Green light for sustainable mobility

Vision and pathway to 2050

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Transport & Environmental Policy Research

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CE Delft
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Content

Executive summary

The need for a truly sustainable mobility sector

Today, life in many areas in Europe is congested, noisy and polluted. Every year, about half a million people in the EU die prematurely due to air pollution. This is more than ten times the number of fatalities from road traffic accidents. In addition, more people than live in Germany and the Netherlands combined are exposed to noise pollution from road traffic at levels at which negative health effects can occur. Increasingly, city authorities recognise that there is a need to change the way in which we use the limited urban space, while reducing pollution and noise. At the same time, keeping rural destinations accessible for people without a private car imposes different kinds of challenges for policymakers. Some steps are being taken towards a sustainable mobility sector, in which the transport system works equally for all of its users and where it does not operate in conflict with the environment. However, in many policy decisions other interests prevail. Too often, policymaking is dominated by cars and aimed at reducing road congestion, rather than at the broader challenge of a transition towards a sustainable transport sector.

Given this current situation, the Greens/EFA group in the European Parliament asked CE Delft and TEPR to explore what a truly sustainable mobility sector in 2050 might look like, and how we might get there.

What do we mean by sustainable mobility?

A mobility sector that protects both nature and human health

The achievement of sustainable mobility requires that a wide range of objectives are met.
It effectively means a transport system that has zero or minimal impact on the environment and which has no – or minimal – adverse social and economic impacts, while at the same time meeting social needs and supporting a sustainable economy. Global warming should be kept well below the 1.5 to 2°C, as agreed under the Paris Agreement, and the environment in cities should change in a way that air becomes safe to breath and that noise levels do not negatively affect health.
A sustainable mobility sector should also be safe and secure, and be designed and operated in a way that people feel safe and secure using all of it. Urban space would be used more efficiently to improve liveability. Natural habitats and wildlife are not negatively affected, ensuring that nature and the services it provides are protected.

A mobility sector that is an integral part of a sustainable economy

From the perspective of resources, a sustainable mobility sector is an integral part of the circular economy, meaning that waste is reduced substantially, through better use of resources and improved recycling, particularly of scarce, or potentially scarce, raw materials. Overall, a sustainable mobility sector reinforces a sustainable economy, while reducing inefficiencies, such as excessive congestion, that damages the economy and the environment. It should continue to provide a varied set of jobs, although these may well be different from those of today.

A mobility sector that provides affordable mobility for all people

A primarily private car-based mobility sector discriminates against those who are too young or too old to drive, or who are unable to drive for reasons of health or income. A truly sustainable mobility sector must therefore be non-discriminative to ensure that it provides all people with the same opportunities. In this way, it will contribute to a cohesive and inclusive society. At the same time, increasing digitalisation of transport, such as cooperative, connected and automated mobility, should be accompanied by mechanisms to ensure that individuals' privacy is protected when we travel.

How to deliver a truly sustainable mobility sector?

The transition towards a sustainable mobility sector in 2050 will not happen by itself; it requires a broad range of policies. By putting an appropriate combination of instruments in place, the various challenges can be tackled. There is more than one approach possible to achieve this, but all should at least include a combination of measures focused on user behaviour on the one hand and on technological change and innovation on the other.

Make sustainable mobility the most attractive, affordable and obvious choice

In order to support people to change mobility patterns and modal choices, alternatives to private car transport should become more attractive and for most trips the obvious and best choice for consumers. This can be achieved by putting policies in place, such as urban planning, developing 'Mobility as a Service', pricing policies and environmental zoning, but also by means of vehicle and energy taxation. Overall, policy measures should result in solid and sound investments for improving the sustainable options in an optimal way, which will benefit all transport users.

Make sure that zero-emission technology is available, affordable and sustainable

Consumers are only able to choose the most sustainable option when there are sufficient numbers of zero-emission vehicles on the market and when there is sufficient infrastructure to fuel these vehicles. This can be realised by putting a mix of policies in place to help to overcome the main barriers associated with the various technologies. Electrification of the car and van fleets can best be accelerated by the regulation of the CO_2 emissions of new vehicles, potentially in combination with zero-emission vehicle mandates. For heavy goods vehicles and buses, ambitious vehicle regulation can also be a very powerful instrument for achieving technology change. Sustainable types of advanced biofuels and synthetic fuels require the CO_2-based regulation of energy carriers, supported by strict sustainability criteria. Standardisation and support in the development of the required energy infrastructure is important for all technologies. Particularly when prices of new technologies are not yet competitive due to a lower level of production and the cost of new technology is higher, vehicle and energy taxation, green public procurement and local incentives can help to stimulate demand and make the new technology affordable.

What are the further considerations in delivering a sustainable mobility sector?

Take care when talking about 'technology neutrality'

It is a misunderstanding that all policies should be 'technology neutral'. Policies aimed at contributing to a more sustainable transport system need to promote low carbon technology and transport modes, and the infrastructure and services that contribute to the transition that is needed. This means that by definition these policies discriminate between technologies. When possible, targets should be set based on the desired end result, e.g. the share of zero-emission vehicles in fleet, or a reduction of urban space available for transport, without specifying what specific technology or solutions should be

used. However, even then, they will and are even intended to discriminate between different technologies. Moreover, some policies, such as those targeting energy infrastructure development, are obviously by definition technology specific.

Consider cost-effectiveness only when it is appropriate to do so

In general, it is clear that achieving a sustainable future for the lowest possible costs to society is to be preferred, i.e. that it should be 'cost-effective'. However, this principle cannot be applied in every stage of innovation and for all kinds of policies and even could hinder the timely preparation of a long-term transition.

Involve people to enhance confidence and encourage change

Change always results in losers and winners. The transition to a sustainable transport sector will also harm vested interests. Therefore, it cannot be a surprise that many of the policies needed for achieving a sustainable transport sector face strong public and/or political resistance. Ways to tackle this are to involve people in developing alternatives and to ensure that no particular group is unreasonably affected. It also helps to combine 'carrots' and 'sticks', e.g. by using revenues from road charges for improving alternatives and making sure that they affordable for all users.

In addition, by following a step-by-step approach, people have time to adapt and can get used to changes. For large changes, like the introduction of an urban congestion charge system, first starting with a trial, before making it definitive is a proven way to overcome public resistance. It gives users time to see the benefits and to get used to the new situation.

What are the benefits of a truly sustainable mobility sector?

Reduced costs and increased productivity

While changes will require large up-front investments, they will deliver significant cost savings over time as a result of lower energy use, reduced health damage from air or noise pollution, as well as the improved physical and mental health from more liveable and better accessible cities and more active travel. Currently, the health related costs of transport are in the order of € 0.5 trillion a year, which is about the same as the total GDP of a country like Belgium or Poland. A significant reduction of the health impacts will therefore deliver large savings. Many of these savings will be in other sectors, e.g. in the health sector, rather than in the transport sector, but overall there are likely to be benefits to the economy. Many examples show that these benefits could be higher than the costs.

Improved social equity

In general, one can expect that the transition to a sustainable transport system as proposed will generally also improve social equity, because mobility options for people without access to a private car will improve. In addition, urban planning aimed at densification and mixing functions will enable all people, including people who cannot afford to own or drive a car, to more easily access jobs, medical care or other destinations.

Increased number of sustainable and healthy jobs

The many jobs in European car manufacturing and vehicle component industries are often used as an argument against policies like strict vehicle standards. The challenge from the perspective of jobs in transport is, however, not in delivering a low carbon, sustainable mobility sector, as reports suggest that this will increase rather than decrease the number of jobs. Increasing numbers of jobs will be needed for developing and maintaining new infrastructure such as cycling or rail networks, running

public services, in bicycle shops and maintenance, the development and operation of multimodal transport planning and payment services, production of renewable energy and putting the necessary charging infrastructure in place (including supporting related services), etc.
A report for the European Climate Foundation estimated that the transition to electric vehicles will result in a net increase of 260,000 jobs in Europe by 2030, as a result of an increase in the number of jobs associated with producing renewable energy and putting the necessary charging infrastructure in place.

With respect to jobs, the main challenge comes from the automation of the transport system, which is likely to happen with or without the achievement of a truly sustainable mobility sector. The extensive automation of the transport system will lead to job losses and some job gains, similar to what is already happening and is expected to continue in many other sectors. The net effect will depend on the scale and impact of automation. This will be a challenge for society as a whole and is not particularly related to transport.

