In terms of the potential shift to rail, Eurostat is currently developing an indicator to measure the number of containers transported by road in journeys longer than 300 km, where the potential for a shift to rail is highest, providing that other barriers are minimised (EC, 2016d).

Regarding passenger transport, long-distance passenger transport volume (passenger-kilometres) accounts for up to 40 % of the overall amount. There are no reliable estimates available for the overall reduction potential of modal shift. Preliminary indicative estimates for the overall GHG reduction potential of modal shift for passenger transport ranges from 2 to 14 % (for a shift from road to rail transport). The shift from aviation to rail transport could in theory also reduce GHG emissions from passenger transport by several percentage points (van Essen et al., 2009). High speed rail services offer great reliability, speed and comfort, as well as more flexible pricing management than conventional rail services. This makes them very competitive for certain hub-to-hub long distance connections. However, expansion of high speed rail requires careful analysis, due to the large financial costs and potential environmental impacts involved in its construction. As in the case of freight, passenger rail transport mostly needs improving market conditions, and overcoming other administrative and technical barriers.

Within urban areas, most of the cargo is likely to remain road-based. However, some opportunities have arisen for the use of urban rail networks and even waterways for deliveries (EEA, 2013). For deliveries made by couriers in more densely populated areas, there is the potential for the final leg of the journey to be by bicycle or on foot. The Intelligent Energy Europe project, Cyclelogistics, states that up to 25 % of deliveries in urban areas can be carried out by cargo bikes (FG-AMOR et al., 2014), similar to the Germany's Transport Ministry estimation ([13]) of a maximum of 23 %, while other estimations elevate that percentage to up to 68 % ([14]) (EC, 2016c).

At the urban scale, cities are encouraged to design and implement ambitious measures through Sustainable Urban Mobility Plans (SUMPs) to increase the share of public transport, cycling and walking (EC, 2016c). Available data show an average journey length for motorised transport between 9 and 22 km per day (EEA, 2013). These distances provide many opportunities for more environmentally friendly modes of transport. What can potentially be more important is the emergence of new types of mobility that are used for short to medium distance transport 'on demand'. A shift from an owning-based to sharing-based system for car use is gaining importance in EU cities, as well as a strong resurgence in cycling and walking. These relatively recent changes can be fuelled and supported by a radical shift in the organisation of city centres.

4.3 Improve

The application of technology has been the primary means of reducing the environmental impacts of transport in previous decades. Biofuels and electricity (and potentially hydrogen) are expected to be the key energy carriers utilised to reduce GHG from transport in the long term.

Improving the energy efficiency of vehicles or switching to other energy sources has an impact on the demand for oil products. Because the EU's transport sector depends on oil for 94 % of its fuel, and Europe imports 87 % of its crude oil and oil products from abroad, a reduction of the oil needed results in a net benefit

([12]) http://data.consilium.europa.eu/doc/document/ST-9599-2016-INIT/en/pdf.
([13]) http://www.bmvi.de/SharedDocs/DE/Anlage/VerkehrUndMobilitaet/Fahrrad/wiv-rad-schlussbericht.pdf?__blob=publicationFile.
([14]) http://mobi.vub.ac.be/mobi/news/decarbonisation-in-city-logistics-shifting-from-vans-and-trucks-to-bikes.

on the EU trade balance. The EU dependence on oil imports makes it particularly vulnerable to instability and changes in the global energy market. A disruption in the energy supply could severely undermine the economy and hamper the quality of life in the EU.

The possibilities to reduce GHG emissions through technical options differ considerably between different modes. Various studies stress the need for a major reduction in the GHG emissions of passenger cars (see e.g. PBL Netherlands Environmental Assessment Agency et al., 2009; McKinsey 2010), because firstly, they are currently responsible for about half of the transport GHG emissions. Secondly, they have the best technological options to reduce emissions, whereas the technical options for airplanes, for example, are limited. In the near future, improving the efficiency of current passenger cars (vehicles with internal combustion engines using fossil fuels), holds the greatest potential for rapid improvements in efficiency (IEA, 2012).

This will not be sufficient in the long term for several reasons. Firstly, there is uncertainty as to whether large amounts of sustainably produced biofuels will be available for passenger cars, given the potential demand for biofuels from other sectors, such as goods vehicles, aviation, maritime transport, the electricity sector and heavy industry (Skinner et al., 2010; McKinsey 2010). Secondly, although the traditional combustion engine may still become some 30 % more fuel-efficient in the coming decades (McKinsey 2010), only up to a quarter of the fuel burnt is actually used for moving the vehicle (EEA, 2016b). This will clearly not be enough to reach the desired levels of GHG emission reduction, and can lead to other environmental problems. Moreover, recent changes in official fuel efficiency statistics have been questioned due to the significant discrepancies between fuel consumption observed in real-world driving and testing under laboratory conditions. Achieving the desired degree of decarbonisation in passenger road transport will probably not happen only through incremental changes to internal combustion engine vehicles (ICEVs). This links in with the 2011 Transport White Paper goal of 'halving the use of conventionally-fuelled cars in urban transport by 2030, phasing them out in cities by 2050 and achieving essentially CO_2-free city logistics in major urban centres by 2030'.

The move to new technologies and fuels is necessary. This implies a much larger transition towards sustainable mobility based upon innovative technologies using non-fossil fuels. In the case of alternative fuel vehicles, there is also a need for common standards and an extensive fuelling infrastructure. In the absence of these, the uptake of such vehicles may be hampered. The comprehensive alternative fuels strategy covering all modes of transport, was put forward in 'Clean Power for Transport' (Directive 2014/94/EU), needs to be seen in this light. Even if the required infrastructure is in place, the renewal of existing fleets with cleaner models will take time. This is especially the case for aircraft, trains and vessels that have a much longer lifetime than cars, vans or trucks (see also Chapter 6).

Innovative technologies have a positive effect on employment growth. The majority of studies show a positive relationship between product innovation and employment growth in manufacturing (see e.g. (Hall, et al., 2008; Harrison et al., 2014)) and in services (Harrison et al., 2014; Peters et al., 2013). European car manufacturers have proven to be very competitive, having a strong position in foreign markets, and being seen as leading of technological advances. Incentives to the industry could increase this competitiveness and lead to the creation of innovative and successful technology.

Therefore, a transition towards sustainable mobility could contribute to a stronger and more innovative European economy, thanks to the development of clean technologies and low- or zero-carbon energy, leading to growth and jobs. However, the transition will not be effective if policies are not combined with others aiming at controlling transport volumes, and shifting activity to more sustainable transport modes.

4.4 Combination of pathways for a sustainable mobility

A number of potential pathways have been identified to achieve a transition towards sustainable mobility that could contribute to a stronger and more innovative European economy. These can be compared with a 'business as usual' path (see Figure 4.2). This latter path assumes that economic growth (G) implicitly underpins a growth in transport activity (TA) derived from increases in trade, business trips or tourism, as well as from the current high carbon mobility system. Such growth generates similar increases in emissions (E) and other pressures (O) on the environment i.e. changes in land use. The four spheres under the business as usual pathway are coupled and correlated.

Compared to the business as usual path, the 'Avoid, Shift, Improve' framework brings considerable environmental benefits without necessarily compromising on economic growth. On the contrary, the transition towards sustainable mobility represents a major opportunity for jobs and growth in the transport sector, as markets for low-emission mobility grow globally (EC, 2016c).

Figure 4.2 represents the comparison of the business as usual pathway with that of the ASI framework. The improve section of the figure notes that better efficiencies and technological factors have already affected the environmental performance of transport with more expected. However, greater benefits are only possible if shift and avoid policies are also applied. One can see in the **improve path** a decoupling process has taken place between transport activity (TA) and emissions (E), but not for other pressures (O).

Meanwhile the **shift path** generates significantly less emissions (E) and other pressures (O) compared with the improve path, as a higher proportion of trips are made by more environmentally friendly modes. However, transport activity (TA) is still coupled with economic growth (G). This path requires personal changes in everyday practices, such as non-motorised modal choices for commuting.

Finally, the **avoid path** builds from the shift path and obtains economic growth (G) while decreasing transport activity (TA), since a large amount of unnecessary trips have been avoided through better occupancy of transport modes, reduction of the number of trips or the distances driven. This leads to a substantial reduction of emissions (E) and other transport related pressures (O) compared with the shift scenario. This path requires **transformations** or profound changes in dominant practices, policies and thinking in the mobility system.

Figure 4.2 Combination of pathways towards a more sustainable mobility system

Source: Adapted from Givoni and Banister, 2015.

5 External factors influencing the mobility system

Key messages

The mobility system does not operate on its own and is influenced by a number of external factors.

Transport is used by everyone and for different purposes such as commuting, tourism, business trips, and global or local trade. A range of transport services are used with distinct characteristics in terms of costs, speed, and reliability.

Close links between transport and other systems mean that interactions between the two are complex and unpredictable with impacts also coming from external sources. Actions taken within the transport system, such as through specific policies, logically impact on other systems and vice versa. Nevertheless, opportunities exist to address the environmental performance of transport via other societal systems.

European policy measures and developments in technology have proven to be particularly effective when it comes to tackling specific sources of local, regional and continental environmental pressures. However, some of the environmental and climate challenges we are facing today are both systemic and cumulative in their nature and depend not only on our actions in Europe, but also globally.

Many of these challenges are characterised by their complexity (i.e. they have multiple causes and feature many interdependencies between their underlying drivers and associated impacts). They are difficult to delineate or define clearly as they pervade different parts of the environment and society in various ways. Thus, they are often perceived differently by different groups in society and at different geographical scales.

The EEA's SOER 2015 report (EEA, 2015c) highlighted three systemic characteristics that are common to many of today's environmental challenges, and which equally apply to transport:

- Firstly, transport directly and indirectly affects human health and well-being and standard of living.
- Secondly, it is intrinsically linked to our consumption and resource use patterns particularly as regards food, water, energy and materials. The resources within these categories are closely linked as, for example, substituting fossil fuel use with bioenergy crops can have implications in the energy and food sectors.
- Thirdly, its evolution depends on European and global trends, including those related to demographics, economic growth, trade patterns, technological progress, and international cooperation.

The success of a systemic change will largely depend on the ability to understand the varied and complex links between sectors or systems (i.e. transport, land use, energy, consumption and production) and related decision making processes in order to tackle dysfunctionalities and look for synergies when implementing actions.

Transport is used by a variety of stakeholders for different purposes, whether this is for commuting, tourism, business trips, and global or local trade. Very diverse transport services are used, with distinct characteristics in terms of costs, speed, reliability, etc. The way in which our society functions is partly shaped by the transport services that are available. A well-functioning transport system is therefore of crucial importance. The transport system itself is also shaped by what happens in other societal systems.

Due to these close links, interventions become more complex and the outcomes also depend on external factors. Actions taken within the transport system, such as through specific policies, logically impact on other systems and vice versa. Opportunities for addressing the environmental performance of transport via the other societal systems do, however, exist.

This report focuses on the links between transport and three other systems, which have been chosen as they represent well the interdependencies between transport and societal systems:

- land use and transport;
- transport and the globalisation of food production and consumption systems;
- aviation and tourism.

For these three case studies, barriers and opportunities towards a more sustainable path have been identified. The case studies do acknowledge that even if opportunities exist, it may not always be straightforward to fully benefit from them as factors within the transport system may create incentives to avoid fundamental change (see Chapter 6).

5.1 Land use and transport

The relationship between land use and transport is reciprocal and of crucial importance for reducing GHG emissions and other environmental pressures from transport.

Interactions between land use and transport include the different linkages between centres of activities at various scales and territories. It covers both passenger and freight connections between production and consumption centres, and access to jobs and services. The availability of infrastructure certainly influences the location of economic activities and housing since decisions generally take into account the costs of mobility in the broad sense (i.e. monetary costs, time, etc). On the other hand, demand for new infrastructure and mobility services is also determined by existing land use.

Transportation systems have a wide variety of effects on the landscape and land use. Primary, or direct, environmental effects include emissions, noise, changes to the use of land or fragmentation of habitats. Secondary, or indirect, ecological effects from transport infrastructure include the potential degradation in habitat quality due to the intensification of land use (EEA/FOEN, 2011). Better connectivity alongside relatively low transport costs can offer increased economic returns from the land (such as agricultural intensification or urban sprawl), which can imply the loss of other benefits such as the ecological value of natural habitats or the cultural value of traditional landscapes (EEA, 2015c).

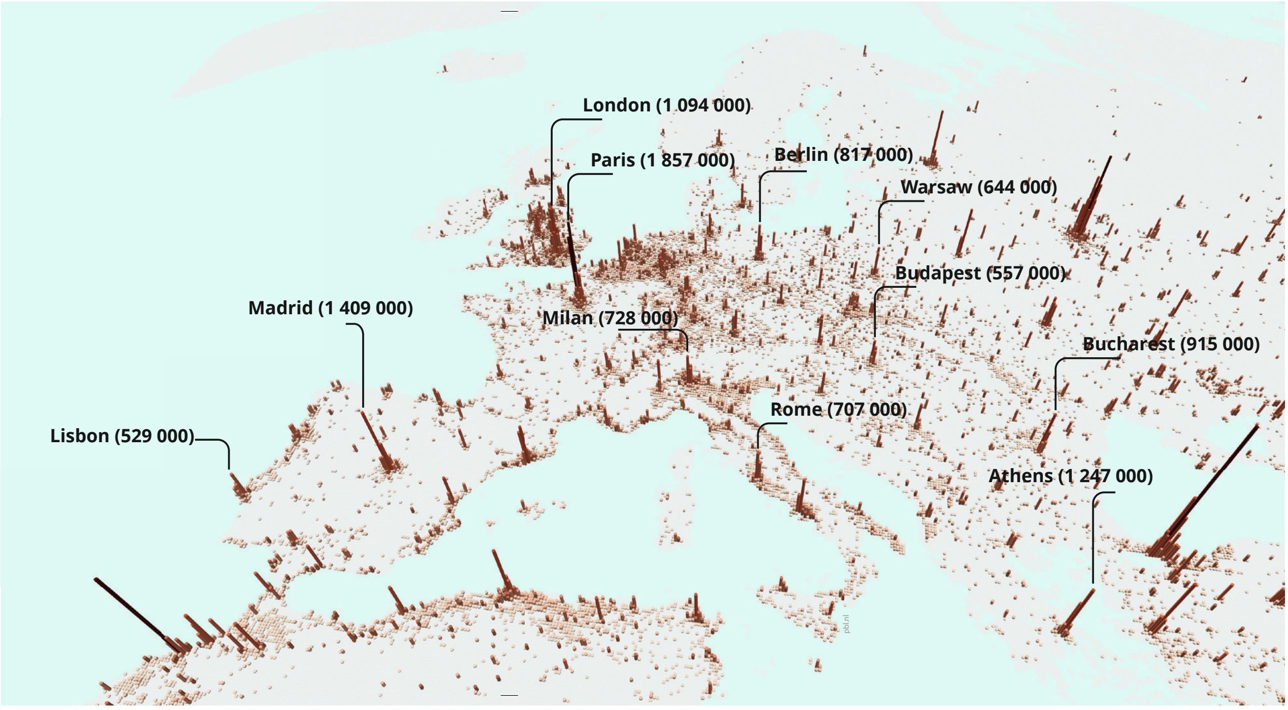
Urbanisation is the dominant trend regarding land use in Europe. 72.5 % of the EU-28 population lives in urban areas, with 41.6 % residing in cities and 31.0 % in towns and suburbs ([15]). Over the past 50 years, the urban population has known a steady growth, with the strongest increase coming in towns and suburbs, and in newly developed residential areas surrounding existing cities. The forces that have fuelled urban sprawl in Europe include both micro and macro socio-economic trends such as the means (and price) of transportation including the rapid growth of private car ownership, the price of land, individual housing preferences, demographic trends, cultural traditions and constraints, the attractiveness of existing urban areas, and, not least, the application of land use planning policies at both local and regional scales (EEA and FOEN, 2016).

The urban structure in many urban regions in Europe is polycentric, with several towns and cities close to each other. However, there are also distinct cases where a more monocentric pattern with one dominant city is observed (Figure 5.1), as well as a limited number of linear urban regions (Nabielek et al., 2016).

It is widely recognised that the degree of urbanisation and the type of urban structure have implications for sustainable development. The interrelationships

([15]) http://ec.europa.eu/eurostat/en/web/products-statistical-books/-/KS-01-16-691.

Map 5.1 The European urban landscape



Source: PBL Netherlands Environmental Assessment Agency (Nabielek et al., 2016).

between land use and transport are of crucial importance for sustainable mobility and reducing GHG emissions and other environmental pressures from transport. Land use refers to factors such as population density, job density, diversity of land use, city size or neighbourhood design. Figure 5.1 presents the so-called 'land use transport feedback cycle' showing the main mechanisms through which transport and land use mutually influence each other.

These mechanisms can be summarised as follows (Wegener, 2004):

- The different dimensions of land use (density, neighbourhood design, etc.) affect where people choose to live, work, shop, go to school or undertake their leisure activities. It also influences where businesses choose to establish their premises.

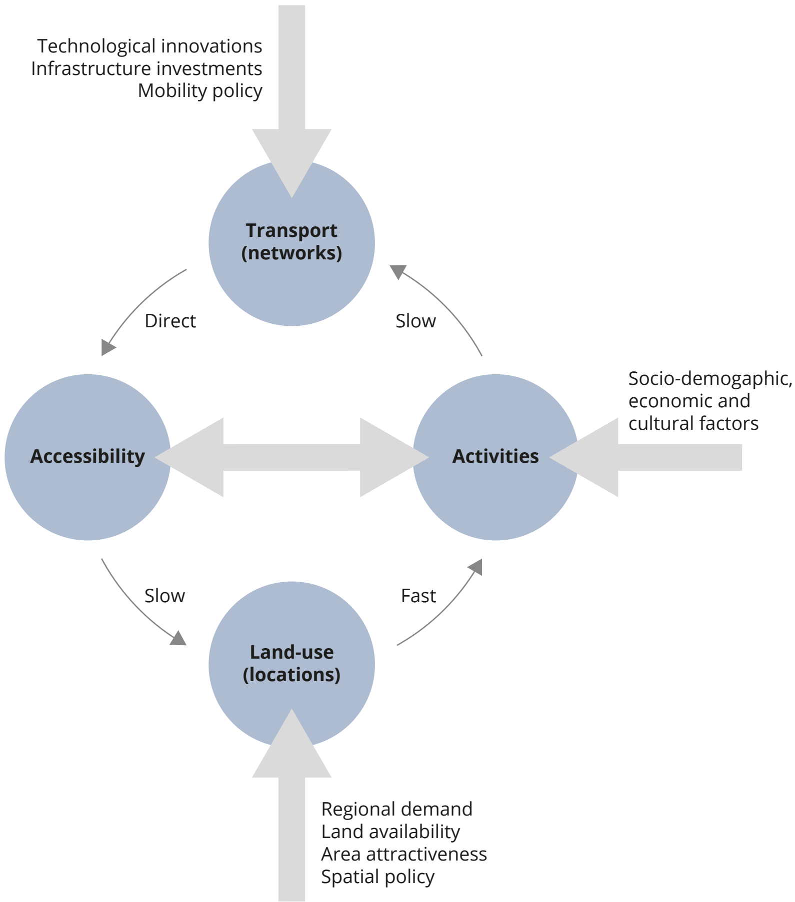
- People and businesses use transport for different purposes (commuting, going to school, visiting family, delivering goods, etc.). They can choose from a variety of transport services in terms of transport mode, travel time periods, routes and vehicle types. All of these choices have implications for the environmental performance of the transport system.