Recommendations

The narrative concludes with a long list of policy measures for achieving the transition towards a truly sustainable transport sector that could be applied at the EU, national or local level (see Page 42).
In many cases, the effectiveness of, and support for, policies increases when they are combined, e.g. improving cycling and public transport combined with parking policies and urban road pricing. Most measures listed can be regarded as 'no regret' policies that are beneficial in any scenario.

Glossary

BEV	Battery Electric Vehicle
CO_2	Carbon-dioxide
GHG	Greenhouse Gas
ICE	Internal Combustion Engine
MaaS	Mobility as a Service
NO	Nitric Oxide
NO_2	Nitrogen Dioxide
NO_x	Nitrogen Oxides
OEM	Original Equipment Manufacturer
PM	Particulate Matter
$PM_{2.5}$	Particulate Matter, particles with a diameter of 2.5 µm or less
PM_{10}	Particulate Matter, particles with a diameter of 10 µm or less
WHO	World Health Organisation
ZE	Zero Emission
ZEV	Zero-Emission Vehicle

1 Introduction

1.1 Background: the need for change

Today, life in many cities in Europe is congested, noisy and polluted. Unless you manage to find one of the few relatively isolated pedestrianised areas, streets are often full of traffic, which is barely moving. Cars, often with a single person sitting in the driver's seat, take up most of the road space.
The increasing number of delivery trucks disappear at speed down side roads and block pedestrian and cycle routes while they make their deliveries. Cycle tracks – where they exist – are blocked by parked cars, or are full of cars that ignore the road markings. Cycle tracks often end at junctions – where the danger to cyclists is highest – leaving cyclists to fend for themselves at traffic lights. Frustrated passengers sit in buses stuck in slow moving traffic worrying about missing appointments as they are delayed by the traffic.

Public urban space is dominated by roads, leaving little space for people to socialise, even if they could hear each other speak above the noise of the traffic. Foul smelling, and toxic, air circulates in residential streets. The few children who walk or cycle to school breathe in exhaust fumes as they avoid the traffic, while their classmates breathe in the pollution in their parents' cars as they are being taken to school. Less visible, but by no means less important, the traffic in our cities emits gases that are changing the climate, with uncertain consequences for future generations.

Increasingly, city authorities recognise that there is a need to change the way in which we use the limited urban space, while at the same time reducing pollution and noise. In many cities, the centre and the main shopping streets are being pedestrianised. Cycle lanes are being put in, and cycle networks planned, while city authorities are trying to encourage people to cycle more. Cities are helping public transport move people around more quickly, and are requiring operators to use less polluting buses. While in some cities, such actions are extensive, in others they are isolated in an urban environment that is still dominated by the car. The vision that cities are starting to work towards is one of sustainable mobility, in which the transport system works equally for all of its users and where it does not operate in conflict with the environment.

The Greens/EFA group in the European Parliament asked CE Delft and TEPR to explore what a truly sustainable mobility sector in 2050 might look like, and how we might get there. We were not asked to produce a research report; rather we were asked to develop a narrative for the attainment of a truly sustainable mobility sector. This report sets out such a narrative. It is by no means the only way to deliver a sustainable mobility sector; indeed CE Delft and TEPR recognise that there are many different potential routes forward, so we are not necessarily endorsing the vision presented. However, the narrative is a potential route to a more sustainable transport future and demonstrates what a sustainable mobility sector might look like in practice for land-based passenger and freight transport in 2050. It begins by exploring the issues that a sustainable mobility system will need to address, as well as the continued benefits that it will need to support. It then sets out a vision for a sustainable mobility sector in 2050 – which is far enough away for the necessary changes to be delivered. This vision outlines how people and freight might move around in 2050, given the continuation of current developments in technology.

Achieving this vision is not without its challenges. A range of policy actions will be needed to ensure that the mobility system develops in a way that is truly sustainable, and that full advantage is taken of the most promising technologies. The necessary measures, along with the implications for people and businesses, are set out. Investment will be required, as would the achievement of any future vision, but a sustainable mobility system is achievable and will deliver a transport system that meets everyone's needs, while at the same time respecting the environment. Vision will be needed by politicians, so we conclude with some recommendations for actions in the short- and medium-term.

1.2 Outline of the narrative

The narrative begins in Chapter 2 with a description of what a sustainable transport sector would look like in 2050. In Chapter 3, an analysis is presented of the transition paths and policy strategies that are required to reach this vision. These transition paths and policy strategies will result in both positive and negative implications, require investments and result in costs and savings. A qualitative overview of these implications is presented in Section 4. The narrative ends in Chapter 5 with the most important recommendations.

2 Vision of the transport sector in 2050

2.1 Sustainable mobility: what does it mean?

The achievement of sustainable mobility requires that a wide range of objectives are met. It effectively means a transport system that has zero or minimal impact on the environment and which has no – or minimal – adverse social and economic impacts, while at the same time meeting social needs and supporting a sustainable economy. This encompasses many different elements.

Climate change – keeping global warming well below 2°C

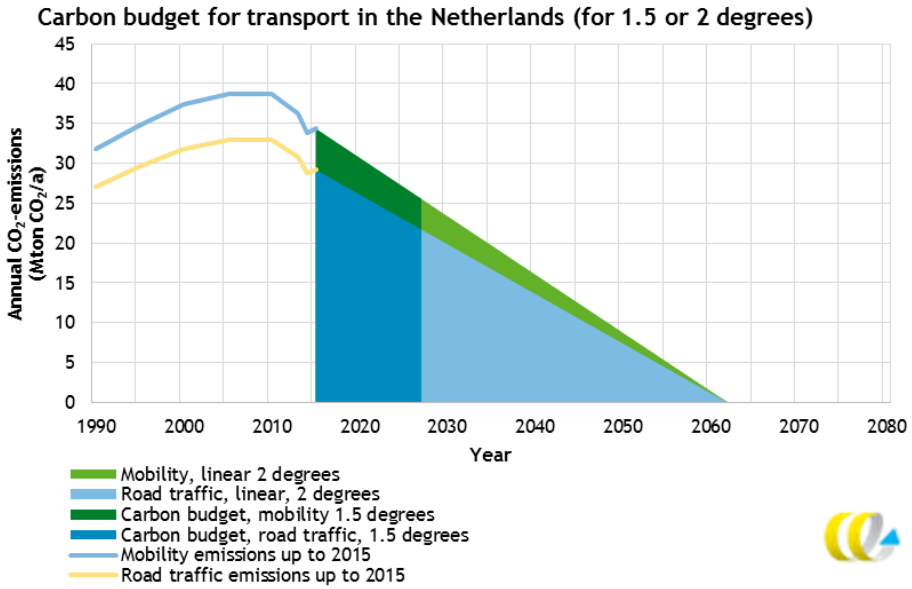
The most important environmental challenge for the current transport system is the need to mitigate global warming and climate change, which is caused by the emission and accumulation of greenhouse gases (GHGs) in the atmosphere. By far the most significant GHG emitted from the transport sector is carbon dioxide (CO_2), which is emitted from the combustion of diesel, petrol and other fossil fuels by cars, trucks, diesel trains and barges, as well as from the production of the electricity used by electric trains, trams and cars. According to the European Environment Agency, road transport emits 25% of the EU's CO_2 emissions, making it the second largest source of CO_2 emissions behind electricity production. While the CO_2 emissions from the electricity sector have been decreasing significantly in recent years, CO_2 emissions from road transport have increased in each of the last three years. Transport is now the most problematic sector in terms of mitigating climate change.

The Paris Agreement from 2015, which has been ratified by over 170 countries, called for the increase in global temperatures to be limited to 2°C above pre-industrial levels and that efforts are pursued to limit warming to 1.5°C. This would require the virtual decarbonisation of the economy by 2050, i.e. that there would be virtually no GHG emissions by that time. Keeping the temperature increase within the proposed limits effectively means that there is an upper limit – or carbon budget – that restricts the amount of CO_2 that can be emitted from the transport sector.

Figure 1 shows for the Netherlands the recent development of CO_2 emissions from mobility in general, and from road transport in particular, and the linear reduction that is in line with limiting warming to 2°C. This will be similar for other countries and for the EU as a whole. The graph makes clear that even if the emissions continued to decline, the carbon budget to limit warming to 1.5°C would be exhausted within ten years. With current levels of CO_2 emissions, the total budget for limiting warming to 2°C would be exhausted around 2035.