- The accessibility of the different locations is closely linked to the general performance of the transport system. It depends on, amongst others, the geographic coverage of the transport network for the various modes, the availability of public transport, and the design of the networks in terms of capacity, safety, etc. The actual accessibility mainly depends on the total cost and speed of different modes and the reliability of travel times, which depend on congestion levels, and accident risks, etc.

- The level of accessibility can lead to changes to how the land is used.

Many other factors also play a role in the 'feedback cycle': land demand and supply characteristics, socio-demographic, economic and cultural factors, technological innovations (such as ICT developments) and, last but not least, transport and spatial policies. Transport infrastructure policies, the supply of

Figure 5.1 The land-use transport feedback cycle



Source: Based on Bertolini, 2012 with Wegener, and Fürst, 1999 as original source.

public transport, transport pricing, traffic demand management systems, parking management, safety measures, etc., all have an impact on the attractiveness of the different transport services.

Urban density is a key factor in the land use / transport equation. 'Urban density affects GHG emissions in two primary ways. First, separated and low densities of employment, commerce, and housing increase the average travel distances for both work and shopping trips ... Second, low densities make it difficult to switch over to less energy intensive and alternative modes of transportation such as public transportation, walking, and cycling because the transit demand is both too dispersed and too low ... .' (Seto et al., 2014).

Settlements spread out over a large area (diffuse) often result in more resource-intensive lifestyles because of increased transport and domestic energy needs. Citizens living in these areas tend to commute by car to the main urban area, whether by choice or due to the limited transport options, resulting in pollution and the lower environmental quality of urban areas.

In addition to density, key factors explaining distance travelled are land use mix, connectivity and accessibility. This last aspect follows directly on the work of Banister who showed that while the average speed of urban travel may become higher when a city becomes motorised, this does not directly imply a higher level of accessibility (Banister, 2011a). Overall, using faster (non-active) transport modes has led people to cover more distances, but has not resulted in any significant time gains, as society adjusts towards the new equilibrium by occupying more space and increasing distances between economic activities. The faster the means of transportation, the less dense the city gets and the more energy the transport system consumes. On the contrary, a higher land use mix or diversity reduces travel distances and thereby makes it possible to walk or cycle to the destination (Banister, 2011a). Finally, highly accessible cities offer short commuting distances and travel times, and a range of transport modes to choose from, thereby also reducing distance travelled (Seto et al., 2014) and potentially private car trips.

The overall conclusion is that a combination of increased densities, the mixed use of land, improved connectivity and better accessibility can and should play a role in reducing transport demand and encouraging the use of non-car modes. As European cities are dense but are becoming less so, urban sprawl is continuing (EEA and FOEN, 2016). Land use planning is currently an undervalued means for improving accessibility in a sustainable way. On the basis of the available evidence Banister (2011b) therefore presents an argument '... for the use of all available policy levers in mutually supporting ways, including economic, planning and technological opportunities'.

A comprehensive package of land-use and mobility measures covering all modes of transport in a metropolitan area can therefore create more liveable cities, while guaranteeing its social and economic development. This, in return, will increase its attractiveness.

5.2 Transport and the globalisation of food production and consumption systems

The EEA's SOER 2015 report states that 'driven by a combination of economic incentives, consumer preferences, environmental standards, technological innovation, development of transport infrastructure, and liberalisation of trade, production-consumption systems for many goods and services span the globe, engaging multiple actors' (EEA, 2015c).

The performance of the transport sector is one of the factors that enable the existence of such globalised systems. It is yet another example of how the functioning of our society is closely linked with transport. Together with other drivers, transport co-determines the locations where production takes place and more generally how the whole supply chain is organised. Note that the interaction is two-way. The transport and production-consumption systems are mutually influencing each other: the way in which the latter system is organised has an impact on the magnitude and type of transport flows. This means that the transport flows are also partly determined by drivers that are external to the transport sector.

The food production-consumption system is an example of such a globalised system. Consider, for example, the market in fruits and vegetables, the following maps show high levels of trade between the EU and the rest of the world for the period 2010-2014. Within the EU the quantities of fruits and vegetables traded are substantial (CBI, 2015).

A lively debate exists on whether it is best to have more local or more global food production-consumption systems ([16]). Many considerations, including environmental ones can be put forward.

A more globalised system offers the possibility of reaping the benefits of comparative advantage ([17]) and economies of scale ([18]) in the production of food products. This lowers the production costs and, indirectly, the prices that consumers pay. More efficient production also means that there is a potential for increasing the output, which is important for guaranteeing food security, in view of population growth projections. Moreover, with a more global food system consumers can enjoy a larger variety of products with less dependence on the seasons, a benefit that is highly valued.

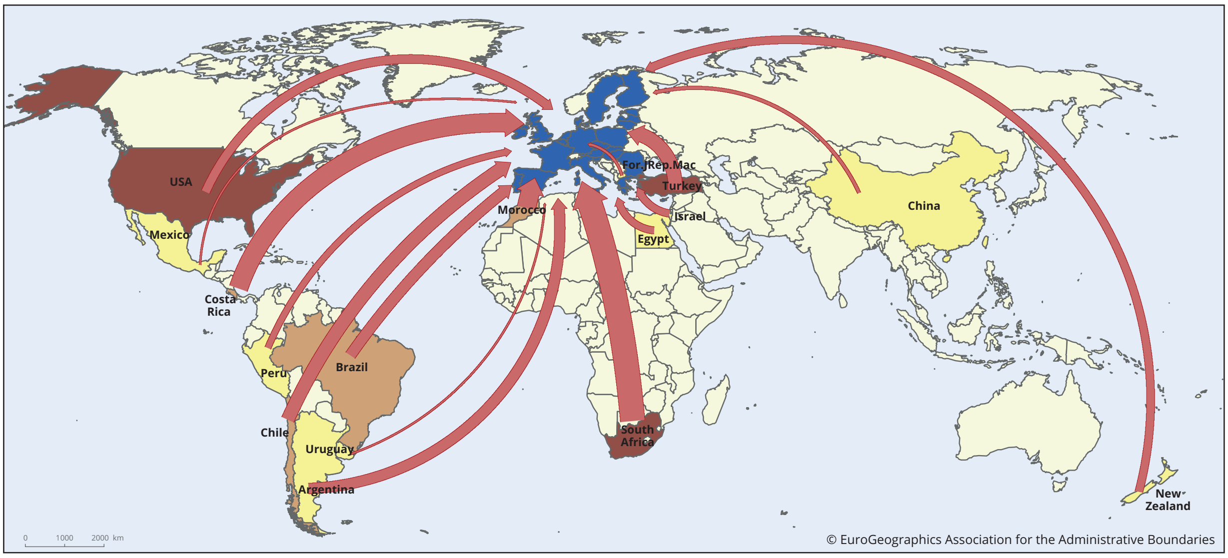
The way in which the food production-consumption system is organised affects the distribution of any costs and benefits. It can also determine a country's GDP and the extent to which developing countries can attain economic growth. These distributional aspects also depend on working conditions, how much workers are paid and on how the final consumer price is subsequently divided among the different parts of the supply chain.

With more globalised systems, consumer awareness and knowledge of the economic, social and environmental impacts of their purchasing decisions can be limited, as they are less directly confronted with these impacts. As a consumer, it becomes more complicated to know whether one is a responsible buyer or not.

The environmental impacts do not solely depend on the distance the food travels (often termed 'food miles'). The intensity of production and farming practices also plays a key role. When it comes to

([16]) See, for example, Cleveland, 2015; Desrochers, and Lusk, 2015; Scharber, and Dancs, 2016.
([17]) Comparative advantage is defined as the ability of a country to produce a good at a lower cost than another country.
([18]) Countries trade to take advantage of their respective specialisation in a particular food area, which allows large-scale production.

Map 5.2 **The international trade flows of fruits and vegetables between the EU-27 and the rest of the world, 2010–2014**



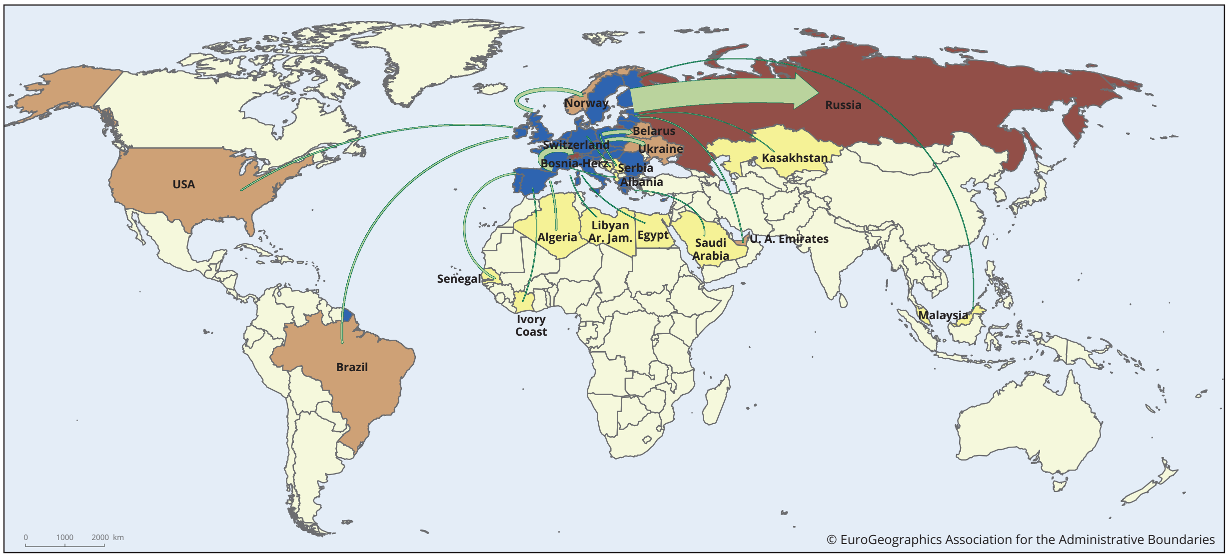
Fruits and vegetables import, EU-27

Countries and territories representing 80 % of the total quantity of EU imports (minimum 1 %)

200 Ktonnes   400 Ktonnes   800 Ktonnes

Value of EU imports for countries

Million EUR   ≤ 500   500–1 000   > 1 000   Not included



Fruits and vegetables export, EU-27

Countries and territories representing 80 % of the total quantity of EU exports (minimum 1 %)

100 Ktonnes   300 Ktonnes   1 000 Ktonnes

Value of EU exports for countries

Million EUR   ≤ 100   100–500   > 500   Not included

Note: The figures refer to the EU-27.

Source: European Commission, Agricultural trade statistics 2005–2014 (http://ec.europa.eu/agriculture/statistics/trade/2014/index_en.htm.).

food, simply reducing meat consumption, switching to different types of meat and cutting down on food waste may well reduce the GHG emissions related to food by a quarter (EEA, 2016a). Environmental impacts also depend on how the food is produced at different locations and how much energy, water, land, and pesticides are used in the production processes. Generally they are determined by the environmental sustainability of the whole supply chain, including production, storage, packaging and consumption. For this reason, the concept of 'food miles', which is sometimes proposed as a measure of the environmental impact of food production, is an imperfect measure (EEA, 2014).

The environmental impacts related to the different parts of the supply chain are very case specific. Therefore, no general statements can be made about the environmental advantage of producing food more locally or more globally. Some examples may help to underpin this.

One example looks at where tomatoes are grown and then subsequently transported. If consumers wish to have access to fresh tomatoes all year round, the choice is between imported vegetables or those produced in artificial conditions. Several studies ([19]) indicate that 'sourcing tomatoes in warm, southern countries seems more favourable from an energy perspective even if adding the extra burdens due to transport' (Payen et al., 2015). The studies compared local production with Moroccan or Spanish tomato production and delivery to markets in France or the United Kingdom. However, it is important to include other environmental impacts. For example, analysis reveals a trade-off between the energy-related impacts and the freshwater impacts of production if the production takes place in an arid climate (Payen, et al., 2015).

A second example is the market for apples comparing those grown in the EU with countries, such as New Zealand, much further away. Analysis found that even though maritime transport can bevery energy efficient per tonne-kilometre, the environmental costs to transport apples from New Zealand to the EU are very high due to the distances travelled (Rizet et al., 2012). If the environmental costs of growing apples are similar, local production would be more environmentally friendly in this case. On the other hand, other studies ([20]) show that New Zealand apples may have a better energy balance compared to local apples if local produce needs to be stored (with related cooling energy consumption) longer than six months. The latter would imply that local apples provide better balance from August to February while New Zealand apples may do so from March to July. Making the right environmental choice can be complicated.

The relatively low share (no more than 10 %) of transport in the final price of goods (Christidis and Brons, 2010) makes affordable access to food regardless of the season possible. For a transition to a more sustainable consumption and production pattern, the externalities created by the system, be it in transport or in the rest of the supply chain, should be reflected in the final price (EEA, 2014). This would encourage a correct trade-off by consumers and make sure that incentives are in place to make the supply chain cleaner.

Transporting large quantities of food from one point to another can actually be highly efficient. However, personal choices of transport mode — on foot, by bicycle, car or bus — to the supermarket and home may be much more important when estimating the environmental impact of the meals we eat. (EEA, 2016a).

5.3 Aviation and tourism

Tourism plays a major role in Europe and further afield and is a fast growing sector. The total (direct and indirect) contribution of travel and tourism to the EU's GDP was 9.9 % in 2015, and is projected to rise to 11.0 % of GDP in 2026 (WTTC, 2016).

GHG emissions related to tourism account for about 4.9 % of global emissions (with lower and upper limits of 3.9 % and 6 % respectively). Transport is responsible for 75 % of these emissions (Fischedick et al., 2014) meaning that tourism related transport contributes about 3.7 % of global GHG emissions. Travelling by car takes up the largest share of overall trips made by tourists and it has the largest impact on air pollution and noise (Peeters et al., 2007). However, in terms of GHG emissions, aviation has the largest impact. (Peeters et al., 2015).

([19]) Such as Payen et al., 2015; Webb et al., 2013, and studies cited therein.
([20]) https://www.ifeu.de/landwirtschaft/pdf/Langfassung_Lebensmittel_IFEU_2009.pdf.

A recent carbon footprint study for Dutch tourists (Eijgelaar et al., 2015) illustrates that the type of tourist trips has evolved since 2002.

- While the number of holidays ([21]) taken by Dutch tourists almost was the same in 2014 as in 2002, the total distance travelled increased by more than 33 %.
- In the same period the average CO_2 emissions per kilometre travelled improved slightly, mainly because of technological improvements in aviation.
- While the car is used for more than 70 % of the trips, its share in the total distance travelled is substantially smaller and decreasing: from 34.1 % in 2002 to 23.6 % in 2014.
- The share of air transport in the total distance travelled has grown significantly: from 57.5 % in 2002 to 71.9 % in 2014. Not only are the Dutch travelling more by plane, they also travel longer distances.

Such observations can be found elsewhere. The European Aviation Environmental Report 2016 (EASA et al., 2016) shows that, as of 2014, the number of scheduled and chartered passenger flights is similar to 2005 levels, but there has been a growth of 32 % in air passenger-kilometres between 2005 and 2014 ([22]). This is due to an increase in the mean distance per flight, a general trend towards longer flights and larger aircrafts, and increasing load factors (the proportion of seats that are occupied). The report points to a likely 45 % increase in the total number of flights by 2035 compared to 2014. Given these developments, this section focuses on the growing role of aviation in tourism.

In its long term outlook for 2050 Eurocontrol points to the level of economic growth and the extent of globalisation as two of the drivers for the evolution of aviation (Eurocontrol, 2013). Since the 1990s, the liberalisation of air transport, together with the growing importance of low cost airlines, especially after 2000, has made air transport more attractive. The number of routes and frequencies has increased. Many European regions have become more accessible as a result. It has also become easier to travel within Europe and to intercontinental destinations due to airports acting as hubs (Burghouwt et al., 2015). The report noted that all of these factors improved connectivity and were beneficial for trade, tourism and the broader economy.

However, these benefits have come at the price of higher emissions of some pollutants from air transport. Between 2000 and 2014 GHG emissions by European aviation ([23]) have increased by 12 % in spite of better fuel efficiency. NO_X emissions have risen by 20 %.

Both the evolution in distance travelled and modal choice play a role, with interdependencies between them. For distances below 500 km, aviation is rarely used, while for trips of more than 1 000 km, air transport becomes the dominant mode (EEA, 2014). In the case of distances between 500 and 1 000 km, it is realistic to state that travellers have a genuine choice between air transport and other transport modes ([24]).

The carbon footprint strongly depends on modal choice, as the specific climate impact of a passenger-kilometre may vary by a factor of 10 or more. Figure 5.2 presents the CO_2 emissions per passenger-kilometre of different transport modes, using an average loading factor.

In order to mitigate the environmental impacts of these growing air flows, the EU and its aviation sector are considering a number of policy options. These may consist of technological measures for aircraft, the uptake of alternative fuels, the improvement of air traffic management and operations, environmental measures taken by airports and the provision of the correct incentives via market based instruments (EASA et al., 2016).

Tourists can also reduce their environmental impact by travelling to closer destinations, staying a longer time at each destination instead of making frequent short trips, and asking for voluntary carbon offsets ([25]). These fundamental changes in consumer behaviour require that tourists are increasingly aware of the environmental costs of their decisions and that they act accordingly.