There have been many studies looking at how CO_2 emissions from the transport sector might be reduced to levels that meet, or are even below, those implicitly required by the Paris Agreement. The Vision Scenario developed by the Öko-Institut for the Greens/EFA Group has CO_2 emissions from transport declining to zero by 2050, which is clearly consistent with the aspirations of the Paris Agreement. The mobility sector would then be effectively climate neutral.

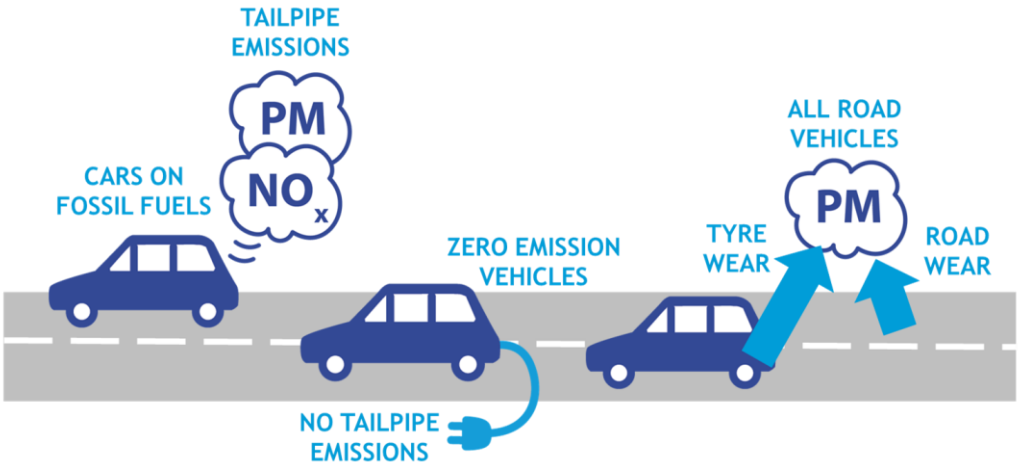
Figure 1 - Carbon budget for transport in the Netherlands (CE Delft, 2017)



Air pollution – the need for air that is safe to breath

The next most pressing environmental concern to which the mobility sector currently contributes is air pollution. Emissions of various pollutants from transport, and particularly from road transport, are a major cause of polluted and unhealthy air. It is peoples' exposure to air pollution that causes adverse health effects, such as respiratory and cardiovascular diseases and cancer. This underlines the need to improve air quality in urban areas where exposure levels are highest.

Figure 2 - Sources of air polluting emissions from road transport



The World Health Organisation (WHO) assesses the emerging scientific evidence on the adverse health effects of air pollutants. Because of its assessment, WHO publishes Guidelines that include recommendations on the maximum safe concentration and the duration of safe exposure for each air pollutant. The main air pollutants of concern in 2018 are nitrogen dioxide (NO_2) and particulate matter (PM). Currently, EU limit values for NO_2 follow WHO's Guidelines; breaches of the limit values for NO_2 are the basis of some of the legal action currently being taken by the European Commission against various Member States. EU limit values for PM and fine PM (PM_{10} and $PM_{2.5}$, respectively) are currently less stringent than those proposed by the current WHO Guidelines. Unlike the emissions that lead to NO_2, which are only caused by the combustion of fossil fuels, PM emissions also come from other sources, including tyre wear, brake wear and road wear.

In Europe, air pollution kills ten times more people than car accidents every year

The European Environment Agency estimates that 3% of the population of the EU, which is nearly equivalent to the combined population of Slovakia and the Czech Republic, are exposed to levels of NO_2 above the EU's legal limits, with similar figures for the EU's legal limits for PM_{10} and $PM_{2.5}$. However, 43% of the EU population is exposed to levels of PM_{10} above the levels recommended by the WHO Guidelines, while 84% are exposed to levels of $PM_{2.5}$ above the levels proposed by WHO.

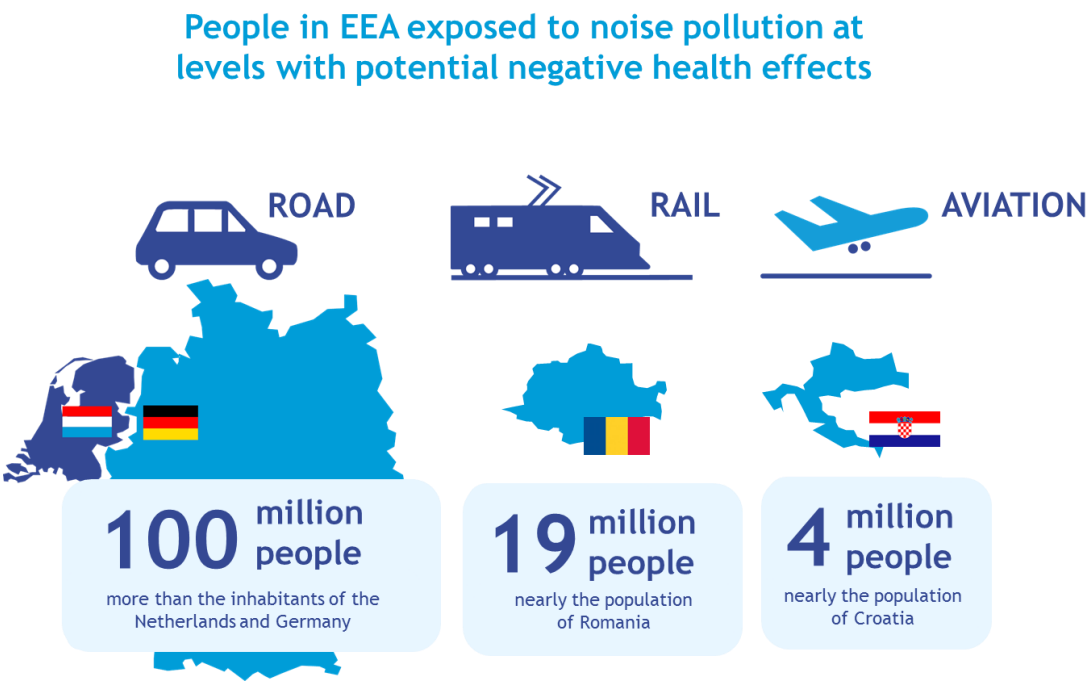
Every year, about half a million people in the EU die prematurely due to air pollution. This is more than ten times the number of fatalities from road traffic accidents. In addition, poor air quality has caused more than six million people to become ill with diseases such as asthma or bronchitis, which is more people than the entire population of Denmark.

In order to be sustainable, the level of air pollutant emissions from the mobility sector, particularly those of NO_2 and PM, should be minimal and lead to concentrations that are well below the levels recommended by the current WHO Guidelines, as these are likely to be strengthened between now and 2050.

Noise pollution – quiet cities needed for improved health

Noise pollution is arguably an overlooked environmental problem, even though it has a detrimental impact on human health. The three most significant sources of noise pollution are all transport: road, rail and air transport. The European Environment Agency estimates that 100 million people in the EEA member countries, i.e. more people than live in Germany and the Netherlands combined, are exposed to noise pollution from road traffic at levels at which negative health effects can occur. Nineteen million people – nearly the population of Romania – are adversely affected by noise pollution from railways, and four million (nearly the population of Croatia) are effected by aircraft noise. Noise from vehicles is generated by the operation of the engines, but also from the contact between the tyres and the road surface and, for railways, the contact between the wheels of the train and the tracks. A sustainable mobility sector should be much quieter.