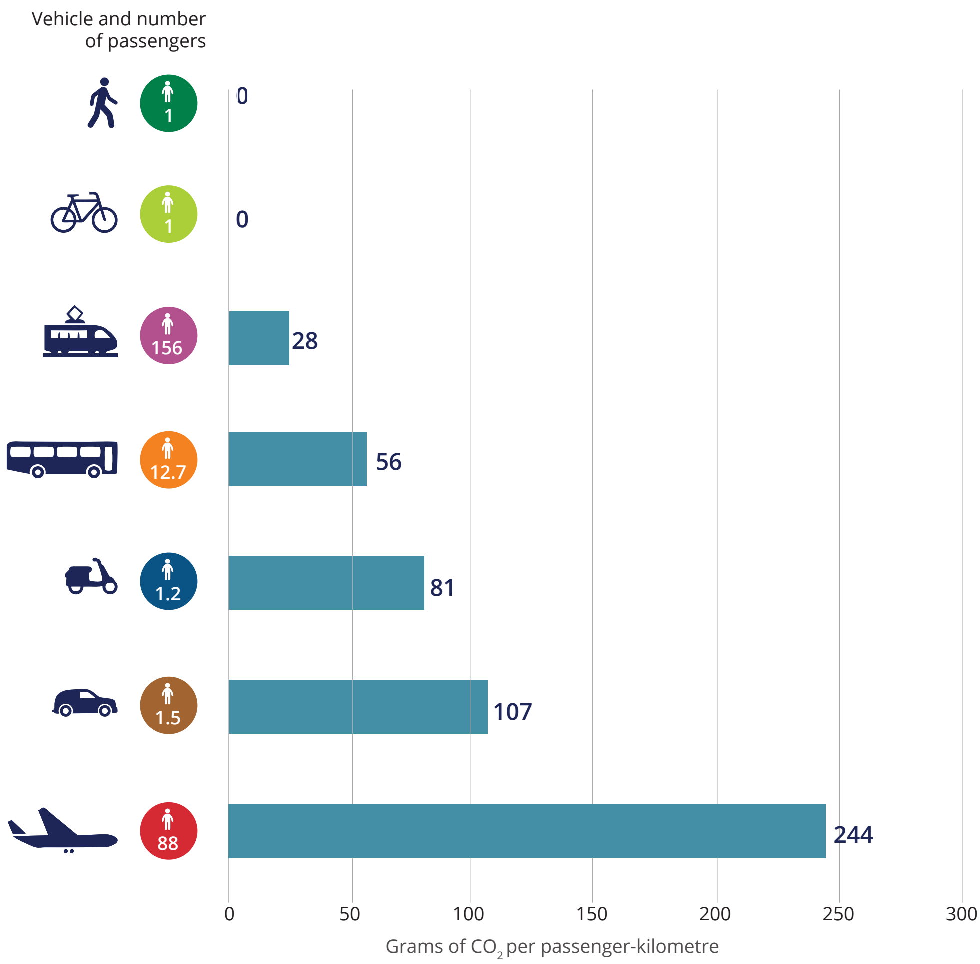
The outlook for the evolution of air transport as reported by Eurocontrol (Eurocontrol, 2013) and EASA (EASA et al., 2016) indicates that there are significant

([21]) In the study, a holiday is defined as a stay outside one's own home for recreation or leisure. A stay in the home country with family, friends or acquaintances is not included, unless the hosts are absent for most of the time.
([22]) The coverage in EASA et al. (2016) is all flights from or to airports in the EU and the European Free Trade Association (EFTA).
([23]) EU-28 domestic and international flights (i.e. intra-EU and from or to the EU) flights. See TERM 02 and TERM 03.
([24]) See EEA 2014 (Chapter 5) for a discussion of the driving forces of modal choice in long-distance passenger transport in Europe.
([25]) Carbon offsetting is a way to 'neutralise' carbon emissions on a particular journey by investing in carbon reduction projects.

challenges to come. The study by Eurocontrol projects a growth in take-offs and landings by 20 % to 80 % for 2035 and by 10 % to 170 % in 2050 ([26]), depending on the scenario considered. The scenarios take into account external driving forces, such as economic growth and the extent of globalisation, as well as the degree of regulation necessary to reconcile the environmental, social and economic demands. The study states that 'another big challenge going forwards will be to decouple aviation resource use from economic growth by using less oil fuel products and reducing environmental impact, and yet maintain an environment where economies continue to grow, where necessary mobility is still available' (Eurocontrol, 2013).

Some goals do exist for the environmental performance of aviation. Members of the International Civil Aviation Organization (ICAO) have already agreed to a goal of carbon-neutral growth by 2020. The ICAO is also committed to designing a global CO_2 emissions offsetting scheme that could be implemented from 2020. Aircraft and their engines must meet international

Figure 5.2 Specific CO_2 emissions at average occupancy for various transport modes, 2014



Note: The addition of more passengers (the loading factor) results in fuel consumption — and hence also CO_2 emissions — penalties as the vehicle becomes heavier, but the final figure in grams of CO_2 per passenger is obviously lower. This effect is significant for CO_2 emissions from passenger cars and two-wheelers. For other vehicles, which are generally much heavier, this effect is insignificant. The inland ship emission factor is estimated to be 240 g CO_2/km, but data availability is still not comparable with that of other modes.

Own estimations based on the UNFCCC and the EU Greenhouse Gas Monitoring Mechanism (see TERM 02 indicator) and total activity (pkm) from DG MOVE pocketbook 2016 (DGMOVE, 2016). Rail emissions include those from diesel and electricity powered trains at European level compiled by the International Union of Railways (UIC). PRIMES is used for aviation CO_2 emissions. Linear interpolation of the PRIMES data, available in five-year steps, is needed for the intermediate years.

([26]) The scope of the study is broader than tourism related traffic, as it considers all passenger traffic (not only that related to tourism) as well as air cargo.

standards for noise and pollutant emissions. Additional standards for CO_2 and PM are currently being developed and are expected to enter into force in the near future (EASA et al., 2016).

Advanced biofuels are currently the only low-CO_2 option for substituting kerosene, pending further progress with the electrification of aircraft. The 2011 Transport White paper set a goal for low-carbon sustainable fuels in aviation to reach 40 % by 2050. However, the development of biofuels in aviation is very slow, is still facing technical hurdles and cannot yet compete with kerosene to be economically viable (EC, 2016d), giving the current tax-free status of kerosene (EEA, 2015b). An important window of opportunity may be the option to produce renewable jet fuel using renewable electricity, known as Power-to-Liquids (PtL). A recent study from the German Environment Agency demonstrated the clear environmental benefits of PtL when using electricity, CO_2, and water from renewable sources to produce it (UBA, 2016).

As shown in TERM 2015, the EU has also considered revising the current tax-free status of aviation fuel. This was raised by the ICAO during the organisation's annual meeting in 2001. Debates highlighted difficulties in reaching an agreement. The option of taxing fuel in Europe gives rise to concerns about competition between European air companies and third country operators. Air transport also benefits from no VAT for intra-EU and international flights, whereas some Member States apply VAT to intra-EU coach and rail passenger services. This variety further distorts competition in intra-EU travel.

Until now, the use of economic instruments for aviation in the EU has been limited to the inclusion of aviation in the European Trading System. Following the agreement by the ICAO in October 2013 to develop a global market-based mechanism addressing international aviation emissions by 2016, the EU suspended the ETS requirements for flights to and from non-European countries in 2012 (Decision No 377/2013/EU).

6 Lock-ins and barriers for a change

Key messages

There are a number of elements that prevent systemic change towards sustainability. Some of them can be defined as barriers, which can be overcome given the right solutions at hand, whilst others stem from past decisions or pathways that have locked the system into a particular technology or product.

Interests of incumbents in dominant technologies, the long lifespan of ships and aircrafts, the slow decision-making processes in the international transport sector and rebound effects are all examples of barriers for sustainable mobility.

System lock-ins include current investments in improving internal combustion engines, rather than shifting these resources to zero emission cars, and policies that still favour the use of diesel in Europe are examples of system lock-ins. Investments in carbon intensive electricity generation may form a lock-in as part of a transition towards electrical mobility, due to the long life-time of consequences from today's decisions.

Due to the current road hegemony in passenger and freight transport, most infrastructure investments are in roads. This reinforces our car and road dependency and hampers investments in more sustainable modes of transports.

As shown in Chapters 2 and 3 the transport sector is and will most likely be a major source of GHG emissions. Incremental improvement in the sector has so far been the preferred method to achieve GHG reductions. Yet, in the long run, improving the efficiency of existing transport modes will not lead to GHG reduction targets if the growth in transport activity continues and the current modal split remains unchanged. To reach the 60 % GHG reduction goal, a transition towards a low carbon transport system is necessary and requires determined actions at different levels. This is also the case for other transport related pressures.

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Various barriers and lock-ins may obstruct the necessary systemic changes. Barriers in this context are defined as current problems that hamper a successful transition towards sustainable mobility, but can be overcome. Additional elements hampering change stem from past decisions or pathways that have locked the system into a particular technology or product that it is not desirable in the long term. More determined decisions are needed to transform the system, or its dominant regime, into sustainability. Industrial economies, and society itself, have been locked in to fossil fuel-based energy systems through a process of technological and institutional co-evolution. This lock-in, has created persistent market and policy failures that can impede the spread and use of carbon-saving technologies despite their environmental and economic advantages (Unruh, 2000).

Being aware of the similarities between barriers and lock-ins is essential so that policies can be designed to overcome and avoid them. This chapter discusses a selection of the barriers and lock-ins impeding a pathway to sustainable mobility.

6.1 Lock-ins

6.1.1 The petrol and diesel-powered internal combustion engine (ICE) is the principal source of automobile propulsion

One of the most important historical lock-ins has been the establishment of the petrol and diesel-powered internal combustion engine (ICE) as the source of automobile propulsion. When looking into alternatives for the horse and carriage to propel vehicles at the beginning of the last century, steam, electric and petroleum products options were competing. As explained in the article *Understanding carbon lock-in* (Unruh, 2000), there was no single reason for the establishment of the ICE as the dominant design, but rather it was considered the least promising option, being the most noxious, noisy, complicated and dangerous alternative. Among other reasons, the relative cheap cost of gasoline, seen as a hazardous by product from the production of kerosene, clearly played a role. Once established, cars driven by an ICE, and subsequent mass production, entered a period of increasing returns to scale, driving prices down, improving performance and locking-in the ICE as the dominant propulsion design.

6.1.2 Current transport patterns are dominated by road transport and car use

Over time, land use patterns have changed to reflect car use. European cities, originally organised to cater for non-motorised transport needs, started to accommodate the new emerging mode. Shops and services have moved to car-accessible locations, national governments spend more on road infrastructure than on infrastructure for all other modes together. These road investments formed a lock–in, hampering sustainable mobility in two ways: firstly, these road infrastructures influence our behaviour, and therefore reinforce our car-dependency and, secondly, money spent on highways cannot be spent on other, more sustainable forms of transport.

Funds for improving accessibility are often reserved for investments in transport networks which reduce travel time by increasing travel speed. However, travelling at higher speeds encourages longer trips and therefore increases energy use and environmental pressures. Another way to reduce travel time is to reduce distances, for instance by designing high density urban areas with mixed amenities. As pointed out in Chapter 5, urban developments favourable to lower GHG emissions do not receive adequate support.

6.1.3 Aversion to change

There is a natural resistance to change, that can encourage the use of a technology or service that is familiar, even though better ones may be available. This phenomenon is known as the cognitive lock-in (see e.g. Johnson et al., 2003; Murray and Häubl, 2007) that makes the introduction of a new technology more difficult, especially when the dominant option is intrinsically embedded in the current regime. Cities, and their use of land, as well as citizens have all adapted to the dominance of cars within the transport system. It could be argued that as a result of this adaptation and even acceptance citizens actively resist efforts to improve their environmental and social situation (Unruh, 2000). In the case of ICE cars versus electric vehicles (EVs), doubts about the ability of the system to provide adequate recharging points and issues to do with range, as well as lack of information about the benefits of electric vehicles for the user, intensifies a lock-in towards conventionally fuelled cars.

6.1.4 Resistance from transport operators and state confined systems

Protectionist barriers act as serious obstacles for cross-border and multimodal travel, and are viewed as examples of lock-ins due to the heavy investments needed. This is obvious in the case of rail transport where the dominant rail operators had generally been state-owned (referred to as state confined systems). In order to increase competition the EU has made significant efforts to separate the management of passenger and freight transport services; and infrastructure management activities. The EU is also looking for assurance that no financial transfers took place between those activities. Court cases are ongoing (see EC, 2016d). In January 2013, the Commission put forward its Fourth Railway Package that proposes to open up domestic passenger markets to competition and to remove the remaining legal, institutional and technical obstacles in order to increase the performance of the railway sector and its competitiveness.

New approaches such as the so-called 'seamless transport' and 'synchronised logistics' options face resistance from transport operators who prefer not to share their timetables and other information (EC, 2016d).

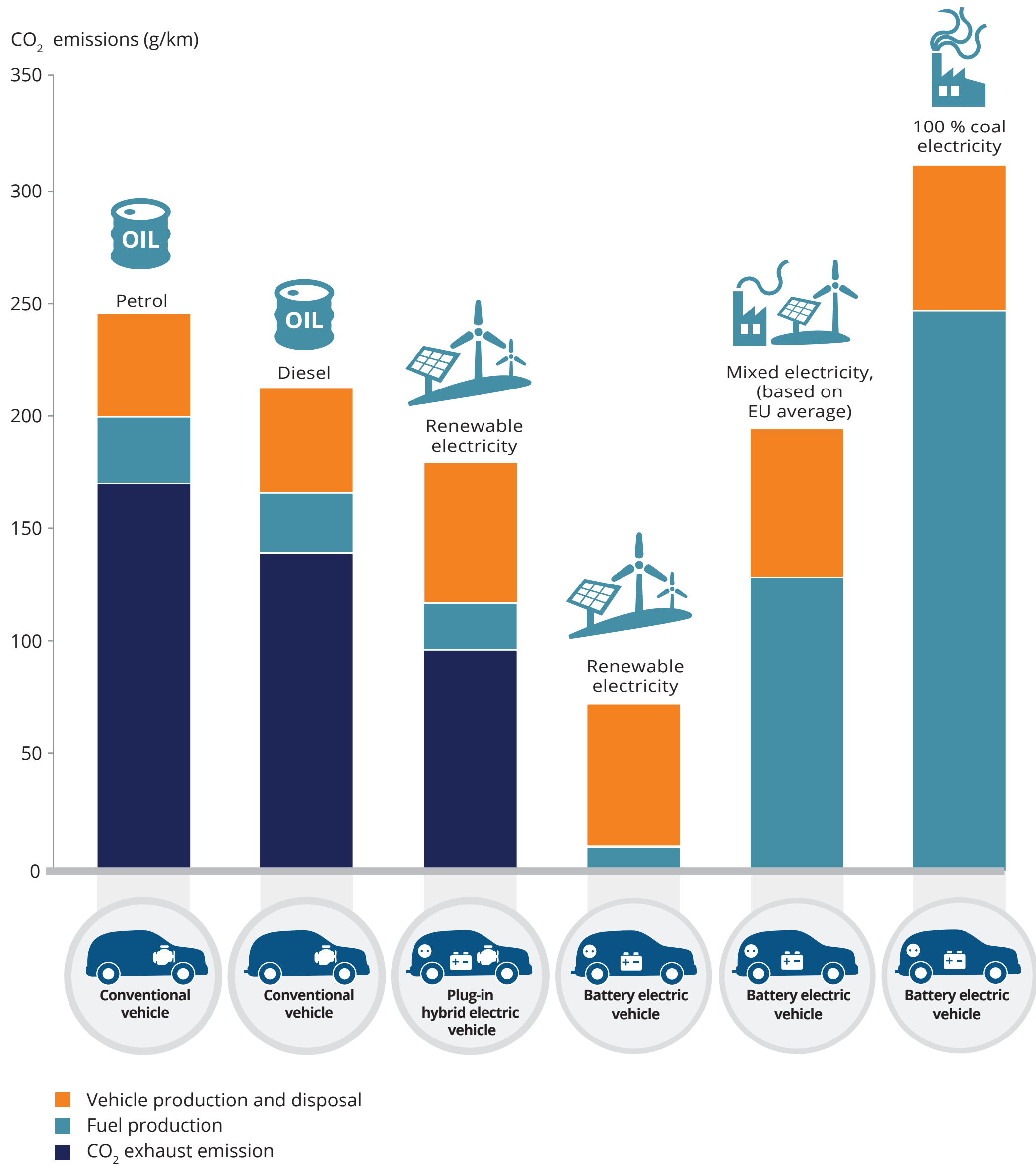
6.1.5 Lock-ins in other sectors

A sustainable transport system is closely connected to the energy system. Replacing conventional vehicles with EVs can help reduce emissions, although this is dependent upon the source of the electricity used to charge vehicles, i.e. from renewable sources, nuclear or fossil fuel (EEA, 2016g).

The reduced emissions during the electric vehicle's lifetime are considered to outweigh the environmental effects of the production and end-of-life phases. Electric vehicles can therefore significantly reduce the adverse environmental effects of conventional passenger vehicles, as long as the electricity is from renewable sources. Illustrating this, a recent Dutch study compared relative emissions across the lifetime of different types of vehicles, from their manufacture to disposal (TNO, 2015). The study clearly showed the differences in estimated lifecycle emissions for mid-size conventional cars, PHEV and BEV, and the importance that the source of electricity, ranging from 100 % renewable through to a hypothetical 'worst-case' 100 % coal combustion, has on these categories (Figure 6.1).

Investments in carbon intensive electricity generation may form a lock-in for a transition towards electrical mobility, as these plants have long life-spans and obstruct low-emission mobility. Much of the EU's coal-based power capacity is near the end of its lifetime. At present, operators tend to extend the lifetime of their fossil fuel capacity. If this continues, this

Figure 6.1 Range of life-cycle CO_2 emissions for different vehicle and fuel types



Note: The values are estimated for an average mid-size vehicle, based on 220 000 km.

Source: EEA, 2016g, TNO, 2015; authors' own calculations.

Box 6.1 Underused airports as an example of lock-in the tourism and aviation sectors.

Airlines may be offered a range of incentives for operating at certain airports or serving certain destinations, and some airports may receive state aid from public authorities for new investments or to support operations. Allroggen et al. (2013) provides a review of a sample of 194 European airports, finding that incentives are a part of the charge-setting strategy of airports, and that they are also influenced by external factors. The particular fiscal system of air transport, with no fuel taxes, and VAT being applied only in a handful of European countries, has an influence on the ability of air operators to compete for leisure travellers (EEA, 2014).

Financing and provision of airport infrastructure by the public authorities must comply with EU rules on state aid (EC, 2005). Aid may be justified and declared compatible provided it meets an objective of general interest, such as regional development or accessibility.

The European Court of Auditors published a report that revealed that EU-funded investments in airports did not generate the expected results (i.e. in terms of traffic and revenue or in terms of the expected economic impact on the area) and produced poor value for money. Because of an absence of adequate planning and forecasting, some of the funded airports were situated too close to one another, while some of the construction projects were too big for the numbers of planes and passengers involved (ECA, 2014).

The worst examples are the so-called 'ghost airports' where large sums of money, in some cases EU funds, were spent on improving the infrastructure at regional airports, but where flights did not actually take place. The paradox is that, while there is a well-developed and extensive airport network in Europe, many airports are severely congested, whilst others are clearly underused. This raises serious concerns about how predicted growth in the aviation sector will be managed. Better strategic planning at the EU level is needed which is a key objective of the EU's Aviation Strategy for Europe (EC, 2015a).

Public funding received by these underused airports have increased the environmental pressures from aviation while failing in improving regional development or accessibility. The solution for these airports, and the environmental consequences of the potential increase in traffic because of the lack of capacity at major airports, is still to be seen.

would be incompatible with the EU's decarbonisation efforts (EEA, 2016i). Moreover, energy companies have invested significantly in fossil fuel distribution systems. As these costs have already been allocated it makes them reluctant to invest in distribution systems for new energy carriers.

Alternatively, future reductions in energy demand in other sectors, for example as a result of improved energy efficiency, could counterbalance all or part of the additional electricity demand from electric vehicles (EC, 2016c).

6.2 Barriers

6.2.1 Existing interests of car manufacturing industries and other stakeholders

The interests of the incumbent car manufacturing industries, amongst other interested groups, may stand in the way of necessary changes to the transport system. Changing certain products or production methods may come at a cost. However, one can also argue that as the most profitable companies generate most of their own capital, this in turn often goes towards improving and strengthening the products they sell (Unruh, 2000).

The reaction of major German automobile manufacturers to external pressure to deliver more fuel- efficient cars has been studied in a 2015 article *'Understanding the drivers of fleet emission reduction activities of the German car manufacturers'* (Mazur et al., 2015). They found that activities related to niche technologies that were new to the manufacturers only occurred when induced by internally 'disruptive' events such as the appointment of a new CEO. Other studies have stressed that 'innovation champions' or 'change agents' play an important role with regard to disruptive changes (Benn et al., 2006; Howell et al., 2005).

However, in order for change agents to initiate niche related activities, the presence of sufficient pressure from outside (such as mandatory fleet CO_2emission targets to replace the automotive industry's voluntary agreements) is a necessary condition. Yet, the influence of regulatory policy on the selection of particular disruptive technologies by the automotive industry is limited, in line with the 'technology neutral' approach. The industry determines its own path or technology. This can differ across companies even though they are seemingly in the same position and are subject to the same rules. In the absence of significant external pressures, the car manufacturers did not seek niche technologies (Budde et al., 2012;

Konrad et al., 2012; Wesseling et al., 2015). Typically, they respond to pressures such as fleet emission regulations with incremental technologies created through the combination of internally available solutions. This is in line with the conclusions from the evaluation of Regulation (EC) No 443/2009, which introduced mandatory CO_2 emission performance standards for new passenger cars (EC, 2015b). Data show that the introduction of the CO_2 regulation for cars in 2009 sped up the average annual improvement in energy efficiency/CO_2 emissions of new cars, compared with the previous approach which was based on a voluntary agreement (EEA, 2015b).

Other incumbent interests may also play a role. For example, in the case of preferential tax treatment for company cars, reforms could consist of moving toward tax neutrality, thereby taxing this benefit as any other source of income. How company cars are taxed often allows employers to circumvent high labour taxes. Reforms are therefore likely to meet opposition from incumbent interests, unless they are formulated as part of a more comprehensive reform of labour taxation (EEA, 2015b). The relevance for the environment is that such a preferential tax system leads to greater distances being driven than might otherwise have been the case, often by larger and less efficient cars. It is important to highlight that company cars made up 64 % of new car sales in Germany in 2014 (Kraftfahrt-Bundesamt, 2015), and about 50 % of European new car sales (Copenhagen Economics, 2010).

6.2.2 The long lifespan of transport vehicles

In 2014, air and waterborne transportation (including international bunkers) accounted for 26.1 % of EU transport GHG emissions. Airplanes and particularly ships have very long lifespans. Seafaring vessels typically remain in service for several decades (Ricardo AEA et al., 2013). Ships that are being built now will still be in service by 2050 and although they have to comply to a minimum standard of the Energy Efficiency Design Index (EEDI), greater improvements in the energy efficiency of new ships are still feasible (Faber, and 't Hoen, 2015). Therefore mechanisms in place do not put enough pressure on the maritime sector to reduce their emissions and hampers a transition towards a low-carbon transport system. The EU´s vision is that international shipping emissions are best addressed at the global level. In view of this the EU adopted a strategy in 2013 to initially monitor, report and verify shipping emissions and which stated the preference for a global scheme to be potentially adopted by the International Maritime Organisation (IMO).

6.2.3 Environmentally harmful subsidies

Environmentally harmful subsidies (EHS) may be defined as the '*result of a government action that confers an advantage on consumers or producers, in order to supplement their income or lower their costs, but in doing so, discriminates against sound environmental practices*' Withana et al. (2012).

The use of direct or indirect subsidies in the transport sector is widespread across the EU (EEA, 2015b). Some of these subsidies serve to encourage consumer or business behaviours that are harmful to the environment. Examples of such subsides include tax breaks for company cars and subsidised commuting expenses, the tax concession for diesel fuel (generally taxed below petrol in EU countries) and tax exemptions for fuels used in international aviation and navigation. The actual extent of the harmful environmental effects observed as a result of such subsides often depends on various technical details and how they have been implemented.

Compared to petrol, diesel fuel has high CO_2 emissions and releases more air pollutants such as NO_X and PM per litre of diesel used compared to one litre of petrol. This does not justify the lower tax rates it has been allocated in most EU countries (apart from the United Kingdom). From an environmental point of view, the level of tax needed to reflect these environmental costs should be higher for a litre of diesel than for a litre of petrol (EC, 2016c). The lower tax on diesel fuel was an instrument intended to favour commercial road transport, but it also applies to private cars (UBA, 2014a). It not only leads to more GHGs and other air pollutant emissions, but it also gives road freight a competitive advantage compared to other modes. This is because lower taxes on diesel reduce costs and thereby increases their share of the overall traffic volume, creating little incentive to invest in innovative, efficient drive systems or low carbon fuels.

6.2.4 Decision making processes

The EU decision-making involves three main institutions. The European Commission proposes new laws, but it is generally the Council together with the Parliament that adopts them through the ordinary legislative procedure, also known as 'co-decision'. In 2011, the European Commission proposed a revision of the Energy Taxation Directive (COM(2011)169), which distinguished CO_2 and energy-related components in the excise duty. One of the aims was to remove the price advantage for diesel both at the minimum level as set by the EU and in the final rates as set by the Member States, which would have had a rebalancing effect on supply and demand on the fuel market. The European Commission ultimately decided to withdraw the proposal (alongside a proposal for a Directive on passenger car related taxes) due to a lack of political consensus in the Council. In the case of the alternative fuel package a mandatory minimum number of recharging points proposed by the European Commission for each Member State was removed in the course of the negotiations.

Beyond the EU, international agreements are needed to support transitions towards sustainable aviation and maritime transport, yet may themselves be barriers to this process. Efforts to reduce emissions, and associated policies, such as fuel taxation, are less meaningful if not decided at an international level and will lead to progress towards GHG emissions reductions.

6.2.5 The cost of electric vehicles

The purchase cost of electric vehicles is currently higher than the cost of ICEVs. However, the higher purchase price of electric vehicles is typically partly offset by lower fuel costs (see Box 6.2). The principal barrier to greater update of EVs is their perceived high purchase price compared to an ICEV. This difference can be up to EUR 10 000 (Hacker et al., 2015), mainly caused by the high battery price. Many EU Member States try to overcome this barrier by offering financial and non-financial incentives to potential customers, existing owners and other users on a temporary basis (EEA, 2016g). In the long run, this barrier may be overcome by the expected decrease in battery costs.

If vehicles become more fuel efficient, they become cheaper to drive meaning we may drive more often. This might give a significant rebound effect, causing more mobility and thus lowering environmental pressures to a lesser degree than previously expected. Although there is general agreement that rebound effects exist, opinions vary on their size and causes (Dimitropoulos et al., 2016). Based on a literature review, Dimitropoulos et al. (2016) suggested that 25 % to 27 % of expected CO_2-savings due to driving more fuel-efficient cars is 'compensated for' by the rebound effect in the short run. In the long run, the rebound effect is even 15 to 17 percentage points higher. Restructuring our car-related taxes, taxing the use of a car more heavily (and taxing car ownership less), is generally seen as one of the few ways to diminish the rebound effects.

The cases described here are examples of barriers and lock-ins that may hamper a transition towards sustainable mobility. More, or other, instances than the ones described here may occur. Some of them will occur under specific circumstances only, as there is a certain path-dependency in the lock-ins and barriers described. In most cases, there is a distinct role for governing bodies, whether local, national or European. If they want the transition to succeed, it is of the utmost importance that they are aware of the problems ahead and of the possibilities to counteract them.

Box 6.2 Total cost of ownership

Total cost of ownership (TCO) is a measure designed to include all costs of owning a car from when it is purchased (financing, fees and taxes) to the time it is sold or passed on (residual value), including operating costs (fuel, insurance, repairs, fees and taxes, and maintenance). The higher purchase price of electric vehicles is typically partly offset by lower fuel costs. If the electric vehicle is used frequently, then its lower running costs are even more favourable. Estimates of the difference in TCO between electric vehicles and conventional vehicles vary widely, from about EUR 5 000 to EUR 20 000 per vehicle (over four years with an annual mileage of 20 000 km), depending on country, type of electric vehicle model, fuel prices and other variables (McKinsey, 2014).

A number of country-specific factors can, however, further improve TCO for electric vehicles. These include tax exemptions, reduced electricity prices and proportionally smaller costs for charging infrastructure (Hacker et al., 2015).

Electric vehicles can deliver additional advantages if combined with measures such as:

- smart charging, leading to potentially lower electricity prices for consumers;
- car sharing;
- intelligent fleet management.

TCO is clearly affected by changes in government policies such as withdrawing incentives for electric vehicles or, conversely, higher taxes on conventional fossil fuels in the road transport sector.

Source: EEA, 2016g.

7 Niches and policies that can create change

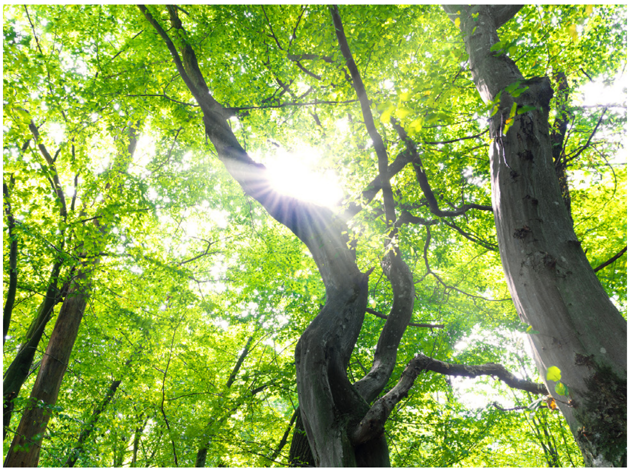
Key messages

In recent years, important technological developments and innovative business models have arisen that could lead to a drastic overhaul of the transport system. Among these are the 'shared mobility' concept — using a mix of shared transport options, driverless cars and alternative fuel vehicles.

The market for shared mobility is growing fast. Currently, users of shared mobility solutions tend to exhibit more sustainable travel behaviour. Shared automated vehicles could also deliver more environmental benefits, but deployment is still in a very early stage.

Electric cars are already a mature option. They currently give opportunities for car sharing as issues such as range limitations are less of a concern whilst the higher purchase costs of electric cars matter less if the vehicles are shared.

The first and the last miles of a journey using public transport take up a significant share of the overall time travelled. Local governments should partner with shared mobility providers to solve this problem and to invest in infrastructure. This will improve the ability of public transport to compete with other travel modes and improve its overall environmental performance.



The demand for mobility partly stems from lifestyle and habits. This chapter discusses a number of developments in the mobility sector that have the potential to change travel behaviour. They all fall within the concept of 'niches' as previously defined. They have emerged as the result of changes in the ICT sector and other innovations in mobile telephony, data technology, machine learning and battery technology which took place outside of the transport sector. The car industry is also starting to adopt these products and business models but industry outsiders were the first to adopt these developments.

Developments that will be discussed in this chapter include the strong growth in the market for shared mobility, the likely breakthrough of alternatives to the internal combustion engine in the coming decades, especially EVs, and the development of driverless vehicles.

In recent years, thanks to developments in ICT, there has also been a shift in emphasis in network development, both for passenger and freight transport, from physical connectivity towards service connectivity. The concept of multimodality has been transformed to allow for synchromodality (Pfoser et al., 2016), i.e. where service schedules and operations amongst modes of transport bring opportunities to both users and service providers. Synchromodality also helps reducing the environmental pressures through an optimization of demand. In the freight sector this can also influence operations taking place in the terminals (including transhipment and storage of containers) leading to seamless operations, reduced waiting times and intermediate storage, and reducing overall transportation costs (Tavasszy et al., 2015).

7.1 Shared mobility

Developments in IT technologies have led to new business models which have the potential to rewrite the rules of mobility including a focus on options for sharing, both for private and public transport, especially in cities (EC, 2016c; Roland Berger, 2014; ITF, 2016).

How these changes in ICT can impact on the environment are still to be fully understood. Optimism in these changes is well founded since shared mobility services are based on some of the key principles to achieve sustainable mobility: increasing the efficiency of the system through better use of the available infrastructure, and higher vehicle occupancy. Shared mobility has the potential to lower the average age of vehicles (due to more intense use) which in turn encourages the uptake of new and cleaner technologies. Non-motorised transport use, such as the bicycle and walking, may also benefit, since more efficient use of space can support the use of these forms of transport. It is worth pointing out that a wider uptake of on-demand mobility may mean citizens use less public transport, and which may result in an increase in emissions (EC, 2016c).

Shared mobility covers a wide range of services, ranging from established options such as car sharing, carpooling and bicycle sharing to more recent services, such as on-demand rides. In broader definitions, it also includes smartphone apps that enable the implementation of such services.

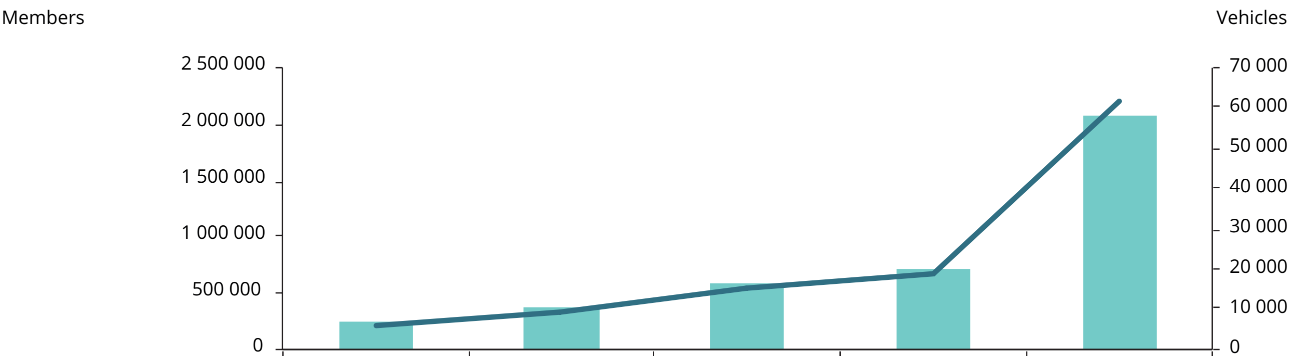
7.1.1 Forms of shared mobility

Car sharing

Compared to traditional car renting, the distinctive features of car sharing are the emphasis on short term access to the car and on the possibility for the members to access the cars without having to visit the rental organisation. There is also a clear differentiation between station based car sharing and free-floating car sharing ([27]).

The two largest operators in this market segment, Car2Go and DriveNow, operate in dozens of cities in Europe ([28]) and North America. The rapid growth of car sharing in Europe is illustrated in Figure 7.1 The growth from around 250 000 members of car sharing systems in 2006 to more than 2 million in 2014 is significant.

Figure 7.1 European trends in car sharing



	2006	2008	2010	2012	2014
Vehicles	7 491	10 833	16 779	20 464	57 947
Members	212 124	334 168	552 868	691 943	2 206 884
Membership growth rate		26 %	29 %	12 %	79 %
Fleet growth rate		20 %	24 %	10 %	68 %
Member-vehicle ratio	28.3	30.8	32.9	33.8	38.1

Members   Vehicles

Source: Shaheen and Cohen, 2016.

([27]) Station-based car sharing requires the user to pick up the car and return it in a specific location while the free floating system allows the user to pick up and return the car in a much wider area (i.e. within the city's limits).

([28]) As of January 2016, Car2Go was active in the following European cities: Düsseldorf, Hamburg, Amsterdam, Vienna, Madrid, Berlin, Cologne, Stuttgart, Munich, Milan, Rome, Florence, Frankfurt, Stockholm, Turin and Prato. DriveNow operates in Berlin, Cologne, Copenhagen, Düsseldorf, Hamburg, London, Munich, Stockholm and Vienna.

Box 7.1 Car sharing and sustainable outdoor tourism

Car sharing operators can develop partnerships to find new sources of revenue. One example is a car sharing scheme that the Co-wheels Car Club set up with Cumbria County Council, the Lake District National Park Authority and Cumbria Tourism in the United Kingdom. The scheme offers Renault Twizys, a two-person electric vehicle. These vehicles are agile, compact and lightweight, and offer tourists a possibility to visit the Lake District with minimal impact on the local environment (Intelligent Mobility Insight, 2016).

Car sharing operators are often integrated through a partnership with public transport. In Copenhagen members of one car sharing scheme can use their public transit cards to rent one of the 100 % EVs.

However, membership still amounts to just around 0.5 % of the driving age population. In the absence of aggregate data on the use of shared cars, membership rates are the best indicator available, however they are at best a very rough indicator as regards the importance of this market.

On-demand ride services ([29])

The traditional taxi market is being profoundly disrupted by the rise of Transportation Network Company (TNC) services, with Lyft and Uber being two well-known examples. Such services use smartphone apps to connect passengers in real time to drivers.

The success of TNCs is attributed to a large extent to the 'efficiency and reliability of the matching platform and pricing mechanisms, along with the accountability of the rating system'. (Rayle et al., 2016) Evolutions in this industry, such as the use of the app to connect customers with drivers, (Shaheen et al., 2015) are being replicated by competitors, such as the taxicab market, to bring down waiting times for taxis. Both TNCs and some traditional taxicabs also offer 'ride-splitting', which consists of sharing a ride with someone else. TNCs increasingly offer parcel delivery as an additional service. Such synergies between passenger transport and delivery of small loads could improve load factors in urban freight without increasing vehicle routes and travel times of freight delivery vehicles. Public transport companies and agencies can also cooperate with TNCs to take advantage of their selling points (such as the high door-to-door flexibility) to complement their own strong points (such as their capacity to move large quantities of people). For instance, the Pinellas Suncoast Transit Authority in Florida has started a six month pilot subsidizing half an Uber ride to or from a transit station. In order not to exclude riders without smartphones or credit cards, the agency also works with a taxi company (Spector, 2016).

There are many positive examples of integrated transportation network platforms, which offers on-demand ride services including public transport, taxi, car sharing and bike sharing. Mobile trip planning apps may play a crucial role in the provision of the information that is needed to plan trips, especially multimodal trips or trips involving shared mobility (ITS America, 2015). Such apps can enable the use of shared mobility, but also improve the competitive position of public transport by providing real time information and allowing for electronic ticketing.

Box 7.2 Mobility as a Service (MaaS)

One of the emerging examples providing tailored services is the Swedish start-up Ubigo, which purchases access to various different forms of transport from the providers themselves and then offers the potential to households to combine this mobility on one single platform. This is being referred to as Mobility as a Service (MaaS). Households can subscribe to prepaid packages that are tailored to their needs for each participating mode (public transport, car sharing, car rental, taxi). If households exceed their budget, they are billed for the additional trips. ICT, payment, ticketing and car access are integrated in a single app (ITF 2015a). These services were tested in Gothenburg between November 2013 and April 2014 in a pilot project involving 70 households. The pilot project revealed that one of the main challenges in setting up MaaS services is to convince public transport authorities about the benefits of them participating in a concession/reseller agreement. The project is now about to be rolled out on a larger scale in at least one other city in partnership with Ericsson ([30]).

([29]) Also referred to as ride-sourcing, TNCs, ride-hailing, and ride-booking.
([30]) E-mail correspondence with Hans Arby of Ubigo (9 June 2016).

Box 7.3 Partnerships between 'official' public transport and a micro-transit service provider

One interesting experiment is taking place in in the United States in Kansas City. In February 2016, a one-year pilot project was announced as a partnership between the Kansas City Area Transit Authority (KCATA), Ford and Bridj. The latter is a company which provides a 'mobile application that enables customers to request a ride in select neighborhoods (...). After the Bridj system receives pickup requests, its algorithm sets a central passenger meeting spot (...). Customers then walk to the meeting spot and share a ride with other passengers that have a similar route or destination as defined by the algorithm.' (Shaheen et al., 2015). In the Kansas City pilot, residents will be able to reserve seats on Bridj vehicles (Ford vans), using the Bridj app, but driven by KCATA employees. One option that has been considered to make the system accessible for people without smartphones or credit cards is to distribute phones with limited capability beyond using the Bridj app (Marshall, 2016).

The next step is the move to Mobility as a Service (MaaS). With such systems 'consumers can buy mobility services that are provided by the same or different operators by using just one platform and a single payment. The platform provides an *intermodal journey planner* (...), a *booking system*, a *single payment method* (single payment for all transport modes), and *real time information*.' (Kamargianni et al., 2015).