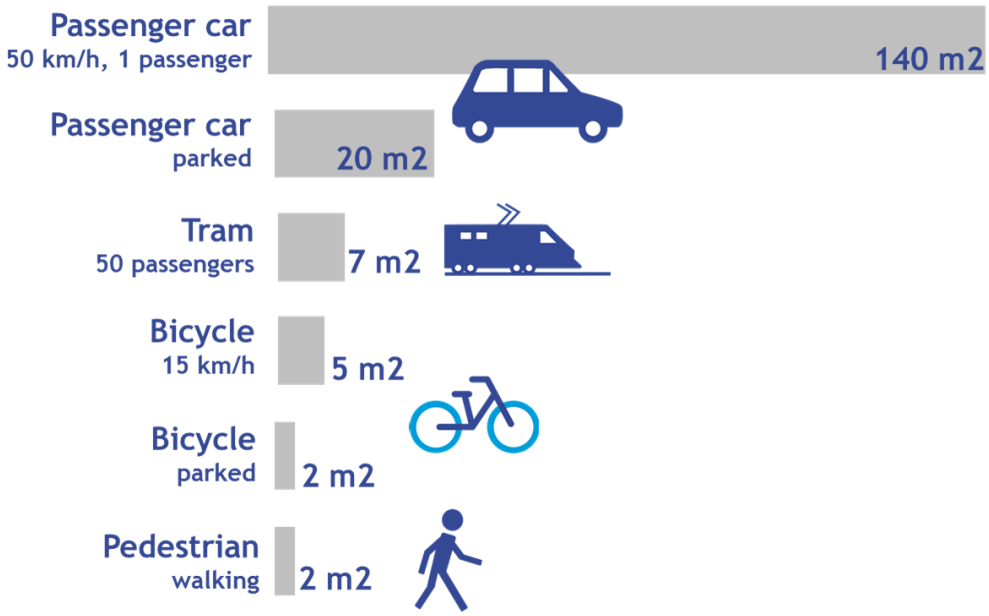
Figure 3 - People in EEA exposed to noise pollution at levels with potential negative health effects



Urban space and liveability – cities for people

Within urban areas, space is limited and has to meet the demands of many different uses. In addition to transport, space is needed for the purpose of accommodation and employment, the provision of services and to enable the purchase of products, including food, and for socialising. The latter in particular is important for the liveability of urban areas. Without constraints, transport's demand for urban space, particularly in large cities, risks increasing congestion and reducing liveability, thus adversely contributing to sustainability from both an economic and a social perspective. Individualised motorised transport is a relatively inefficient user of space compared to other modes (see Figure 4). A sustainable mobility sector would ensure that urban space is used more efficiently to improve the liveability of our urban areas.

Figure 4 - Comparison of transport modes on their efficiency in use of urban space



Protecting nature

Transport also has impacts on nature. Air pollution can adversely affect the growth of vegetation, including crops, while certain pollutants, including NO_2, can contribute to the acidification and the subsequent eutrophication of soil and watercourses. Noise from transport can adversely affect wildlife. The location and design of infrastructure have an impact as the construction of infrastructure can lead to habitat and species loss and the fragmentation of the habitats that remain. Additionally, large numbers of animals are killed on roads each year. On the Dutch road network, about 6,000 large mammals (such as deer, wild boar and foxes) are killed every year by collisions with road vehicles. In Germany, 210,000 road accidents involving wild animals were reported in the 2012-13 hunting season.

Transport infrastructure can also adversely affect the landscape. Last, but not least, nature provides 'ecosystem services' to people, through replenishing oxygen in the air and providing water and soil to maintain life and grow crops, while access to nature improves peoples' wellbeing. Infrastructure can adversely affects nature's ability to provide such services. A sustainable mobility sector should result in no net loss of habitats and be designed to ensure that it has a minimal impact on wildlife and that it protects the services that nature provides.

Circular economy – reusing materials and eliminating waste

In addition to the use of fossil fuels, the mobility sector uses other resources, from steel and aluminium in vehicles, to aggregates for road building and, increasingly, rarer metals, such as lithium and cobalt, for the batteries of electric vehicles. The increasing use of electronics, both in vehicles themselves and in traffic control systems, including intelligent transport systems (ITS), provides a further complication in terms of resource use. Öko-Institut's Vision Scenario envisages that by 2050 99% of the final energy demand in the transport sector would come from renewable sources of energy. A sustainable mobility sector would be an integral part of the circular economy, meaning that

waste is reduced substantially, through better use of resources and improved recycling, particularly of scarce, or potentially scarce, raw materials.

Safety and security – reducing casualties and secure and comfortable travel

While both air and noise pollution adversely affect human health, the mobility sector is directly responsible for thousands of deaths as a result of accidents. According to European Commission figures, there were more than 26,000 deaths on the EU's roads in 2017, which is equivalent to 300 full London double decker buses, while there were one million road traffic accidents that resulted in serious injury to an individual. While there are significantly fewer casualties from accidents involving other modes, all accidents cause disruptions and delays to other users of the mobility system. A sustainable mobility sector would have as close to zero fatalities and personal injuries as possible.

A sustainable mobility sector should also be secure, and be designed and operated in a way that people feel safe and secure using all of it. It is not just actual safety and security that is important, but also peoples' perception of these. The perception of safety and security can be a barrier to the use of certain modes, including cycling and public transport, which must be overcome through the way in which infrastructure and vehicles are designed and operated. In this respect, the needs of different genders, ages and minority groups need to be taken into account, including the different ways in which they might use and perceive infrastructure and vehicles. A sustainable mobility sector must ensure that it addresses the concerns of all sections of society in order to provide a safe and secure system that all feel comfortable using.

Social sustainability – access and opportunity for all

As well as not putting up barriers that discourage people from using the transport system as a result of concerns over safety and security, a sustainable mobility system must also allow all groups within society to meet their needs and indeed to enable them to flourish as individuals. The mobility system needs to be designed to enable all members of society to access the services, and to buy the food and other products, that they need. It needs to ensure that people of all ages, genders, income groups and ethnic minorities can access education and employment to enable them to participate fully in society. A single parent needs to be able to access employment opportunities, while at the same time looking after the needs of his/her children. A car-based mobility sector discriminates against those who are too young or too old to drive, or who are unable to drive for reasons of health or income. A truly sustainable mobility sector must therefore be non-discriminative to ensure that it provides all people with the same opportunities. In this way, it will contribute to a cohesive and inclusive society.

Privacy – restricting access to our data

An emerging area, which it is important to ensure is addressed in the context of a sustainable mobility sector, is that of respecting privacy. As technology develops, it enables the implementation of traffic management instruments, such as urban vehicle access restrictions, which are often monitored by cameras that register all of the cars that enter the restricted area. Speed enforcement is also increasingly being undertaken by cameras, while the smart cards that we use to travel on public transport enable operators to monitor where we have been. While such approaches are beneficial from the perspective of sustainable mobility, as they are efficient ways of ensuring that the relevant policies can be enforced and they also enable us to travel, care needs to be taken that the information that is gathered is not used for other purposes, or that it does not fall into the wrong hands.

Looking into the future, privacy is likely to become even more of an issue as a result of the increasing digitalisation of transport, which could ultimately lead to a mobility system in which vehicles and infrastructure are cooperative, connected and automated. For such a system to be effective, the position, and even behaviour, of many, if not all, transport vehicles will need to be known, and so all vehicle movements will need to be monitored. It is important to ensure that mechanisms are put in place to ensure that our privacy is protected when we travel and when policies are enforced. These mechanisms will need to be reinforced as the mobility system becomes more connected and automated.

Sustainable mobility to support a sustainable economy

The transport system also enables activities that contribute to the health of the economy and to the wellbeing of society more generally. From an economic perspective, transport should be delivered as efficiently as possible, as well as meeting the environmental and social conditions that have already been set out above. Inefficient use of transport vehicles and transport infrastructure is not just bad for the environment, but is also bad for the economy. Congestion is a good example. While it would not make economic or environmental sense to eliminate congestion entirely, at its current levels, particularly in many urban areas, congestion incurs significant costs for the economy and for the environment. A sustainable mobility sector must reinforce a sustainable economy, while reducing inefficiencies that damage the economy and the environment.

Employment – many jobs in a sustainable transport system

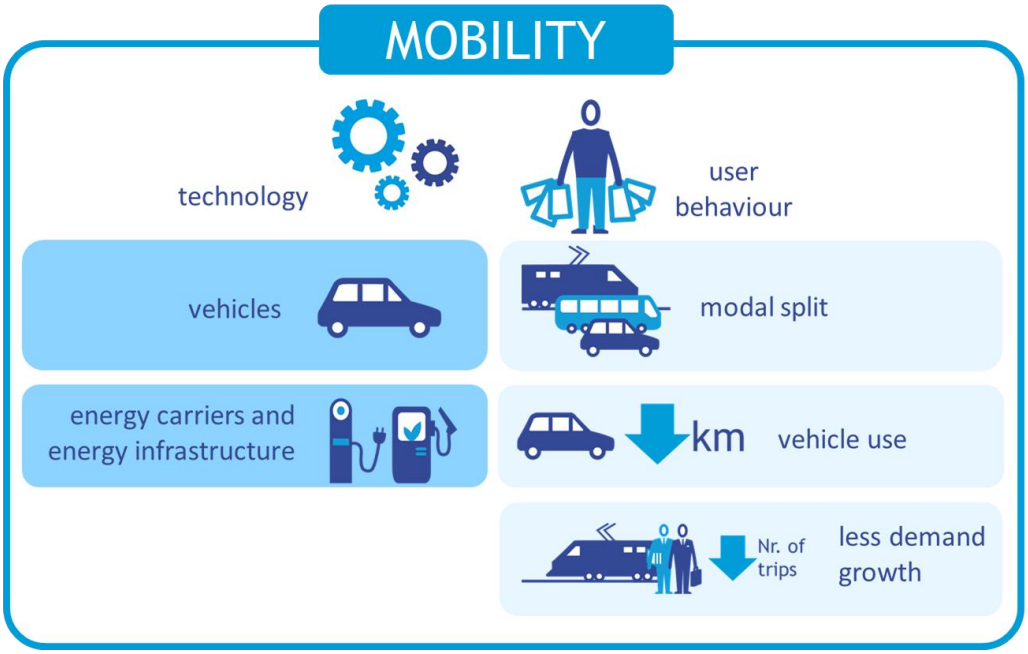
The mobility sector is also a major employer. The latest figures from the European Commission suggest that the sector directly employs eleven million people in the EU, or around 5% of the EU's workforce. These jobs range from the manufacture of vehicles and the construction of infrastructure to those involved with the operation and management of the transport sector. Identifying how the total number of jobs is divided between the various transport subsectors is challenging, as many jobs that might be considered to be a 'transport' job may not be classified as such by statistics. WHO (2014) reviewed estimates of sustainable transport jobs. It reported that a study for Spain estimated that there were nearly 300,000 jobs in sustainable transport, which was around one third of those who worked in the transport sector in that country. A similar study for the UK (another country with a significant car manufacturing industry) estimated that there were 450,000 jobs in sustainable transport, which represented 38% of the national transport workforce. A large proportion of the 'sustainable transport' jobs were in the rail and bus industries. In both cases, the share of more sustainable transport in jobs appears to be larger than its share in the transport performance.

More generally, the link between environmental protection and jobs was highlighted by the International Labour Organisation, which estimated that 16% of jobs were in sectors that relied on a healthy environment, i.e. sectors that relate to or rely on there being biodiversity and the presence of ecosystem services. A sustainable mobility sector would continue to provide a varied set of jobs, although these are likely to be different from those of today, while at the same time protecting the environment and the jobs that rely on a healthy environment.

2.2 What will a sustainable mobility sector in 2050 look like?

A sustainable mobility sector will be made up of the same fundamental elements as the mobility sector of today, as set out in the diagram in Figure 5, but will be different in terms of the vehicles and energy sources that are used, and in the way those vehicles are used.

Figure 5 - Schematic overview of the fundamental elements of the mobility sector



Renewable energy – power that does not pollute

As foreseen by the Öko-Institut's Vision Scenario for 2050, the vast majority of the energy used in a sustainable mobility sector will be from renewable sources. Significant investment will be needed on the part of energy suppliers to replace the fossil fuels used by the 2018 transport system with the renewable fuels and energy sources that will power the sustainable mobility sector of 2050. Under the Vision Scenario for 2050, the energy used by the transport sector will come from electricity, hydrogen or other synthetic fuels and advanced biofuels. Renewable electricity would power 75% of the transport activity of passenger cars, 80% of rail and a third of freight.

Under this scenario, it is anticipated that still a significant amount of liquid fuels and gases would be used, which would amount to around 25% of the current level of fossil fuel use. The Scenario foresees that most of this (about 20% of the energy used by the transport sector in 2050) will come from second and third generation biofuels, i.e. biofuels that have been accredited as being sustainable so are carbon neutral and minimise other adverse environmental impacts. It foresees that such fuels will largely be used by road-based freight transport.

The remaining fuels will be 'power-generated' fuels, i.e. using wind and solar energy to produce synthetic fuels such as hydrogen (and, potentially, fuels similar to existing fossil fuels with the addition of carbon) that can be used in transport. Currently, the production of these fuels is extremely limited. In order to contribute to the scale foreseen in the Vision Scenario for 2050, the production of these fuels will need to be expanded considerably and produced in a way that is truly sustainable.
The Scenario underlines that such power-generated fuels, which are likely to be used in aviation more than in other transport modes, should be a last resort for the purpose of decarbonisation. In another report, the Öko-Institut noted that synthetic fuels only lead to lower CO_2 emissions if they are generated using renewable electricity and take any carbon that is needed directly from the atmosphere. Otherwise, they will simply be adding CO_2 to the atmosphere in the same way that burning fossil fuels does.

Electrification of vehicles – electricity instead of fossil fuels

As a result of the need for a significant decline in the use of fossil fuels, and the increase in the mobility sector's use of electricity, the vehicles used in 2050 will be largely powered by electricity. This means that the domination of diesel and petrol in the vehicle fleet of2018 will be replaced by a domination of electric powertrains in 2050. Electric cars will be able to go significantly farther on one battery charge than they can today, while battery charging will be a lot faster. Local buses and small distribution trucks will also largely be electric by 2050. Even large long haul heavy goods vehicles may become electric, depending on the energy density of future battery packs. The Vision Scenario for 2050 notes the potential importance for decarbonising long-distance road freight of electric road systems, which connect a hybrid lorry to overhead lines on motorways, much in the same way that electrical energy is provided to trams in some urban areas.

By 2050, electric vehicles will also be much cheaper. Again, significant investment, this time by vehicle manufacturers, will be needed to redesign their vehicles and to ensure that the new electric vehicles operate as efficiently as possible, so that they are energy-efficient and cheaper to buy.

Many petrol stations will have been replaced by electric charging stations, but there are likely to be much fewer of these compared to the number of petrol stations in 2018 as a lot of vehicle charging will take place at home, at places of work or in public or private car parks. Investment by the electricity supply industry will be needed, both to produce more electricity from renewable sources and to ensure that the electricity can be supplied to the transport sector. Investment will also be needed to ensure that there is sufficient electric vehicle charging infrastructure in place, and that this is fast enough to meet the needs of a predominantly electric vehicle fleet.

Vehicle use and modal shift – the right vehicle for each journey

While the technology in the vehicles, and the energy sources that they use, will be substantially different in 2050, so will the way in which vehicles are used. In urban areas, public transport, cycling and walking will be the primary means of travel. Urban areas, large and small, will be designed to improve liveability and to enable access to employment, education, services and recreational activities with the most appropriate means of transport. On the main transport corridors between urban areas, mass transit public transport services will run very frequently. For the first and last miles, walking, cycling or (shared) car services will be commonly used. Car use will be much less dominant than nowadays, but it will still have a significant role, particularly in rural areas and in combination with other modes of transport.

Interchange between the modes will be facilitated by the integrated planning and design of the respective infrastructure. Electric bicycles will be common, both for long-distance commuting and for cycling in hilly cities and the countryside, as well as for urban freight distribution. The line between a car and a bicycle will have become increasingly blurred, as electric bicycle technology develops.

Long-distance freight will maximise the use of rail and inland waterway transport. Long-distance road freight will be powered by electricity from electric road systems for most of the journey, and then by synthetic fuels or advanced biofuels when travelling from the main road network, or intermodal interchanges, to consolidation centres on the outskirts of cities. Freight will be taken from these consolidation centres to be distributed within the city using cargo-bicycles for the smaller and lighter items, and electric vans for the rest.

Shared mobility – an efficient use of resources

Trends towards the shared economy, which are in evidence today, will be widespread by 2050. Car clubs and bike share systems will be popular in all cities, especially in the smaller cities that are not able to support mass transport systems that meet everyone's needs. Shared systems provide the benefits of use without the responsibilities of ownership, and are symbolic of the sharing economy.

Manufacturers will have followed this trend, building on the existing trend towards leasing, rather than selling, batteries for electric cars, and leasing, rather than buying cars. The prevalence of sharing and more sophisticated forms of leasing in 2050 will facilitate the refitting and eventual recycling of vehicles and their parts. Fewer cars will be owned by individuals, with manufacturers becoming mobility service providers and cars being designed to last longer. Vehicle manufacturers' income will come almost exclusively from the provision of services based on their vehicles. Car sharing will enable those from urban areas to travel to more remote areas that cannot be served by public transport. The private car ownership that remains will largely be in more remote, rural areas.

Automated vehicles – providing access to those in need

Many of the vehicles in use in 2050, for both private and public transport, will be automated, i.e. self-driving. The line between public transport and 'car' sharing will have become blurred, as on-demand automated vehicles complement the 'conventional' public transport system. Automated vehicles help those who would not otherwise be able to drive and/or who live in areas that cannot be served by mass public transport, to access employment and education opportunities, as well as services and recreational activities. Online shopping is consolidated and delivered by automated vehicles, in a way that minimises the amount of travel needed for such deliveries. Trains and urban tramways will largely be automated.