In many US jurisdictions, alternative transport services exist in parallel with 'official' public transport. Such services target communities with low car ownership rates with less access to public and private operators, connecting residential areas with business areas. The term 'micro-transit' refers to technology-enabled services which allow for flexible routing and timing, or both (Shaheen et al., 2015).

Ridesharing

Ridesharing refers to what is commonly known as 'vanpooling' or 'carpooling', depending on the number of people boarding a single vehicle. An essential element in ridesharing is its non-profit nature (Chan, and Shaheen, 2012). New developments include specialised internet services to connect potential carpoolers ('peer-to-peer ridesharing') (Shaheen et al., 2015). The combination of mobile application and GPS enables the implementation of dynamic ridesharing, where drivers can be matched with each other in real time.

7.1.2 Assessing the environmental impacts of sharing

The shared mobility option could lead to fewer cars being produced, which in turn could lead to people using the shared services only occasionally due to the higher costs per trip compared to a single trip if they owned their own car (Firnkorn and Shaheen, 2016). Moreover, because shared cars are used more intensively, older models are replaced more quickly with more efficient cars.

The most important challenge in evaluating the impacts of shared mobility is to understand how people would otherwise have travelled. In some cases, shared mobility will lead to private cars being replaced. However, some people who use shared cars may have otherwise taken public transport (Martin, and Shaheen, 2011; Firnkorn et al., 2016; Nijland et al., 2015). The latter is more likely to occur in households who own no cars due to financial constraints. This is especially relevant in the EU-13, where car ownership remains relatively low, but is growing (Marsden et al., 2015).

In the case of *station based* (sometimes also called *roundtrip*) car sharing, where vehicles must be returned to the location where they were picked up, members are more likely to sell one or more of their own cars (estimates range from 25 % to 30 %) or postpone the purchase of a car (estimates range from 25 to 66 %) ([31]). Moreover, those joining a station based car sharing scheme tend to travel less with estimates ranging from 27 to 80 % reduction in distances. The average net reduction in driving distance hides the fact that car sharing leads to more driving by some (such as people who would not otherwise own a car), which is compensated by those who drive less.

Station based car sharing is also associated with an increase in walking, cycling and carpooling. The estimates of the impact on public transport use are more mixed, with some studies finding less public transport use ([32]). In general, the impacts found vary widely, depending on the region and time period under evaluation, as well as the methodologies used in the assessment.

([31]) Based on Martin and Shaheen, 2011; Shaheen and Cohen, 2013; Le Vine et al., 2014; Fournier et al., 2015; ITS America, 2015; Shaheen et al., 2015; Boyle and Associates, 2016; Firnkorn and Shaheen, 2016 and Kopp et al., 2015.

([32]) Martin and Shaeen, 2011 have suggested that this decrease in public transport may be due to households who did not own cars before joining the car sharing scheme.

One-way systems, where vehicles can be dropped off at another location, or *free-floating systems*, with return anywhere within a particular area, are starting to be analysed. In general, these mobility services only exist in big cities with more than 500 000 inhabitants. No firm conclusions can be drawn about their impact on travel choices. In some cases there is evidence that some people swap private car ownership for membership of one-way systems and that participation could lead to a reduction in the distance travelled (Shaheen et al., 2015b). However, in a study of Car2go users in Ulm, Germany, people who did not own a car before joining the scheme, walked less, cycled less and used less public transport after joining it (Firnkorn, 2012). In another study free-floating car sharing users take more and different forms of transport for their journeys than the general population (Kopp et al., 2015).

The observations referred to in this chapter focus on current users of shared mobility. They tend to be younger, better educated, live in urban areas, and have less car-dependent lifestyles than the general population (Le Vine et al., 2014; Nijland et al., 2015). The observed behavioural changes may not necessarily extrapolate over to the general population (Grischkat et al., 2014). One could also argue that positive experiences with carsharing amongst these early adopters will lead to further growth (Kopp et al., 2015), and that this critical mass will lead to important improvements in the efficiency of car sharing.

7.1.3 Shared mobility to complement or substitute public transport

Shared mobility, in its various forms, can be both a complement and a substitute to public transport. For instance, although shared mobility options appear to reduce car and taxi use, there are cases where most of the modal shift is away from trips made by public transport and walking (Fishman, 2016). Nevertheless, there are also examples of increases in the use of public transport. For example, TNCs can serve connections to public transport or provide mobility to or from low-density areas or at night, in order to support the main public transport services. Seen from this perspective, on-demand ride services could play a role as 'a gap-filling mode that allows a generally car-free life-style' (Rayle et al., 2016).

Wherever shared mobility is a complement to public transport, it can be an effective tool to bridge the first and last mile in a transport chain. The 'first/last mile' problem can have a dramatic effect on door-to-door travel time, and is therefore an important barrier to a shift from private car use to public transport. However, if shared mobility turns out to be mainly a substitute for public transport, the move to shared solutions could create a vicious circle of lower public transport patronage and lower service levels.

In a recent modelling exercise, the International Transport Forum (ITF) highlights the potential of the use of real-time data streams that make it easier and more efficient to provide citizens with optimized access to their cities (see Box 7.4, based on ITF, 2016). The research analyses the impact of replacing all car and bus trips in a city with mobility provided through fleets of shared vehicles. The results are largely positive, with a reduction of 37 % of total vehicle-kilometres driven and the resulting positive impact on congestion and GHG emissions, as well as a freeing up of 95 % of the space currently used in cities for parking.

7.2 Vehicle technology niches

7.2.1 Synergies between shared mobility and electric mobility

EVs charged with low-emission electricity can play an important in reducing CO_2 emissions in passenger road transport (EEA, 2016g). This section describes the potential synergies between shared mobility and electric mobility.

With the current state of technology, electric cars are probably better adapted for car sharing than for car ownership (Fournier et al., 2015). Indeed, with battery ranges typically varying between 100 and 200 km, they are adequate for most car-sharing trips. Moreover, as shared vehicles are used much more intensively than vehicles used by single households, the higher acquisition costs of EVs matter less if they are shared. Several operators of shared vehicles include a limited number of EVs in their fleet (Le Vine et al., 2014), and at least two operators (Autolib' in Paris, and car2go in San Diego, Amsterdam, Madrid and Stuttgart) own a fleet containing only EVs.

Moreover, car-sharing operators could gain additional income from the provision of vehicle-to-grid services: 'In a grid with a high proportion of renewable energy sources but fluctuating energy production, the load can be stabilised by the storage, feeding and charging of electricity from EVs. It is possible to use surplus power from renewable energy systems to substitute peak-loads.' (Fournier et al., 2015).

Box 7.4 Could all car and bus trips in a city be replaced by fleets of shared vehicles?

Private cars are typically used during peak hours and rarely for more than 10 % of any given day. They also have very low levels of occupancy. Nevertheless they provide flexibility, comfort and availability which are not always apparent in other options.

The evolution of technology and the widespread use of its key element — the smartphone — allows the shared mobility market to grow and become viable. The ITF scenario presents a large scale deployment of shared vehicle fleets that provide on-demand transport, replacing all car and bus trips in a city (the ITF exercise focused on Lisbon). While rail and metro services keep operating, shared mobility is delivered by a fleet of six-seat vehicles ('shared taxis') that offer on-demand, door-to-door shared rides in conjunction with a fleet of eight-person and 16-person mini-buses ('taxi-buses') that serve 'on demand' stops and provide transfer-free rides. Almost all the trips are direct. The simulation model is able to reproduce as accurately as possible the interaction between users and shared mobility options in a realistic transport network and urban context, whilst maintaining the mobility needs of today's citizen.

All of the above allow shared mobility to compete with the three areas where the private car is mostly seen as the preferred mode: flexibility, comfort and availability. The results of the research are summarised as follows:

- total vehicle-kilometres would be 37 % less even during peak hours;
- congestion would disappear;
- traffic emissions would be reduced by one-third;
- the car fleet needed would be only 3 % in size of the today's fleet, but each car would be running almost ten times more kilometres than today.

This has various knock-on effects:

- cars would have shorter life cycles, enabling faster uptake of new and cleaner technologies and therefore reducing emissions;
- huge amounts of space, previously dedicated to car parking, can be converted to uses that increase liveability. Non-motorised mobility can be improved by creating new bike lanes or wider sidewalks;
- access and social inclusion is improved as prices for journeys are cheaper and shared vehicles and rides are offered for a wide variety of starting and final destinations, so inequalities in access to jobs, schools or health services across the city virtually disappear.

Achieving such a reality is a certainly an enormous challenge. The research tested a scenario in which private cars are allowed to drive into the city two working days per week. As a transition phase, this rule will allow car owners to experience the shared mobility solutions on the other days of the week. This would be just a potential path to cope with the challenge of changing from individual use of cars to shared mobility.

What seems very clear from the ITF research is that shared mobility services can fundamentally change the way we currently experience mobility, and can create significant environmental benefits just by reducing the amount of vehicles-kilometre travelled. Public authorities should guide the change and anticipate the impacts. Creating the right market conditions and operating frameworks can boost the change. Some businesses and transport public services may need to change dramatically, such as the car industry or the taxi sector, while others, such as local bus services, may disappear entirely.

Source: Based on ITF, 2016,

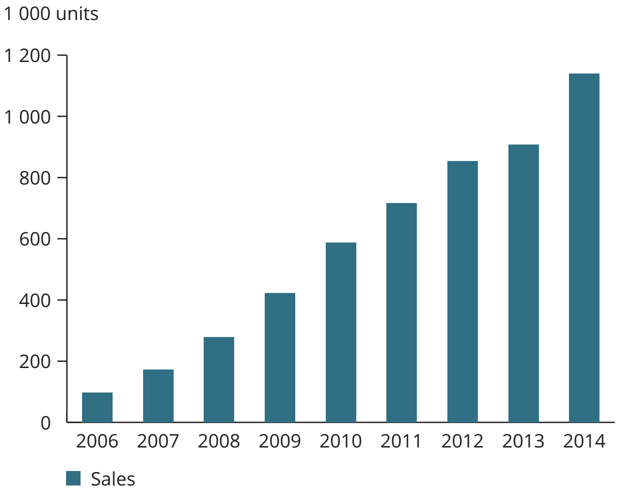
7.2.2 Electric bicycles

The market for electric bicycles emerged first in China in the early 1980s, and started growing exponentially in the 1990s. Currently, the Chinese e-bike fleet still accounts for 90 % of the 150 million units in use worldwide (Weiss et al., 2015). In the EU, the total number of bicycles currently in use (both electric and non-electric) is about 200-250 million bicycles, with annual sales of about 20 million. Yearly sales of e-bikes were around 1 139 000 in 2014 (CONEBI 2015) of which around two thirds took place in Germany and the Netherlands. In terms of annual sales, e-bikes correspond to less than 5 % of the European market for bicycles. However, there are significant differences between countries. For example, 31 % of the bicycles sold in Belgium in 2015 were electric (http://www.belgiancycling.be/news.asp?language=nl&id=1856.)

Compared to conventional bicycles, electric bicycles 'broaden the sphere of activity of bike travel, especially for trips of distances between 5 and 20 km and the transport of cargo/shopping and/or children.' (UBA, 2014b) They are especially useful in rural and hilly areas. In an urban environment, the main advantage of e-bikes is that they are often the fastest mode from a door-to-door perspective. E-bikes are also thought to be an increasingly important alternative to commuting by car, in particular with a range of new fast dedicated cycle-highways being built across Germany and elsewhere in Europe. Moreover, compared to cars, they require less space to drive and park. It is also in cities that the most important external benefits, such as a decrease in pollutant emissions, noise and traffic congestion, are expected (UBA, 2014b; Weiss et al., 2015).

From an environmental perspective, their main advantages are their very low noise levels and the absence of any tailpipe emissions. In any case emissions from e-bikes will always compare favourably to the emissions of a conventional car. In Germany, for example, the total CO_2 emissions of a petrol powered-car are 39 times higher than those of an e-bike (well-to-wheel, i.e. taking into account the production and distribution of the fuel) (UBA, 2014b). In Europe, e-bikes are generally equipped with metal-hydride or lithium-ion batteries. As a result, and compared to the battery types in use in China (mostly lead-acid batteries), the production and disposal of batteries typically used in Europe do not cause concerns linked to lead pollution (Weiss et al., 2015). Nevertheless, from a sustainability perspective, the establishment of an effective collection and recycling system for old e-bike batteries is crucial to ensure that all valuable materials, such as rare earths, are recycled and others are disposed of in an environmentally friendly-manner.

Figure 7.2 Electric bicycle sales (EU 28)



Source: CONEBI, 2015.

It appears clear that a modal shift away from cars to e-bikes will benefit the environment. However, it will largely depend on the shift to e-bikes coming from private car users rather than users of conventional bicycles or public transport (Weiss et al., 2015).

From a user's point of view, the main barrier to the adoption of e-bikes is the considerable additional cost compared to conventional bicycles. This cost premium depends on the battery capacity and lifetime, and varies widely. Based on data from retailers, manufacturers and consumer organisations, it is estimated that the mean price differential between electric and traditional bicycles is around 5 000 EUR per kWh of battery capacity. There are no indications that prices in Europe have significantly dropped over the last decade, but this may mainly be due to significant improvements in quality parameters over the same period, such as battery performance (Weiss et al., 2015). However, e-bikes are a favourable alternative to owning a car, not just in terms of environmental impact but also as regards cost.

7.2.3 Automated mobility

Currently, about 30 companies are reported to be working on autonomous vehicles (AVs — also known as self-driving or driverless vehicles) (Business Insider, 2016). Technology has improved significantly in recent years, and there are several examples of large scale pilot projects being deployed, largely in closed environments such as business parks. However, it is estimated that the technology needed to enable high levels of automation currently costs around

133 000 EUR per vehicle (Greenblatt and Shaheen, 2015). This exceeds even the average purchase price of luxury brands, and is about five times more expensive than the average for all car classes (ICCT, 2015). Moreover, there are many technological challenges still to be resolved in order for such cars to be operational, taking into account quickly changing environments, especially in cities (The Economist, 2016).

Because the rate at which the cost of AVs will decrease is not known, the future evolution of their market share is still very uncertain. AVs are not expected to exceed a 50 % market share before the mid-2030s or even later (Litman, 2015; Beirstedt et al., 2014; Greenblatt and Shaheen, 2015).

Proponents of AVs claim numerous potential benefits, including increased traffic safety, better use of travel time and decreased congestion (Morrow et al., 2014; Greenblatt and Shaheen, 2015; Childress et al., 2015; Wadud et al., 2016) ([33]). AVs would also provide mobility services to people currently unable to drive, for example due to physical impairment. AVs do not need to be parked as they will be able to be constantly on the move. This could free significant amounts of urban areas for alternative uses if AVs are shared. Estimates of the number of private cars that could be replaced by shared AVs range from 66 % to 90 % ([34]). The reduced need for parking space could imply a dramatic change in the urban landscape.

One key downside of AVs is that they could lead to a dramatic increase in distance travelled (Morrow et al., 2014; Childress et al., 2015; Greenblatt, and Shaheen, 2015) Indeed, after having dropped their passengers, the vehicles will have to reposition themselves to park (likely outside the city centre) or to get a new passenger (in the case of shared AVs). In full AVs, people will be able to read, play, or even rest. As a result, they will tolerate long travel times, and especially longer commutes. In combination with other elements (such as larger, more luxurious vehicles or higher average speeds) made possible by automation, these longer distances travelled could lead to dramatic increases in energy use (Morrow et al., 2014).

Even if AVs induce new traffic, the net effects on energy use remain extremely uncertain: estimates range from more than 90 % fuel savings to more than 150 % increase in energy use, depending on the dominating factors (Brown et al., 2014; Morrow et al., 2014; Wadud et al., 2016).

Several elements indeed point to a potential for increased efficiency. For instance, shared AVs can be adapted to the number of passengers. As a result, manufacturers can build smaller and lighter vehicles, or larger vehicles will have higher occupancy rates. Additional energy savings (up to 80 %) could be possible through platooning ([35]) and efficient traffic flow (and thus less sporadic acceleration and braking).

Moreover, shared AVs may also be better suited for electrification, because they can be dispatched to meet a user's specific need, only serve trips within a particular range, or because they can distribute the high upfront cost over many users (Brown et al., 2014). With BEVs, it has been estimated that, by 2030, GHG emissions per km (including upstream GHG emissions) could decrease by up to 87–94 % below the emissions of current vehicles (Greenblatt and Saxena, 2015).

7.3 Public policy

In general, existing policies provide more support to incremental changes (i.e. technology improvements in ICE that maintain the dominant position of private vehicles) than upscaling niches for fundamental changes in the way people and freight are transported in the EU. Upscaling niches could bring sustainability while improving services and guaranteeing mobility (Temmes et al., 2014).

Governments, have long used a variety of tools to support innovation and protect new technologies from market pressures, including product standards, tax exemptions and subsidies, as well as investment in research and development. While businesses and civil society stakeholders lack the state's unique resources and rule-making powers, they still have significant opportunities to create niches and promote innovation. Interestingly these corporations often failed to exploit their own innovations since they challenged or distracted from their established line of business. As such, these examples also illustrate how organisational incentives can lock industries into prevailing technologies.

([33]) Thanks to a combination of shorter distances between each car, a decrease in accidents, and better and more dynamic management of road infrastructure.

([34]) Based on Burns et al., 2013; Zachariah et al., 2013; Fagnant, and Kockelman, 2014; Spieser et al., 2014; ITF 2015b; Fagnant et al., 2015; Levin et al., 2016.

([35]) Brown, et al. (2014) define 'platooning' as 'method of groups of vehicles travelling close together at high speed. This has the potential to reduce energy intensity resulting from aerodynamic drag.'

Policy decisions can actively support innovation and new businesses linked with sustainable pathways in transport that emerge through technology development in transport and ICT, but also through changing attitudes and everyday practices helped by new ways of providing mobility services. Policy decisions can also identify and tackle barriers and lock-ins that prevent innovations from flourishing. Box 7.5 summarises some of the key policy measures that foster system-level change.

Car sharing, for example, often requires active support measures from public authorities (such as making parking space available for station based car sharing systems i.e. those which have to be picked up and returned to the same space). Governments could also promote the modes that complement car sharing, for instance by expanding investments in pedestrian and bicycling infrastructure (Martin et al., 2011), and by providing the necessary infrastructure of bike-, ride- and car sharing in the neighbourhood of public transport hubs (Hallock, and Inglis, 2015).

The net environmental impacts of shared mobility solutions and of AVs are still uncertain and, in the worst-case scenario, they could even imply an important increase in energy consumption. The correct pricing of transport will thus play a key role in ensuring that the potentially significant benefits are harnessed. Moreover, the pricing of distance travelled will need to be coordinated with the pricing of other services, such as parking and vehicle-to-grid services. Policies other than pricing are also important.

A key point will be to design policies that harness the strengths of shared mobility solutions to solve the 'first/last' mile problem, and thus to promote an alternative to unimodal car mobility. The concept of 'Mobility as a Service' fits within this pattern. It has also been argued that 'traditional' public transport needs to create partnerships with TNCs and micro-transit services.

However, there are definitely some niches where shared solutions, such as micro-transit services, are likely to outperform traditional public transport services. Moreover, the rise of AVs will reduce the 'opportunity cost' of time spent in car travel i.e. the time lost whilst driving could be spent on another activity, which will further undermine the competitive position of some public transport services. Therefore, public transport will probably increasingly concentrate on the task where it has the biggest competitive advantage: moving significant quantities of people from one transport hub to the other. Whether this can only be implemented by metro, light rail, or bus rapid transit systems (which benefit from priority at traffic lights and other support), or whether traditional bus services still have a role to play in such a landscape, remains an open question.