Seamless mobility – a fully integrated, seamless mobility system

Mobility will be an integrated, seamless service. Rather than buying multiple tickets for a multi-modal journey, public transport users will buy a single ticket for the entire journey. Public transport tickets will no longer be issued on paper, but on smart cards, which will also be used to pay for the use of a shared car or a shared bike and to pay for the charging of an electric vehicle. Public transport users will be able to use the same smart card in different cities and on different inter-urban networks, rather than needing to have multiple cards for different cities and routes. Route planners will be real-time and multi-modal enabling users to identify the best multi-modal trip that meets their needs, taking account of current service levels.

Sectoral integration – an integrated mobility and energy system

The transport sector will be integrated with the energy and telecommunications sectors. Electric vehicles will be used as energy storage devices when they are not in use and will be an integral part of a city's energy system. Connected vehicles will rely on a fast telecommunications network to ensure that cooperative and connected systems operate to their full potential.

A truly sustainable mobility sector

As a result of all of these factors, by 2050 car use will have declined and the use of other modes will have increased. There will be fewer cars, as a result of the increased use of other modes and the fact that most of the cars still in use are shared. Emissions of CO_2, NO_2 and PM are zero, or have been

reduced to levels that do not significantly damage human health. The extensive use of electric vehicles, including buses, vans and bikes, as well as conventional bicycles, in cities means that urban areas are much quieter places to be and that urban space will be much more liveable. Cities will have fewer cars, less land devoted to motorised, private transport, including to parking, and more space devoted to people. The adverse health impacts of transport will have been reduced to minimal levels, while increased physical activity and human interaction in our cities will have improved the physical and mental wellbeing of the population.

2.3 What do we need to get there?

The need to mitigate – and, where necessary, to adapt to – **climate change** is the most significant challenge for the transport system. This requires first of all significant and widespread changes in **technology**: the fuels and energy sources that vehicles use, and therefore, in the way in which vehicles are designed. This needs investment in vehicle technology, in the production and decarbonisation of the relevant fuels and energy sources and in infrastructure to charge the vehicles. To overcome the existing barriers, such as high costs, risk aversion and people's existing habits, demand for these alternatives will need to be stimulated by policy.

For limiting global warming to less than 2°C, technological change alone will be not be sufficient. Changes are also needed in **user behaviour**: the way we travel and make use of the various modes. Changes in user behaviour are also required to ensure the accessibility and liveability of cities and an urban environment that improves people's health rather than contributes to making them unwell. The way in which we use the **limited space, particularly in cities**, will need to change. As more people move to cities, the opportunities that cities offer in terms of supporting public transport, and enabling cycling and walking, need to be harnessed and maximised. This will also require changes to the way in which cars are used and owned, which will require a wider cultural change. Hence, reaching the above vision is not without significant challenges. In order to get there, we need: a cultural shift and a transition in the jobs available; investment in a sustainable mobility future; and innovation for sustainable transport.

2.3.1 Cultural shift and a job transition

From car ownership to shared mobility

While it has already begun, a widespread cultural shift will be needed by 2050. Car ownership will no longer be seen as an aspiration, and cars will no longer be seen as status symbols, but simply as a means of transport that complements other elements of the mobility system. Public transport, shared mobility, cycling and walking will be seen as something that everyone can and should use, which will be helped by the improvements to the respective infrastructure and services that will occur. In order to manage the limited, and less extensive, road space in 2050, as well as to prevent unrestrained use of relatively cheap-to-use electric, automated vehicles, fuel taxation will have been replaced by a pay-as-you-go system for private car use. Acceptance of such a system will require a significant cultural change in the intervening period.

Transition in employment opportunities

Achieving the vision will also entail significant changes in the industries involved, and therefore in the jobs that those industries provide. Fewer cars, and more shared cars that will be designed to last longer, will lead to a decline in car manufacturing by 2050, and the associated jobs needed.
An increase in the use of public transport and cycling will lead to more jobs associated with the

manufacture of these vehicles. Electric vehicles are less complex than petrol and diesel vehicles, so building and maintaining these will be easier and require fewer jobs, whereas building hybrid and plug-in hybrid vehicles is expected to be more labour-intensive. An increase in automated vehicles will mean that there will need to be fewer drivers, particularly in public transport, but also potentially in the taxi business. Jobs will be created in the operation, control and maintenance of automated systems. Jobs will also be created in research and development, as this needs to continue at a significant pace, while short-term, but regular, jobs will be created in construction to put in place the new infrastructure and changes to urban space that are needed.

This will require a significant transition, both within the industries that manufacture the vehicles and that produce the energy, but also within society in terms of how we use vehicles and travel more generally. The nature of the jobs in the various industries will change, with some industries potentially declining, while others grow.

2.3.2 Investing in a sustainable mobility future

The scale of technological development needed highlights the second main challenge: the need for extensive investment. For whatever vision for 2050 is set out, sustainable or otherwise, investment will be needed. In order to achieve a truly sustainable mobility sector by 2050, investment will need to focus on the following elements.

Investing in new technologies

Vehicle manufacturers will need to continue to research and develop vehicles that operate purely on electricity, and perhaps hydrogen. Investment will be needed in the installation and development of electric vehicle charging infrastructure, and potentially the development of a hydrogen refuelling infrastructure. Resources will also need to be put into the development and implementation of electric road systems, as well as to improve the environmental performance of biofuels.

Investing in the existing transport system

Investment will also be needed in existing transport systems and in the development of cities, including in infrastructure for public transport, cycling and walking, as well as in inter-urban infrastructure. Railways and intermodal interchanges will need to be expanded, both for passengers and freight. Resources will be needed in cities and towns to respond to the increased demand for electric mobility. Investment will be needed to provide space for shared mobility systems, and it will also be needed to transform urban space from car-dominated places to liveable cities designed for people.

2.3.3 Innovation for sustainable transport

As noted above, there is a need for investment in a range of technologies. The technologies needed already exist, but innovation is needed to ensure that they perform at the levels and cost needed to fulfil their potential and role in a truly sustainable mobility sector.

Innovation in electric vehicles

While electric vehicles – cars, vans and buses – are on the market and are being used, they are still relatively expensive compared to comparative vehicles that rely on fossil fuels. Similarly, there are some cars and buses that use hydrogen, but these are even more expensive. The range that electric cars in particular can be driven on one battery makes it challenging to use these vehicles in ways that

people can currently use diesel and petrol cars. Innovation is needed to improve the range and reduce the price of such vehicles. Such challenges need to be addressed well before 2050, given the typical lifetimes of vehicles. Road transport vehicles tend to have an average lifetime of 10 to 20 years, with some vehicles being around for much longer, while the typical lifetime of rail locomotives and carriages and inland waterway vessels can be at least double this. Hence, if the road transport vehicles operating in 2050 are to be largely powered by electricity, electric vehicles with the high electric ranges need to available extensively well before 2050.

Innovation in infrastructure

There is also a need for innovation with respect to the charging infrastructure that will be needed for private electric vehicles, particularly to improve charging speeds, as these are not yet comparable with the time it takes to fill up a petrol or diesel vehicle. Electric road systems are currently being trialled, but for these to fulfil their role in the vision, such systems need to be widespread and easy for all vehicles to use well before 2050.

Innovation in automation

Automated vehicles are also still in their early stages; trials of individual vehicles are taking place, but innovation is needed to ensure that these vehicles can be widely deployed and can be considered to be an integral part of a sustainable mobility system. Mass transportation systems within and between the growing urban agglomerations require significant innovation to meet the demands of a sustainable mobility sector. Innovation is needed to improve the automation of train operations and supervision, which has the potential to bring significant benefits for rail passengers and freight.

Innovation in renewable energy sources

Innovation is also needed in relation to the energy sources that will be required by the vision.
The electricity supply sector needs to decarbonise the production of electricity. Cost-effective ways of producing hydrogen, and potentially other synthetic fuels, in sustainable ways and at sufficient volumes to support their widespread use are needed. Advances in biofuel technology will be required to ensure that these are sustainable and carbon neutral.

3 Achieving the vision: A possible approach

3.1 How to deliver a truly sustainable mobility sector?

The transition to a sustainable mobility sector in 2050 will not happen by itself – it requires a broad range of policies. By putting an appropriate combination of policies in place, the vision that has been set out can be achieved. While there is more than one approach to delivering this vision, this chapter aims to describe one possible approach, including the policies that are seen by various experts as being an effective means of tackling the challenges.

The transition to a sustainable transport sector requires two main types of changes: a shift towards zero-emission technology and a change in modal split and travel behaviour. This means that policies are needed to speed up innovation with respect to zero-emission vehicles, energy supply and related technologies, as well as to increase the number of such vehicles purchased and used and to phase out polluting technologies, when appropriate. So, policies are needed that address both innovation, and the supply and demand of zero-emission technology.

As noted in Paragraph 2.2, replacing all petrol and diesel vehicles with zero-emission vehicles is not enough to deliver a truly sustainable mobility sector. Policies are also needed that make alternatives to private car use the logical and most attractive option for many more trips and users than is the case nowadays. Some policies address both, but many are primarily focused on technology change or changes in travel behaviour and the modal split. Both aspects are described in the following sections.

3.2 How to support people to travel in a sustainable way?

Make sustainable mobility the most attractive, affordable and obvious choice

For healthy, well-accessible and truly sustainable cities, a shift from the current car-dependent mobility system to a more balanced multi-modal system is required. Although technological change is the cornerstone of climate policy, and a precondition for a zero-emission mobility system, in order to meet the commitments of the Paris Agreement, changes in the way we travel are also needed.

In order to change the way we travel, alternatives to private car transport should be more attractive and for most trips the obvious and best choice for people. This can be achieved through the following policy actions:

- make public space people oriented, rather than car oriented;
- make solid and sound investments for improving sustainable modes;
- develop ‘Mobility as a Service’ for making multi-modal journeys easy and enjoyable;
- support employers in encouraging more sustainable and healthy transport choices;
- ensure that pricing policies make sustainable travel affordable;
- make sustainable travel fast and attractive;
- introduce environmental zones to deliver clean air in the most polluted and populated areas.

Each of these policy areas are explained below.

Make public space people-oriented, rather than car-oriented

In order to reduce the negative impacts of city traffic, more and more cities are transforming public space previously used by traffic into open, green areas. A famous example is the Cheonggyecheon Stream in Seoul: in 2005 a highway was transformed into a green zone, which created a lot of extra space for inhabitants to walk and enjoy the open air. In 2016 the city of Paris created a car-free zone on the Seine-boulevard: 3.3 km of prime Paris riverside stretching from the Tuileries tunnel to the Henri IV Bridge were transformed.

Rethinking urban planning goes much further than such examples. In order to support the changes that are needed for the vision, the way in which cities, and their wider regions, are planned will need to change, which needs a cultural shift amongst those responsible, including politicians. In urban areas, planning policies will need to support the use of public transport, cycling and walking, as well as shared mobility, while at the same time discouraging private car use. This includes, for example, planning new houses around nodes of public transport, along public transport corridors and within existing urban areas, preferably near to city centres. The amount of road space allocated for use by motorised transport, including the number of parking places for cars, is reduced. At the same time, infrastructure for public transport, cycling, walking and shared mobility, as well as their associated services (including car sharing schemes), have been improved to a high quality and level. In such a scenario, alternatives for car use are accessible and can be attractive transport options.

Furthermore, the ongoing urbanisation is in itself an opportunity for more sustainable transport. This requires urban planning focusing on densification and mixing functions, such as living, working, shopping and leisure. This means that people can meet their daily needs by travelling fewer kilometres than today and in many cases, make their journeys by foot or bicycle. However, if urban planning is not undertaken sustainably, there is a risk of urban sprawl and office buildings and shopping centres being located at motorway locations rather than where they are accessible by public transport. In such cases, people would travel more and car transport would increase.

Urban planning polices will also need to ensure that there is space for freight consolidation centres on the outskirts of cities, thus allowing zero-emission city distribution by electric vans, electric trucks or cargo-bikes.

Make solid and sound investments for improving sustainable modes

Making alternatives for private car use truly attractive requires radical changes in investment policies. Currently, investments are often mainly focused on reducing motorway congestion, which in fact contributes only a minor share of total congestion that is experienced in many countries.

Infrastructure investments and planning need to be aligned with an overall long-term vision on mobility and spatial planning. To deliver the vision set out above, new modes of sustainable and healthy transport need to be introduced and implemented. Likewise, investments in the transport modes that are healthier and use space more efficiently are a first step towards delivering attractive alternatives to (individual) car use. Good practices around the world show that investing in excellent cycling infrastructure (including bicycle parking) and high quality and high capacity public transport (particularly in and between urban agglomerations), can change the modal split significantly.

Cities such as Copenhagen, Utrecht, Strasbourg, Berlin, and Tokyo show that such an approach can be successful and have multiple benefits. Copenhagen, for example, has invested $ 50 million in cycling infrastructure and facilities over the past decade. This includes building sixteen new bridges for bicycles and pedestrians, a new traffic light system that detects and prioritises cyclists, and new

bicycle superhighway routes that connect Copenhagen with the surrounding region. While in many other cities car transport dominates commuting, in Copenhagen 41% of all commuting is by bicycle.

Some cities that historically have had a very low modal share of cycling, have also announced significant investment plans. These include London, which has announced its intention to invest a total of € 1 billion in cycling infrastructure over the next five years. Transport for London estimates that almost eight million daily journeys currently made by cars, motorcycles, taxis or public transport in the capital could be undertaken by bicycle.

Develop 'Mobility as a Service' for making multi-modal journeys easy and enjoyable

Integrated, seamless transport services need to be developed mainly by businesses. However, governmental policies are needed to make it a truly seamless system and to ensure that services can be used across different transport modes, service providers and countries and so deliver the potential of 'Mobility as a Service'. This is true for integrated planning, booking, ticketing and payment systems. In addition, in order to develop a new service, pilots are needed which may also require public co-financing.

Public transport operators also need to innovate from focusing only on public transport to expanding their horizons to a truly multimodal system. New organisations will start to offer similar services, while existing transport operators may choose to deliver new services. For example, public transport operators could choose to run car or bicycle sharing schemes, lease companies could offer multimodal business cards and payment systems or even ICT companies and financial service providers could offer system integration services. Such fundamental changes in the way in which transport services are delivered requires public authorities to adapt their own role and the way they run, contract or tender services. The transition to 'Mobility as a Service' therefore also needs municipalities and provinces to support and/or facilitate new services, e.g. by making arrangements with car sharing companies for the use of parking spaces or working with public transport operators to ensure that important routes have sufficient levels of service.

Support employers in encouraging more sustainable and healthy transport choices

Commuting and business travel contributes a large share of the total kilometres travelled, emissions and congestion. Employers can influence the way in which their employees commute or travel for business purposes. In addition, they have a large influence on new car sales. While only 12% of the car fleet in the EU28 is a company car, their share in terms of the total number of kilometres driven is about 18% and their share in new car sales is as high as 50%.

Driven by an ambition to improve the company's sustainability, to reduce its environmental impact and to reduce costs, many companies promote teleworking, choose (mainly) low carbon or zero-emission company cars and/or try to change the way their employees commute, e.g. by providing business travel cards or offering multimodal 'mobility budgets' instead of a company car.
The occasions when people change jobs or move house are natural moments for people to reconsider the way in which they commute. The relocation of companies can also help to change habits and stimulate employees to choose a more healthy and sustainable way of commuting. Employers' policies need to make the maximum use of these opportunities.

National governments can support these developments by removing fiscal barriers for such new arrangements and stop implicit subsidies to car use in company car taxation. Removing tax exemptions for the reimbursement of commuting costs, which exist in some countries, is also a way to

support this transition. Local authorities can support this by, on the one hand, improving public transport services or cycling routes to work locations and at the same time introducing parking policies that discourage private car use.

Ensure that pricing policies make sustainable travel affordable

Improving the infrastructure and the quality and level of service of alternatives to car transport alone will not, in most cases, be sufficient to bring about a massive shift to these alternatives. As long as private car transport remains competitive in terms of both cost and travel time, the potential of the alternatives is unlikely to be fully delivered.

Taking into account the cost of purchasing and owning a vehicle, as well as the fuel costs, the total cost per kilometre of driving a private car is often higher than using public transport for the same distance. However, once a driver owns a car, they tend to ignore these costs, and so only consider the cost of fuel before making a journey. In this case, the cost of fuel only is usually cheaper than a public transport ticket for the same journey. As the use of zero-emission vehicles become more widespread, this gap will increase. Future electric vehicles will largely be charged at home and will be much cheaper to use than today's cars, as it is unlikely to be politically or socially feasible to increase the tax on domestic electricity in 2050 to anything like the levels of fuel duty in place in 2018. If the cost of purchasing an electric, automated car in 2050 is comparable to the cost of buying a petrol or diesel car in 2018, the fact that these cars will be cheap to use could make it very difficult for public transport to compete. With the potential increase in cheap, private mobility, the road system will either grind to a halt, or will require significant expansion, which would be accompanied by the negative impacts outlined in the previous chapter.