Box 7.5 Key policy measures that foster system-level change

Support strategic experiments that aim to enhance changes in the whole socio-technical system through, for example, innovation programmes for enhancing entrepreneurial experimentation, reducing transport demand, and promoting seamless intermodal transport, thereby supporting multiple and complementary niches.

Map and then reduce the barriers to niche innovations.

Emphasise learning and the 'acceptability' of failure through experimentation and demonstration programmes.

Strengthen cooperation between policy domains to improve the coherence of policies and create policy mixes for sustainability transitions.

Design policies for market formation, and to improve the access of consumers to affordable high quality sustainable products and services.

Create ways for effective collaboration between traditional public transport services and new mobility services (such as MaaS) which leads to an opening-up information on schedules and other characteristics, and which looks for synergies throughout the whole mobility system.

Sources: Based on Temmes et al., 2014.

8 Concluding remarks

The EU's long-term outlook for transport in the EU and its associated emissions demonstrates that the 2050 decarbonisation goals for the transport sector require not only incremental changes, but a systemic change. Without such fundamental transitions, the EU's objectives for 2050 will be difficult to reach.

A comprehensive mix of alternative (renewable) fuels and improved fuel efficiency is one way in which the future environmental performance of the transport sector may be improved. Research in these areas is supported substantially at the EU and national levels as well as by industry, and has led to technological developments, as well as improvements in fuel efficiency and engines. However to ensure the greater uptake of alternative fuel vehicles, common standards and extensive fuelling infrastructures are required. Implementing the strategic elements described in the 'Clean Power for Transport' strategy, supported by actions defined in supporting legislation such as the EU directive on alternative fuels infrastructure (2014/94/EU), is therefore of crucial importance. Improvements in fuel efficiency are not only relevant for vehicles covered by current legislation (e.g. cars and vans), but also for other vehicle types. In the case of road transport, steps are being taken towards future monitoring of CO_2 emissions and the introduction of emission standards for HGVs.

Even with the required infrastructure in place, the penetration of cleaner vehicles in the fleet will take time. This is especially relevant for aircraft, trains and ships since they have a much longer lifetime than cars, vans or trucks. Moreover, progress can be hampered by barriers such as incumbent interests or the difficulty to reach sufficiently ambitious international agreements (especially in the field of aviation and maritime transport), and by lock-ins induced by past and on-going investments in the existing fossil-fuelled energy sector and technologies.

Pricing can provide another incentive towards making transport more sustainable, as supported by the 2011 Transport White Paper. When prices reflect the real-world external costs caused by passenger and freight transport, consumers and producers will take into account these costs. Pricing can be expected to affect transport not only directly, but also indirectly. For example, given the links between transport and land use, changing transport prices can affect how households and companies decide where to locate, which has important impacts on commuting, congestion, and environmental factors such as emissions and noise pollution.

At present, pricing instruments are already used to some extent for mitigating the environmental impacts of transport such as road user charges in Europe. However, such instruments still have a large potential that has not yet been fully realised. Moreover, there are cases of pricing instruments that give the wrong environmental incentives, including, for example, preferential tax treatments for company cars or fuel tax exemptions for international aviation and maritime shipping (EEA 2015b).

The links between transport and other societal systems such as land use also need to be factored in when formulating policies. They also offer possibilities to address transport issues in an indirect but integrated fashion via policy implementation in other areas, such as spatial and urban planning. There is a key role for land use policies in addressing the environmental problems of transport, together with other policy interventions. For instance, public transport and shared mobility solutions are more economically viable in dense cities.

A part of the demand for mobility stems from lifestyle and habits. Recently there have been a number of innovations with a potential to change travel behaviour in a fundamental way, while still meeting the need for mobility. These innovations consist not only of technological breakthroughs, such as EVs and self-driving vehicles, but also new business and ownership models. New ownership models include shared mobility and 'Mobility as a Service', the latter allowing consumers to buy mobility services that are provided by the same or different operators just by using one platform and a single payment. Shared mobility could help in overcoming the main competitive disadvantage of public transport in comparison to private cars: its longer door-to-door travel times, which is mainly due to the first and the last mile in the transport chain. In the long run, automated vehicles may have a profound impact on mobility. However, their impact will be more beneficial if they are embedded in a system of shared mobility and complemented with high capacity public transport along the principal routes.

Public authorities have a key responsibility in ensuring that different transport systems are connected and inter-operable, that the required infrastructure is in place and that price signals are consistent. Through their regulatory and funding power, public authorities also have the possibility to shape the sustainable mobility system of the future. They could also create a framework that ensures that the potential of these innovative technologies and business models is exploited leading to the desired impacts on sustainability and that any rebound effects are controlled.

References

Allroggen, F., Malina, R. and Lenz, A.-K., 2013, 'Which factors impact on the presence of incentives for route and traffic development? Econometric evidence from European airports', *Transportation Research Part D: Transport and Environment,* (60) 49–61.

Banister, D., 2011a, 'The trilogy of distance, speed and time', *Journal of Transport Geography,* (19(4)) 950–959.

Banister, D., 2011b, 'Cities, mobility and climate change', *Journal of Transport Geography,* (19(6)) 1 538–1 546.

Beirstedt, J, Gooze, A, Gray, C, Peterman, J. R. and Walters, J., 2014, 'Effects of Next-Generation Vehicles on Travel Demand and Highway Capacity' (http://orfe.princeton.edu/~alaink/Papers/FP_NextGenVehicleWhitePaper012414.pdf) accessed 17 November 2016.

Benn, S., Dunphy, D. and Griffiths, A., 2006, 'Enabling Change for Corporate Sustainability: An Integrated Perspective', *Australasian Journal of Environmental Management,* (13(3)) 156–165.

Bertolini, L., 2012, 'Integrating Mobility and Urban Development Agendas: a Manifesto', *disP — The Planning Review,* (48(1)) 16–26.

Borken-Kleefeld, J., Fuglestvedt, J. and Berntsen, T., 2013, 'Mode, Load, and Specific Climate Impact from Passenger Trips', *Environmental Science & Technology,* 47(14)) 7 608–7 614.

Boyle and Associates, 2016, 'The Impact of Car Share Services in Australia' (http://carsharing.org/wp-content/uploads/2016/01/The-Impact-of-Car-Share-Services-in-Australia.pdf) accessed 17 November 2016.

Brown, A., Gonder, J. and Repac, B., 2014, 'An Analysis of Possible Energy Impacts of Automated Vehicle', in: Meyer, G. and Beiker, S. (eds), *Road Vehicle Automation,* Springer International Publishing, Cham, Switzerland

Budde, B., Alkemade, F. and Weber, K. M., 2012, 'Expectations as a key to understanding actor strategies in the field of fuel cell and hydrogen vehicles', *Technological Forecasting and Social Change,* (79(6)) 1 072–1 083.

Burghouwt, G., Mendes de Leon, P. and De Wit, J., 2015, *EU Air Transport Liberalisation Process, Impacts and Future Considerations*, OECD/ITF Discussion Paper, Organisation for Economic Co-operation and Development/International Transport Forum, Paris.

Burns, L. D., Jordon, W. C. and Scarborough, B. A., 2013, *Transforming personal mobility*, Earth Institute, Columbia University, New York.

Business Insider, 2016, '30 companies are now making self-driving cars', *Business Insider* (http://www.businessinsider.com/30-companies-are-now-making-self-driving-cars-2016-4) accessed 12 August 2016.

CBI, 2015, *CBI Trade Statistics, Fresh fruits and vegetables in Europe*, CBI Market Intelligence, The Hague.

Chan, N. D. and Shaheen, S. A., 2012, 'Ridesharing in North America: Past, Present, and Future', *Transport Reviews,* (32(1)) 93–112.

Childress, S., Nichols, B., Charlton, B. and Coe, S., 2015, 'Using An Activity-Based Model To Explore Possible Impacts Of Automated Vehicles', *Transportation Research Record: Journal of the Transportation Research Board*, (2493) 99–106.

Christidis, P. and Brons, M., 2010, *Impacts of the proposal for amending Directive 1999/62/EC on road infrastructure charging: An analysis on selected corridors and main impacts*, JRC Technical Notes, 54766, Office for Official Publications of the European Communities, Luxembourg.

Cleveland, D. A., 2015, 'How does food localization contribute to food system sustainability?', *Frontiers in Ecology and the Environment,* (13(8)) 410–411.

CONEBI, 2015, *European Bicycle Market, 2015 Edition. Industry & Market Profile (2014 statistics)*, Confederation of the European Bicycle Industry, Brussels.

Copenhagen Economics, 2010, *Company car taxation subsidies, welfare and environment*, Copenhagen.

Desrochers, P. and Lusk, J. L., 2015, 'The inability and undesirability of local croplands to meet food demand', *Frontiers in Ecology and the Environment,* (13(8)) 409–410.

Dimitropoulos, A., Oueslati, W. and Sintek, C., 2016, 'The Rebound Effect in Road Transport: A Meta-Analysis of Empirical Studies', Paper presented at the 22nd annual EAERE Conference 2016, Zürich.

EASA, EEA and Eurocontrol, 2016, *European Aviation Environmental Report 2016*, European Aviation Safety Agency, European Environment Agency, Eurocontrol, Cologne.

EC, 2005, Communication from the Commission. 'Community guidelines on financing of airports and start-up aid to airlines departing from regional airports' (OJ L C 312, 9.12.2005, pp. 1–14).

EC, 2011a, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions 'A Roadmap for moving to a competitive low carbon economy in 2050' (COM(2011) 112 final of 8 March 2011).

EC, 2011b, White Paper, 'Roadmap to a single European transport area — Towards a competitive and resource efficient transport system' (COM(2011) 144 final of 28 March 2011).

EC, 2011c, Accompanying document to the White Paper 'Roadmap to a single European transport area — Towards a competitive and resource efficient transport system' (SEC(2011) 358 final of 28 March 2011).

EC, 2013, 'The Clean Air Package' (http://ec.europa.eu/environment/air/clean_air_policy.htm) accessed 12 October 2016.

EC, 2014, *Tax Reforms in EU Member States 2014. Tax policy challenges for economic growth and fiscal sustainability*, European Economy, 6/2014, European Commission, Brussels.

EC, 2015a, An Aviation Strategy for Europe. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM(2015) 598 final.

EC, 2015b, 'Evaluation of Regulations 443/2009 and 510/2011 on CO_2 emissions from light-duty vehicles. Final Report' (http://ec.europa.eu/clima/policies/transport/vehicles/docs/evaluation_ldv_CO_2_regs_en.pdf).

EC, 2016a, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions 'A European Strategy for Low-Emission Mobility' COM(2016) 501 final of 20 July 2016).

EC, 2016b, *EU Reference Scenario 2016: Energy, transport and GHG emissions — Trends to 2050*, Publications Office of the European Union, Luxembourg.

EC, 2016c, Commission Staff Working Document accompanying the Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, 'A European Strategy for Low-Emission Mobility' (SWD(2016) 244 final of 20 July 2016).

EC, 2016d, Commission Staff Working Document 'The implementation of the 2011 White Paper on Transport 'Roadmap to a Single European Transport Area — towards a competitive and resource- efficient transport system' five years after its publication: achievements and challenges' (SWD(2016) 226 final of 1 July 2016).

EC DGMOVE, 2016, 'EU Transport in figures — Statistical pocketbook 2016' (http://ec.europa.eu/transport/facts-fundings/statistics/pocketbook-2016_en) accessed 24 October 2016.

ECA, 2014, *EU-funded investments in airports: poor value for money*, European Court of Auditors, Luxembourg.

EEA, 2012, *The contribution of transport to air quality. TERM 2012: transport indicators tracking progress towards environmental targets in Europe*, EEA Report No 10/2012, European Environment Agency.

EEA, 2013, *A closer look at urban transport, TERM 2013: transport indicators tracking progress towards environmental targets in Europe*, EEA Report No 11/2013, European Environment Agency.

EEA, 2014, *Focusing on environmental pressures from long-distance transport, TERM 2014: transport indicators tracking progress towards environmental targets in Europe*, EEA Report No 7/2014, European Environment Agency.

EEA, 2015a, *SOER 2015, The European environment — state and outlook 2015*, European Environment Agency. http://www.eea.europa.eu/soer-2015/europe/transport.

EEA, 2015b, *Evaluating 15 years of transport and environmental policy integration, TERM 2015: Transport indicators tracking progress towards environmental targets in Europe*, 7/2015, European Environment Agency.

EEA, 2015c, *The European environment — state and outlook 2015: synthesis report*, European Environment Agency.

EEA, 2016a, *Signals 2016 — Towards clean and smart mobility. Transport and environment in Europe*, European Environment Agency.

EEA, 2016b, *Explaining road transport emissions — A non-technical guide*, European Environment Agency.

EEA, 2016c, *Analysis of key trends and drivers in greenhouse gas emissions in the EU between 1990 and 2014*, European Environment Agency.

EEA, 2016d, *Annual European Union greenhouse gas inventory 1990–2014 and inventory report 2016. Submission to the UNFCCC Secretariat*, EEA Report No 15/2016, European Environment Agency.

EEA, 2016e, *Air quality in Europe — 2016 report*, EEA Report No 28/2016, European Environment Agency.

EEA, 2016f, *Monitoring CO_2 emissions from new passenger cars and vans in 2015*, EEA Report No 27/2016, European Environment Agency.

EEA, 2016g, *Electric vehicles in Europe*, EEA Report No 20/2016, European Environment Agency.

EEA, 2016h, *Sustainability transitions: Now for the long term*, Eionet report No 1/2016, European Environment Agency.

EEA, 2016i, *Transforming the EU power sector: avoiding a carbon lock-in*, EEA Report No 22/2016, European Environment Agency.

EEA, 2016j, *Renewable energy in Europe 2016 — Recent growth and knock-on effects*, European Environment Agency.

EEA and FOEN, 2016, *Urban sprawl in Europe. Joint EEA-FOEN report*, EEA Report No 11/2016, European Environment Agency, Federal Office for the Environment, Copenhagen.

Eijgelaar, E., Peeters, P., de Bruijn, K. and Dirven, R., 2015, *Travelling large in 2014. The carbon footprint of Dutch holidaymakers in 2014 and the development since 2002*, NHTV Breda University of Applied Sciences, Breda.

van Essen, H., Rijkee, X., Verbraak, G., Quak, H. and Wilmink, I., 2009, *EU Transport GHG: Routes to 2050? Modal split and decoupling options: Paper 5,* AEA Technology plc and the European Commission, Brussels.

EU, 2001, Directive 2001/81/EC of the European Parliament and of the Council of 23 October 2001 on national emission ceilings for certain atmospheric pollutants (OJ L 309, 27.11.2001, pp. 22–30).

EU, 2008, Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe (OJ L 152, 11.6.2008, pp. 1–44).

EU, 2009a, Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC (OJ L 140/16, 5.6.2009, pp. 16–62).

EU, 2009b, Directive 2009/30/EC of the European Parliament and of the Council of 23 April 2009 amending Directive 98/70/EC as regards the specification of petrol, diesel and gas-oil and introducing a mechanism to monitor and reduce greenhouse gas emissions and amending Council Directive 1999/32/EC as regards the specification of fuel used by inland waterway vessels and repealing Directive 93/12/EEC (OJ L 140/88, 5.6.2009, pp. 88–113).

EU, 2009c, Regulation (EC) No 443/2009 of the European Parliament and of the Council of 23 April 2009 setting emission performance standards for new passenger cars as part of the Community's integrated approach to reduce CO 2 emissions from light-duty vehicles (OJ L 140, 5.6.2009, pp. 1–15).

EU, 2011, Regulation (EU) No 510/2011 of the European Parliament and of the Council of 11 May 2011 setting emission performance standards for new light commercial vehicles as part of the Union's integrated approach to reduce CO_2 emissions from light-duty vehicles (OJ L 145, 31.5.2011, pp. 1–18).

EU, 2013, Decision No 1386/2013/EU of the European Parliament and of the Council of 20 November 2013 on a General Union Environment Action Programme to 2020 'Living well, within the limits of our planet' (OJ L 354, 20.12.2013, pp. 171–200).

EU, 2015a, Council Directive (EU) 2015/652 of 20 April 2015 laying down calculation methods and reporting requirements pursuant to Directive 98/70/EC of the

European Parliament and of the Council relating to the quality of petrol and diesel fuels (http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32015L0652&from=EN) accessed 5 October 2016.

EU, 2015b, Directive (EU) 2015/1513 of the European Parliament and of the Council of 9 September 2015 amending Directive 98/70/EC relating to the quality of petrol and diesel fuels and amending Directive 2009/28/EC on the promotion of the use of energy from renewable sources (http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32015L1513&from=EN) accessed 5 October 2016.

Eurocontrol, 2013, *Task 7: European Air Traffic in 2050*, Eurocontrol, Brussels.

Eurocontrol, 2016, *Performance Review Report. An Assessment of Air Traffic Management in Europe during the Calendar Year 2015*, Eurocontrol, Brussels.

Eurostat, 2016, 'SHARES 2014 results' (http://ec.europa.eu/eurostat/web/energy/data/shares) accessed 24 October 2016.

Faber, J. and 't Hoen, M., 2015, *Historical Trends in Ship Design Efficiency*, CE Delft, Delft.

Fagnant, D. J. and Kockelman, K. M., 2014, 'The travel and environmental implications of shared autonomous vehicles, using agent-based model scenarios', *Transportation Research Part C: Emerging Technologies,* (40) 1–13.

Fagnant, D. J., Kockelman, K. M. and Bansal, P., 2015, 'Operations of Shared Autonomous Vehicle Fleet for Austin, Texas, Market', *Transportation Research Record: Journal of the Transportation Research Board,* (2 536) 98–106.

FGM-AMOR, Outspoken, ECF and CTC, 2014, *Cyclelogistics. Moving Europe Forward*, FGM_AMOR, Graz. (http://www.cyclelogistics.eu/docs/111/D6_9_FPR_Cyclelogistics_print_single_pages_final.pdf) accessed 24 October 2016.

Firnkorn, J., 2012, 'Triangulation of two methods measuring the impacts of a free-floating carsharing system in Germany', *Transportation Research Part A: Policy and Practice,* (46(10)) 1 654–1 672.

Firnkorn, J. and Shaheen, S., 2016, 'Generic time- and method-interdependencies of empirical impact-measurements: A generalizable model of adaptation-processes of carsharing-users' mobility-behavior over time', *Journal of Cleaner Production,* (113) 897–909.

Fischedick, M., Roy, J., Abdel-Aziz, A., Acquaye, A., Allwood, J., Ceron, J.-P., Geng, Y., Kheshgi, H., Lanza, A., Perczyk, D., Price, L., Santalla, E., Sheinbaum, C. and Tanaka, K., 2014, 'Industry', in: *Climate Change in 2014: Mitigation of Climate Change, Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge and New York.

Fishman, E., 2016, 'Bikeshare: A Review of Recent Literature', *Transport Reviews,* (36(1)) 92–113.

Fournier, G., Seign, R., Goehlic, V. and Bogenberger, K., 2015, 'Car-sharing with Electric Vehicles: A Contribution to Sustainable Mobility?', *Interdisciplinary Management Research,* (11) 955–975.

Geels, F. W., 2016, *Socio-technical transitions to sustainability*, Background paper for the European Environment Agency.

Givoni, M. and Banister, D., (eds), 2013, *Moving Towards Low Carbon Mobility*, Edward Elgar, Cheltenham and Northampton, USA.

Greenblatt, J. B. and Saxena, S., 2015, 'Autonomous taxis could greatly reduce greenhouse-gas emissions of US light-duty vehicles', *Nature Climate Change,* (5(9)) 860–863.

Greenblatt, J. B. and Shaheen, S., 2015, 'Automated Vehicles, On-Demand Mobility, and Environmental Impacts', *Current Sustainable/Renewable Energy Reports,* (2(3)) 74–81.

Grischkat, S., Hunecke, M., Böhler, S. and Haustein, S., 2014, 'Potential for the reduction of greenhouse gas emissions through the use of mobility services', *Transport Policy,* (35) 295–303.

Hacker, F., von Waldenfels, R. and Mottschall, M., 2015, *Wirtschaftlichkeit von Elektromobilität in gewerblichen Anwendungen. Betrachtung von Gesamtnutzungskosten, ökonomischen Potenzialen und möglicher* CO_2*-Minderung, im Auftrag der Begleitforschung zum BMWi Förderschwerpunkt für Elektromobilität II: Smart Car — Smart Grid — Smart Traffic*, Öko-Institut, Deutsches Dialog Institut, VDE, Berlin.

Hall, B. H., Lotti, F. and Mairesse, J., 2008, 'Employment, innovation, and productivity: evidence from Italian microdata', *Industrial and Corporate Change,* (17(4)) 813–839.

Hallock, L. and Inglis, J., 2015, *The Innovative Transportation Index*, Frontier Group and U.S. PIRG Education Fund, Boston.

Harrison, R., Jaumandreu, J., Mairesse, J. and Peters, B., 2014, 'Does innovation stimulate employment? A firm-level analysis using comparable micro-data from four European countries', *International Journal of Industrial Organization,* (35) 29–43.

Helsinki City Planning Department, 2014, '*Vision 2050. Urban plan — the new Helsinki city plan',* Helsinki City Planning Department (http://www.hel.fi/hel2/ksv/julkaisut/yos_2013-23_en.pdf) accessed 26 October 2016.

Hofhuis, P., Luining, M. and Rood, J., 2016, *EU Transition towards green and smart mobility. Action Toolbox to Unleash Innovation Potentials*, Clingendael Report, Netherlands Institute of International Relations Clingendael, The Hague.

Howell, J. M., Shea, C. M. and Higgins, C. A., 2005, 'Champions of product innovations: defining, developing, and validating a measure of champion behavior', *Journal of Business Venturing,* (20(5)) 641–661.

HRT, 2013, *'HLJ 2015 Travel behaviour in the Helsinki region in 2012'*, Helsinki Region Transport (https://www.hsl.fi/sites/default/files/uploads/liikkumistottumukset_helsingin_seudulla_2012_hlj2015_raportti_0.pdf) accessed 26 October 2016.

HRT, 2014, *'HLJ 2015 impact assessment report'*, Helsinki Region Transport (https://www.hsl.fi/sites/default/files/uploads/vaikutusten_arviointi_hlj2015_raportti.pdf) accessed 26 October 2016.

ICCT, 2015, *European Vehicle Market Statistics, Pocketbook 2015/16*, International Council on Clean Transportation, Washington D.C., San Francisco, Berlin.

IEA, 2012, *Energy Technology Perspectives 2012. Pathways to a Clean Energy System*, International Energy Agency, Paris.

Intelligent Mobility Insight, 2016, 'EVs take the tourist trail' (http://intelligentmobilityinsight.com/news/Cqr) accessed 12 August 2016.

ITF, 2015a, *Media Release: UbiGo (Sweden) and St. Lawrence Seaway (Canada) Share Prestigious Transport Innovation Award*, International Transport Forum, Paris.

ITF, 2015b, *Urban Mobility System Update. How shared self-driving cars could change city traffic?*, International Transport Forum, Paris.

ITF, 2016, *Shared mobility. Innovation for liveable cities*, International Transport Forum, Paris.

ITS America, 2015, *Rise of the Real-time Traveler: An exploration of trends and innovation in urban mobility*, ITS America, Washington D.C.

Jäppinen, S., Toivonen, T. and Salonen, M., 2013, 'Modelling the potential effect of shared bicycles on public transport travel times in Greater Helsinki: An open data approach', *Applied Geography*, (43) 13–24.

Johnson, E. J., Bellman, S. and Lohse, G. L., 2003, 'Cognitive Lock-In and the Power Law of Practice', *Journal of Marketing,* (67(2)) 62–75.

JRC, 2013, *Quantifying the Effects of Sustainable Urban Mobility Plans*, JRC Technical Report, JRC 84116, JRC — Institute for Prospective Technological Studies, Seville. (http://ftp.jrc.es/EURdoc/JRC84116.pdf) accessed 24 September 2016.

Kamargianni, M., Matyas, M., Li, W. and Schäfer, A., 2015, *Feasibility study for 'Mobility as a Service' concept in London*, University College of London Energy Institute, London.

Konrad, K., Markard, J., Ruef, A. and Truffer, B., 2012, 'Strategic responses to fuel cell hype and disappointment', *Technological Forecasting and Social Change,* (79(6)) 1 084–1 098.

Kopp, J., Gerike, R. and Axhausen, K. W., 2015, 'Do sharing people behave differently? An empirical evaluation of the distinctive mobility patterns of free-floating car-sharing members', *Transportation,* (42(3)) 449–469.

Kraftfahrt-Bundesamt, 2015, 'Jahresbilanz der Neuzulassungen 2014', (http://www.kba.de/DE/Statistik/Fahrzeuge/Neuzulassungen/2014_n_jahresbilanz.html?nn=644522) accessed 14 September 2016.

Le Vine, S., Zolfaghari, A. and Polak, J., 2014, *Carsharing: Evolution, Challenges and Opportunities,* 22th ACEA Scientific Advisory Group Report, Centre for Transport Studies, Imperial College London, London.

Levin, M. W., Li, T., Boyles, D. and Kockelman, K. M., 2016, *General framework for modeling shared autonomous vehicles*, 95th Annual Meeting of the Transportation Research Board, TRB, Washington, D.C.

Litman, T., 2015, *Autonomous Vehicle Implementation Predictions*, Victoria Transport Policy Institute, Victoria.

Loorbach, D., 2007, *Transition Management. New mode of governance for sustainable development. PhD Dissertation*, Erasmus University Rotterdam, Rotterdam.

Markard, J., Raven, R. and Truffer, B., 2012, 'Sustainability transitions: An emerging field of research and its prospects', *Research Policy,* (41(6)) 955–967.

Marsden, G., Atkinson, P., Burkinshaw, J., Edwards, H., Jones, I., Lucas, K., Mattioli, G., Palmer, K., Reardon, L., Wadud, Z., Whiteing, T., Cepeda, M. and Morley, J., 2015, *The World is Changing. Transport Too*, Research for TRAN Committee of the European Parliament, Brussels.

Marshall, A., 2016, 'Is Kansas City's New On-Demand Van the Future of Low-Density Transit?' (http://www.citylab.com/cityfixer/2016/02/kansas-city-bridj-microtransit/462615/) accessed 12 August 2016.

Martin, E. and Shaheen, S., 2011, 'The Impact of Carsharing on Public Transit and Non-Motorized Travel: An Exploration of North American Carsharing Survey Data', *Energies,* (4(11)) 2 094–2 114.

Mazur, C., Contestabile, M., Offer, G. J. and Brandon, N. P., 2015, 'Understanding the drivers of fleet emission reduction activities of the German car manufacturers', *Environmental Innovation and Societal Transitions,* (16) 3–21.

McKinsey, 2010, *A Portfolio of Power-trains for Europe: A fact-based Analysis. The role of Battery Electric Vehicles, Plug-in Hybrids and Fuel Cell Electric Vehicles*, McKinsey & Company, Amsterdam.

McKinsey, 2014, *Evolution — Electric vehicles in Europe: gearing up for a new phase*, Amsterdam Roundtables Foundation, Amsterdam.

Morrow, W. R., Greenblatt, J. B., Sturges, A., Saxena, S., Gopal, A. R., Milstrein, D., Shah, N. and Gilmore, E. A., 2014, 'Key factors influencing autonomous vehicles' energy and environmental outcome', in: Meyer, G. and Beiker, S., (eds), *Road Vehicle Automation,* Springer International Publishing, Cham, Switzerland.

Murray, K. B. and Häubl, G., 2007, 'Explaining Cognitive Lock-In: The Role of Skill-Based Habits of Use in Consumer Choice', *Journal of Consumer Research,* (34(1)) 77–88.

Nabielek, K., Hamers, D. and Evers, D., 2016, *Cities in Europe*, PBL Netherlands Environmental Assessment Agency, The Hague.

Nijland, H., van Meerker, J. and Hoen, A., 2015, *Effecten van autodelen op mobiliteit en CO_2 uitstoot*, Planbureau voor de Leefomgeving, The Hague.

OECD, 2016, *The economic consequences of outdoor air pollution*, Organisation for Economic Co-operation and Development, Paris.

Payen, S., Basset-Mens, C. and Perret, S., 2015, 'LCA of local and imported tomato: an energy and water trade-off', *Journal of Cleaner Production,* (87) 139–148.

PBL, Stockholm Resilience Centre and Stockholm University, 2009, *Getting into the Right Lane for 2050. A Primer for EU debate*, Netherlands Environmental Assessment Agency, Bilthoven.

Peeters, P., Eijgelaar, E., Dubois, G., Strasdas, W., Lootvoet, M., Zeppenfeld, R. and Weston, R., 2015, *Research for TRAN Committee — From Responsible Best Practices to Sustainable Tourism Development, Study Requested by the European Parliament's Committee on Transport and Tourism*, European Parliament, Brussels.

Peeters, P., Szimba, E. and Duijnisveld, M., 2007, 'Major environmental impacts of European tourist transport', *Journal of Transport Geography,* (15(2)) 83–93.

Peters, B., Riley, R. and Siedschlag, I., 2013, *The Influence of Technological and Non-Technological Innovation on Employment Growth in European Service Firms*, Zentrum für Europäische Wirtschaftsforschung, Mannheim.

Pfoser, S., Treiblmaier, H. and Schauer, O., 2016, 'Critical Success Factors of Synchromodality: Results from a Case Study and Literature Review', *Transportation Research Procedia,* (14) 1 463–1 471.

Raven, R., Van den Bosch, S. and Weterings, R., 2010, 'Transitions and strategic niche management: Towards a competence kit for practitioners', *International Journal of Technology Management,* (51(1)) 57–74.

Rayle, L., Dai, D., Chan, N., Cervero, R. and Shaheen, S., 2016, 'Just a better taxi? A survey-based comparison of taxis, transit, and ridesourcing services in San Francisco', *Transport Policy,* (45) 168–178.

Reinhardt, G., Gärtner, S., Münch, J. and Häfele, S., 2009, Ökologische Optimierung regional erzeugter Lebensmittel: Energie ▯ und Klimagasbilanzen, Institut für Energie- und Umweltforschung Heidelberg, Heidelberg.

Ricardo-AEA and TEPR, 2015, *Evaluation of Regulation 443/2009 and 510/2011 on the reduction of CO_2 emissions from light-duty vehicles,* European Commission, Brussels.

Rizet, C., Browne, M., Cornelis, E. and Leonardi, J., 2012, 'Assessing carbon footprint and energy efficiency in competing supply chains: Review — Case studies and benchmarking', *Transportation Research Part D: Transport and Environment,* (17(4)) 293–300.

Roland Berger, 2014, *Shared mobility. How new businesses are rewriting the rules of the private transportation game* (https://www.rolandberger.com/publications/publication_pdf/roland_berger_tab_shared_mobility_1.pdf) accessed 6 October 2016.

Salonen, M. and Toivonen, T., 2013, 'Modelling travel time in urban networks: comparable measures for private car and public transport' *Journal of Transport Geography*, (31) 143–153.

Scharber, H. and Dancs, A., 2016, 'Do locavores have a dilemma? Economic discourse and the local food critique', *Agriculture and Human Values,* (33(1)) 121–133.

Sessa, C. and Enei, R., 2010, *EU transport demand: Trends and drivers*, paper produced by European Commission Directorate-General Environment and AEA Technology plc, European Commission, Brussels.

Seto, K. C., Dhakal, S., Bigio, A., Blanco, H., Delgado, G. C., Dewar, D., Huang, L., Inaba, A., Kansal, A., Lwasa, S., McMahon, J., Müller, D. B., Murakami, J., Nagendra, H. and Ramaswami, A., 2014, 'Human Settlements, Infrastructure and Spatial Planning', in: *Climate Change in 2014: Mitigation of Climate Change, Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Planel on Climate Change*, Cambridge University Press, Cambridge, United Kingdom and New York.

Shaheen, S. A. and Cohen, A. P., 2013, 'Carsharing and Personal Vehicle Services: Worldwide Market Developments and Emerging Trends', *International Journal of Sustainable Transportation,* (7(1)) 5–34.

Shaheen, S., Chan, N., Bansal, A. and Cohen, A., 2015, *Shared Mobility: Definitions, Industry Developments, and Early Understanding*, Transportation Sustainability Research Center — University Of California, Berkeley.

Shaheen, S. A., Chan, N. D. and Micheaux, H., 2015, 'One-way carsharing's evolution and operator perspectives from the Americas', *Transportation,* (42(3)) 519–536.

Shaheen, S. and Cohen, A., 2016, *Innovative mobility carsharing outlook carsharing market overview, analysis, and trends. Winter 2016.*, Transportation Sustainability Research Center — University Of California, Berkeley.

Skinner, I., van Essen, H., Smokers, R. and Hill, N., 2010, *EU Transport GHG: Routes to 2050? Towards the decarbonisation of the EU's transport sector by 2050. Final report by European Commission Directorate — General Environment and AEA Technology plc*, European Commission, Brussels.

Spector, J., 2016, 'Why Transit Agencies Are Finally Embracing Uber' (http://www.citylab.com/commute/2016/04/uber-lyft-ridesharing-apps-public-transportation/475908/) accessed 12 August 2016.

Spieser, K., Treleaven, K., Zhang, R., Frazzoli, E., Daniel, M. and Pavone, M., 2014, 'Toward a Systematic Approach to the Design and Evaluation of Automated Mobility-on-Demand Systems: A Case Study in Singapore', in: Meyer, G. and Beiker, S., (eds), *Road Vehicle Automation,* Springer International Publishing, Cham, Switzerland.

Tavasszy, L.A., Behdani, B. and Konings, R., 2015, *Intermodality and Synchromodality* (http://ssrn.com/abstract=2592888) accessed 6 October 2016.

Temmes, A., Virkamäki, V., Kivimaa, P., Upham, P., Hildén, M. and Lovio, R., 2014, 'Innovation policy options for sustainability transitions in Finnish transport', *Review*, (306/2014).

Tenkanen, H., Saarsalmi, P., Järv, O., Salonen, M. and Toivonen, T., 2016a, 'Health research needs more comprehensive accessibility measures: integrating time and transport modes from open data', *International Journal of Health Geographics*, (15:23) 1–12.

Tenkanen, H., Heikinheimo, V., Järv, O., Salonen, M. and Toivonen, T., 2016b, *Open data for accessibility and travel time analyses: Helsinki Region Travel Time and CO_2 Matrix. Geospatial Data in a Changing World: The short papers and poster papers of the 19th AGILE Conference on Geographic Information Science* (https://agile-online.org/Conference_Paper/cds/agile_2016/shortpapers/184_Paper_in_PDF.pdf) accessed 26 October 2016.

The Economist, 2016, 'The autonomous car's reality check' (http://www.economist.com/news/science-and-technology/21696925-building-highly-detailed-maps-robotic-vehicles-autonomous-cars-reality) accessed 12 August 2016.

TNO, 2015, *Energie- en milieu-aspecten van elektrische personenvoertuigen* (http://www.nederlandelektrisch.nl/file/download/33742992) accessed 6 October 2016.

UBA, 2014a, *Harmful subsidies in Germany*, Umwelt Bundesamt, Dessau-Rosslau.

UBA, 2014b, *Electric bikes get things rolling. The environmental impact of pedelecs and their potential*, Umwelt Bundesamt, Dessau-Rosslau.

UBA, 2016, *Power-to-Liquids. Potentials and Perspectives for the Future Supply of Renewable Aviation Fuel*, Umwelt Bundesamt, Dessau-Rosslau.

University of Helsinki, 2016, *Helsinki Region Travel CO_2 Matrix 2015*, Department of Geosciences and Geography, University of Helsinki, Helsinki. (https://github.com/AccessibilityRG/HelsinkiRegionTravelCO_2Matrix2015) accessed 26 October 2016.

Unruh, G. C., 2000, 'Understanding carbon lock-in', *Energy Policy,* (28(12)) 817–830.

Wadud, Z., MacKenzie, D. and Leiby, P., 2016, 'Help or hindrance? The travel, energy and carbon impacts of highly automated vehicles', *Transportation Research Part A: Policy and Practice,* (86) 1–18.

Webb, J., Williams, A. G., Hope, E., Evans, D. and Moorhouse, E., 2013, 'Do foods imported into the UK have a greater environmental impact than the same foods produced within the UK?', *The International Journal of Life Cycle Assessment*, (18(7)) 1 325–1 343.

Wegener, M., 2004, 'Overview of land-use transport models', in: Hensher, D. and Button, K. B. (eds), *Transport Geography and Spatial Systems*, Pergamon/Elsevier Science, Kidlington.

Wegener, M. and Fürst, F., 1999, *Land-Use Transport Interaction: State of the Art, Deliverable 2a of the project TRANSLAND (Integration of Transport and Land Use Planning) of the 4th RTD Framework Programme of the European Commission*, Berichte aus dem Institut für Raumplanung, Institut für Raumplanung, Dortmund.

Weiss, M., Dekker, P., Moro, A., Scholz, H. and Patel, M. K., 2015, 'On the electrification of road transportation — A review of the environmental, economic, and social performance of electric two-wheelers', *Transportation Research Part D: Transport and Environment,* (41) 348–366.

Wesseling, J. H., Niesten, E. M. M. I., Faber, J. and Hekkert, M. P., 2015, 'Business Strategies of Incumbents in the Market for Electric Vehicles: Opportunities and Incentives for Sustainable Innovation', *Business Strategy and the Environment,* (24(6)) 518–531.

Withana, P., ten Brink, P., Franckx, L., Hirschnitz-Garbers, M., Mayeres, I., Oosterhuis, F. and Porsch, L., 2012, *Study supporting the phasing out of environmentally harmful subsidies.*, IEEP/IVM/Ecologic/Vito, Brussels.

WTCC, 2016, *Travel & Tourism. Economic Impact 2016. European Union LCU*, World Travel & Tourism Council, London (http://www.wttc.org/-/media/files/reports/economic-impact-research/regions-2016/europeanunionlcu2016.pdf) accessed 15 November 2016.

Zachariah, J., Gao, J., Kornhauser, A. and Mufti, T., 2013, 'Uncongested mobility for all: A proposal for an areawide autonomous taxi system in New Jersey', in: Proceedings of Transportation Research Board Annual Meeting, Washington D.C.

Annex 1 Relevant transport targets up to 2050

Target	Target date	Source	Relevant indicator	Comments
Transport GHG emissions (including international aviation, excluding international maritime shipping) + 8 % (versus 1990) 60 % ↓ (versus 1990).	2030 2050	Transport White Paper (EC 2011b), 2050 Roadmap (EC 2011a)	TERM 02	The 2050 Roadmap is the broader strategy that sets the most cost-effective ways to reduce GHG emissions based on the outcome from modelling to meet the long-term target of reducing domestic emissions by 80 to 95 %. The target for the transport sector was set out in the White Paper on Transport on the basis of the 2050 Roadmap.
EU CO_2 emissions of maritime bunker fuels 40 % ↓ (versus 2005).	2050	Transport White Paper (EC 2011b)	TERM 02	
40 % share of low carbon sustainable fuels in aviation	2050	Transport White Paper (EC 2011b)	TERM 31	Potentially monitored through EU ETS reporting.
Use of conventionally fuelled cars in urban transport 50 % ↓ 100 % ↓	2030 2050	Transport White Paper (EC 2011b)	TERM 34	The White Paper goal relates not to vehicle numbers but the share in urban passenger kilometres.
CO_2 free city logistics in major urban centres.	2030	Transport White Paper (EC 2011b)		Not currently possible to monitor.
The majority of medium-distance passenger transport should be by rail.	2050	Transport White Paper (EC 2011b)	TERM 12	Only indirectly monitored through modal shares.
Road freight over 300 km shift to rail/ waterborne transport 30 % shift 50 % + shift	2030 2050	Transport White Paper (EC 2011b)	TERM 13	Only indirectly monitored through modal shares.
10 % share of renewable energy in the transport sector final energy consumption for each Member State.	2020	Renewable Energy Directive 2009/28/EC	TERM 31	
Fuel suppliers to reduce lifecycle GHG of road transport fuel. 6–10 % ↓ (versus 2010 fossil fuels).	2020	Fuel Quality Directive 2009/30/EC	TERM 31	To be monitored in future indicator updates.
Target average type-approval emissions for new passenger cars 130 g CO_2/km 95 g CO_2/km	2012–2015 2020	Passenger Car CO_2 EC Regulation 443/2009	TERM 27 and TERM 34	
Target average type-approval emissions for new light vans. 175 g CO_2/km 147 g CO_2/km	2014-2017 2020	Van CO_2 EC Regulation 510/2011	TERM 27 and TERM 34	
70 % reduction of transport oil consumption from 2008.	2050	Impact assessment-accompanying document to the White Paper. (EC 2011c)	TERM 01	

Annex 2 Explaining the 'target paths'

This annex provides an overview of the method to assess progress towards targets and assign colours to the cells in Table 2.1. This is based on the data presented in Figures A2.1–A2.6.

Reducing transport GHG emissions: In the case of the key target, each year's data will be compared with the 'trajectory' based on the 'preferred policy option' for achieving reductions as set out in the impact assessment accompanying the 2011 Transport White Paper (EC, 2011c) in order to meet the transport GHG reduction target by 2050. The following graph provides a representation of the comparison between real data and the 'target path' defined accordingly. In the column 'Observed' under each given year in Table 2.1, and under the title 'Where we are (current trends vs. 'target path')', a green colour indicates when the latest data show a value equal or below that of the 'target path' for that year. In other words, the reduction achieved is in line with — or better than — the estimations. Because concrete 'preferred policy option' estimations are only available every five years (up to 2050), an interpolation of the values is done for the years in between, prior to the comparison.

In the final column 'latest annual trend', the colour green indicates when the latest data show improvement compared to the previous year in which

Figure A2.1 Transport GHG emissions

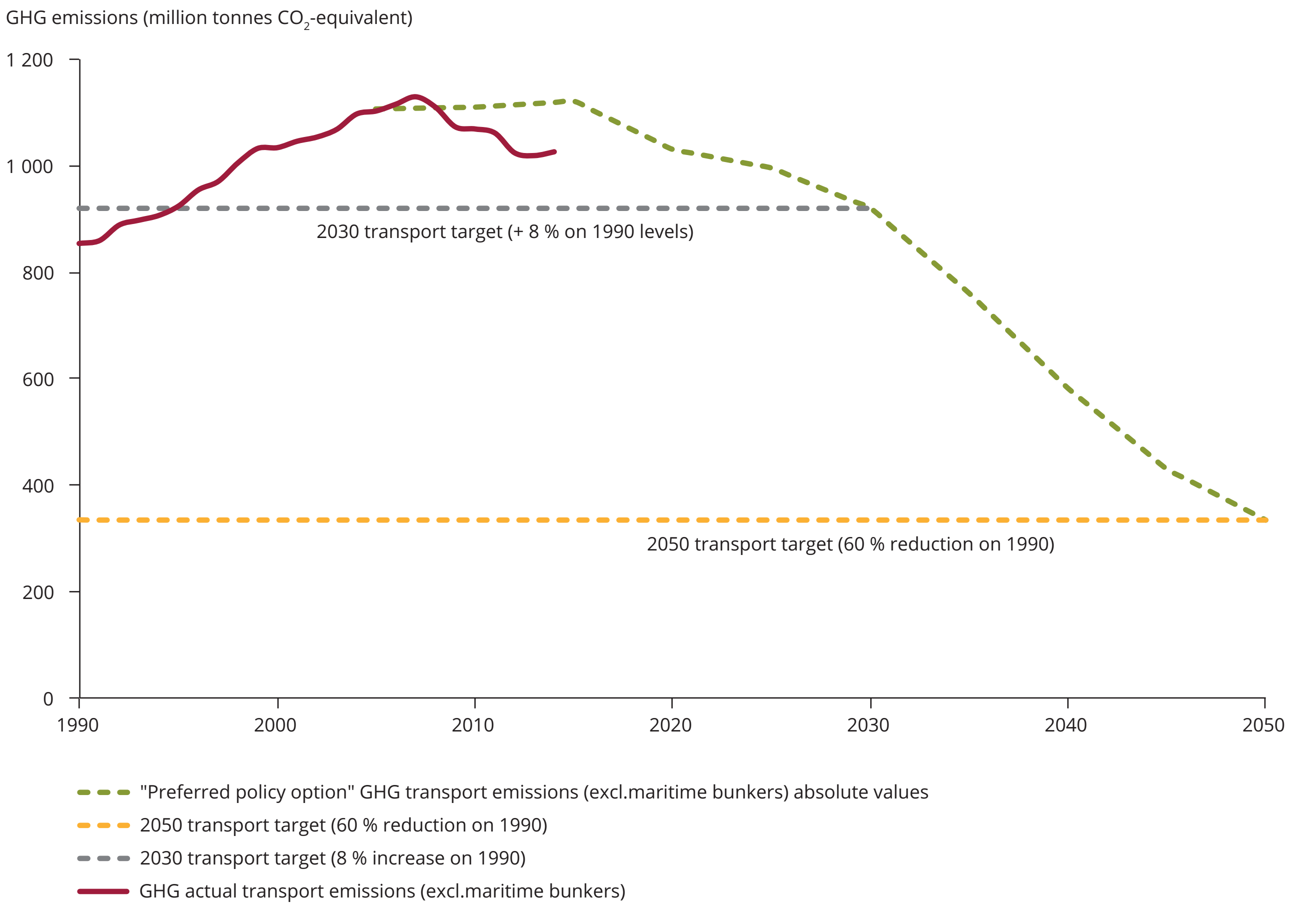
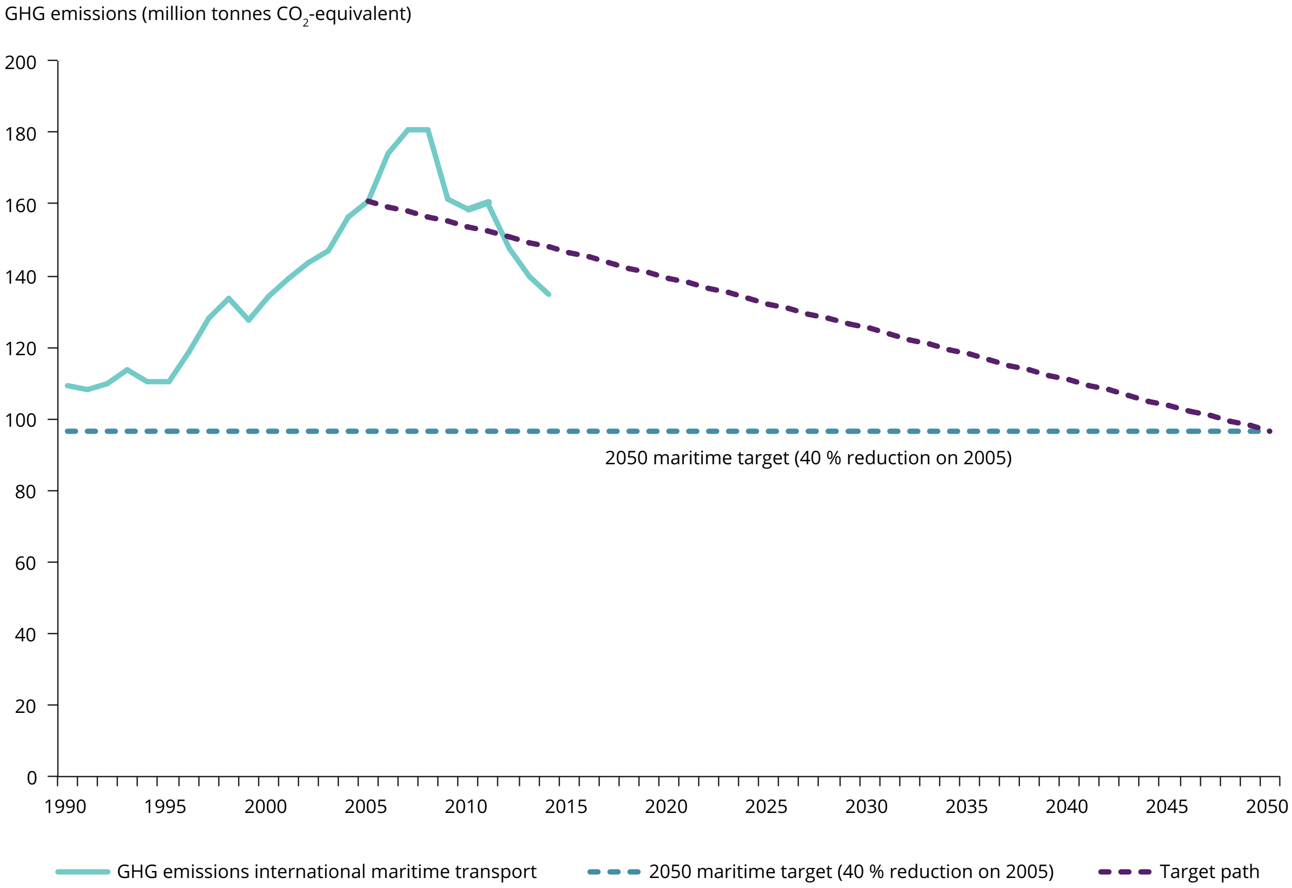


Figure A2.2 EU CO_2 emissions of maritime bunker fuels



data are available, and the colour red indicates that emissions have increased compared to the previous year.

Indicative targets: In order to assign a colour for the cells for the indicative targets, a similar methodology has been followed. However, as there were no official estimations on the 'target path' to be followed, this path is calculated by plotting a straight line from the base year data to the target year data, i.e. assuming a linear trend towards the target. At this point, it is clear that this is a subjective assessment of progress with the only aim being to give an approximate indication of whether the target will be met. Assuming a linear trend could lead to incomplete conclusions because for most of the targets improvements are not expected in the first years. This is as a consequence of fleet renewal and technology uptake, among other circumstances, including temporal breakdowns or recessions. However, these circumstances will be explained when assessing the annual progress, and can also be checked against the evolution of different TERM indicators. In addition, assumed linear trends have been calculated bearing in mind mid-term targets if available (i.e. CO_2 emissions from new passenger cars for the 2015 and 2020 targets) and therefore different speeds to meet the targets, forecast in official scenarios and documents, are taken into account.

Figure A2.3 Target average type-approval CO_2 emissions for new passenger cars

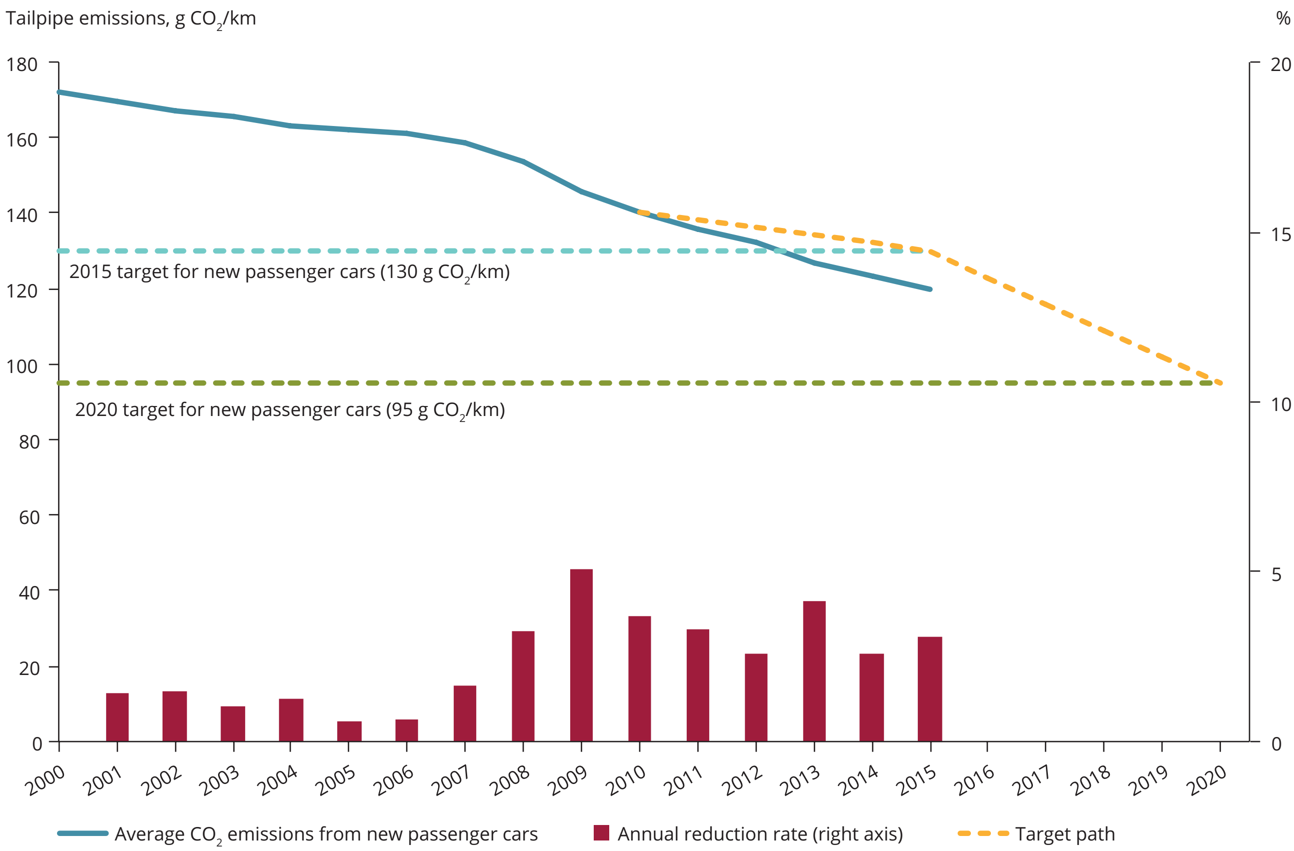


Figure A2.4 Target average type-approval CO_2 emissions for new vans

Figure A2.5 Reduction of transport oil consumption (incl. maritime bunkers)

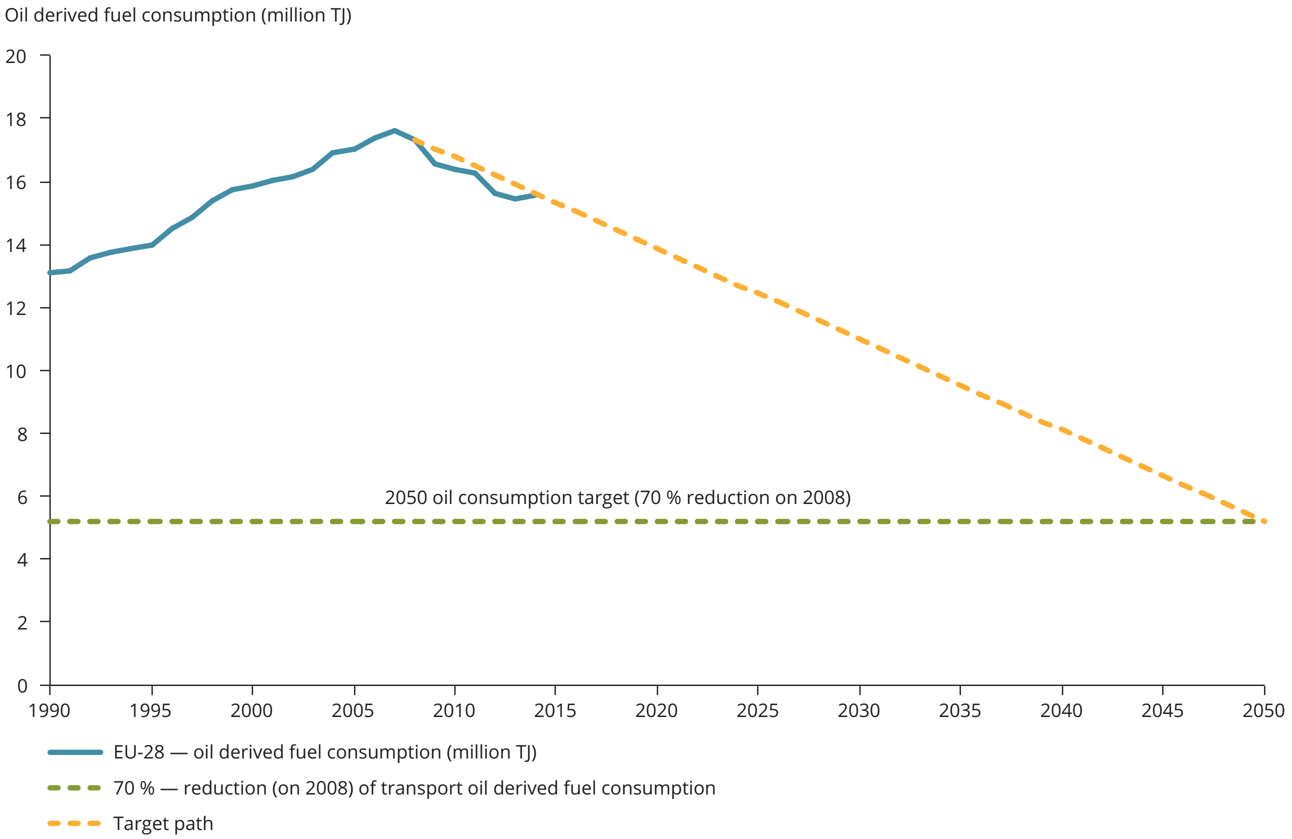


Figure A2.6 Share of renewable energy in the transport sector

European Environment Agency

Transitions towards a more sustainable mobility system
TERM 2016: Transport indicators tracking progress
towards environmental targets in Europe

2016 — 83 pp. — 21 x 29.7 cm

ISBN 978-92-9213-839-4
doi:10.2800/895670

TH-AL-16-034-EN-N
doi:10.2800/895670

European Environment Agency
Kongens Nytorv 6
1050 Copenhagen K
Denmark

Tel.: +45 33 36 71 00
Web: eea.europa.eu
Enquiries: eea.europa.eu/enquiries

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