Another impact of the electrification of the car fleet will be that government revenues from fuel excise duties will decline, thus contributing to a reduction in revenues that the government will have to spend on other services, including healthcare. The most logical and fairest way to tackle both problems is to introduce road pricing. This gives users incentives to take account of the additional costs of the environmental and safety impacts of their travel choices. With some exceptions, most countries already have motorway tolls and/or a kilometre charging scheme for trucks and coaches in place. An extension to other major roads and to urban roads, as well as to different types of vehicle (particularly cars) can play an important role in the transition towards a sustainable transport system. When revenues are used to improve alternatives, such an approach can be beneficial for all.

Parking charges and urban pricing schemes, such as the London congestion charge, or the urban road tolls of Stockholm or Singapore, can also have significant impact on user choices and help to reduce car use in densely populated areas, where it is most harmful.

Make sustainable travel fast and attractive

In addition to the relative costs of different modes, travel times, comfort and the (perceived) safety and security are key elements in people's modal choices. The traffic policies of municipalities and other road operators have large impacts on waiting times, routing, comfort, the ease of use and attractiveness of different transport modes. Prioritising pedestrians, cyclists and public transport in all decisions can make a huge difference. For longer distances, national speed policies on motorways can affect travel times as well as improve the energy consumption of cars. Lowering speed limits in general, and around cities in particular, can therefore contribute to a transition to a more sustainable transport system.

Introduce environmental zones to deliver clean air in the most polluted and populated areas

To reduce particulate matter and nitrogen oxide pollution in cities, local environmental zones or low emission zones are widely applied in the EU, with Germany as a front-runner. In Germany 58 zones have been set up since 2007. Environmental zones for cars and/or trucks are also applied in Austria, Belgium, Denmark, France and the Netherlands. Only vehicles with a specific environmental badge, based on vehicle's emission of NO_2 and PM, are able to enter these zones around or in cities. Such schemes could also include CO_2 emissions and develop into zero-emission zones. These would support both the transition to zero-emission vehicles (for cars, vans, trucks and buses) as well as providing an incentive for cycling and using public transport. Harmonising the way in which such schemes operate nationally, or even at the European level, has the potential to give a strong, consistent message to vehicle manufacturers to develop and sell cleaner vehicles.

3.3 How to ensure that the vehicles in use in 2050 are truly zero emission?

Make sure that zero-emission technology is available, affordable and sustainable

From a technological perspective, there are three main approaches to delivering a truly zero-emission mobility sector: battery electric vehicles, hydrogen vehicles (using fuel cells) and the existing petrol/diesel engines using renewable fuels (either biofuels or synthetic fuels). In order to be commercially viable, zero-emission mobility requires the simultaneous development of the right vehicles, energy infrastructure and energy carriers. However, such simultaneous development will not occur automatically: each approach has different requirements, which need different policies.

For example, currently the high purchase price of electric and hydrogen road vehicles is a major barrier to their increased purchase and use. In addition, networks to distribute hydrogen are lacking at the moment. A high number of electric vehicles also requires a significant increase in vehicle charging infrastructure, but this can partly build on the existing power supply and is therefore less of barrier than for hydrogen. In the case of renewable fuels for vehicles using a petrol or diesel engine, the availability and sustainability of the fuels is the most important challenge, while challenges relating to vehicles and energy infrastructure are relatively easy to solve. This is summarised in Table 1.

It is important to note that Table 1 represents the current situation. The fact that the relevance of some of the challenges has been indicated as 'high' does not imply that these routes do not have the potential to become an important decarbonisation route in the future. This is, for example, the case for hydrogen. Hydrogen has the potential to play an important role in, for example, reducing the CO_2 emissions from long-distance road transport to an extent that is equal to, or even higher than, that of biofuels. However, it is not able to compete with biofuels at the moment. Nowadays biofuels can be used with the current vehicle and refuelling infrastructure, while the availability of hydrogen vehicles and infrastructure is still limited.

Similarly, even though biofuels and synthetic fuels score similarly in Table 1, biofuels are currently used far more often and in larger quantities than synthetic fuels. The different market penetration can be explained by their current availability, although biofuels are currently produced from food crops, which is not beneficial for the environment. For biofuels, there is a strong need to develop advanced production technologies that make use of raw materials other than food crops. In the case of synthetic fuels, there is the need to increase production capacity, as well as to ensure the availability of renewable sources. This will strongly depend on the developments in the energy sector, such as the developments in wind and solar power. While synthetic fuels can be produced from CO_2 that is a

waste product from another industry, such fuels would not be sustainable or carbon-neutral; they would simply be delaying the time at which the CO_2 emissions were released into the atmosphere. As noted above, in order to be sustainable and carbon-neutral, synthetic fuels need to be produced from CO_2 that has been taken from the atmosphere, including that taken indirectly by plants.

Table 1 - Relevance of challenges in vehicle, energy infrastructure and energy carrier, for each approach

	Vehicles	Energy infrastructure	Energy carriers
Electric	Medium-high (battery cost and performance, production capacity)	Medium (extensive charging infrastructure network; high power charging for buses/trucks)	Low (renewable electricity)
Hydrogen fuel cells	High (vehicle cost)	High (new fuelling infrastructure)	Medium (hydrogen production from renewable sources)
Biofuel	Low-medium (existing technology; only need changes to the technology if fuel contains a high proportion of biofuels)	Low-Medium (new fuelling infrastructure needed if fuel contains a high proportion of biofuels)	High (production of raw material used to make biofuel; wider environmental impacts, competition with other economic sectors for limited raw material and biofuel)
Synthetic fuels	Low (existing technology)	Low (existing technology)	High (competition with other sectors, sustainability depends strongly on source)

In the next paragraphs the policy measures which are able to lower these barriers will be described. Policies are needed to:

- regulate to ensure that new vehicles quickly become zero-emission vehicles;
- make zero-emission vehicles an affordable choice through better taxation;
- make the use of zero-emission vehicles the logical and attractive choice through local incentives;
- increase the visibility of zero-emission vehicles through green public procurement;
- support and guide the development of the required energy infrastructure;
- decarbonise the energy mix;
- ensure waste prevention and battery re-use.

The various policies discussed are linked to the challenges identified in Table 1.

Regulate to ensure that new vehicles quickly become zero-emission vehicles

A fast transition to a 100% zero-emissions vehicle fleet starts with ensuring that all new vehicles that are sold are zero-emission. However, the availability of vehicles might be a problem, as a result of their current relatively low levels of production. The most direct and effective way to tackle this is by setting vehicle standards. At the moment the EU, like other regions in the world, has established CO_2 standards for new cars and vans. The USA, Canada, China and Japan also have CO_2 standards in place for trucks and buses and the EU has announced its intention to follow their example soon.

To limit global warming to 1.5°C, all new cars and vans need to be zero-emission in 2030 or probably even earlier (depending on the reduction achieved by heavy-duty transport, aviation, shipping and other sectors). Scenarios for limiting global warming to 2°C allow some more time, but still require the

entire car fleet to be zero-emission around the middle of this century. As fleet renewal takes time, all new cars should be zero-emissions well before then. This can be achieved by the approach followed by the state of California, which will ban the sale of cars with a petrol or diesel engine by 2040. The United Kingdom and France have made similar commitments. Introducing such a ban in the EU, with some ambitious intermediate targets for the short- and medium-term, would provide certainty to the industry. This ensures that innovation will start in time and that investments will be aimed at achieving these targets. As a result, zero-emission vehicles will become more common sooner, so consumers will have more choice and be able to buy a zero-emission vehicle that meets their needs.

At the same time, CO_2 emission standards for the shorter term are needed to guarantee the further development and uptake of zero-emission technology and also to reduce the CO_2 emissions of petrol and diesel powered vehicles sold in the coming years. As these conventional vehicles are expected to stay on the road for up to 20 years, they have a large impact on future CO_2 emissions. To be effective, CO_2 regulation should be based on emission values that are very well correlated with real world emissions. Both 'diesel-gate' relating to NO_x emissions and the increasing gap between real world and test CO_2 emissions have proven that this is an issue that needs to be solved urgently in order to ensure that regulations deliver what they were designed for.

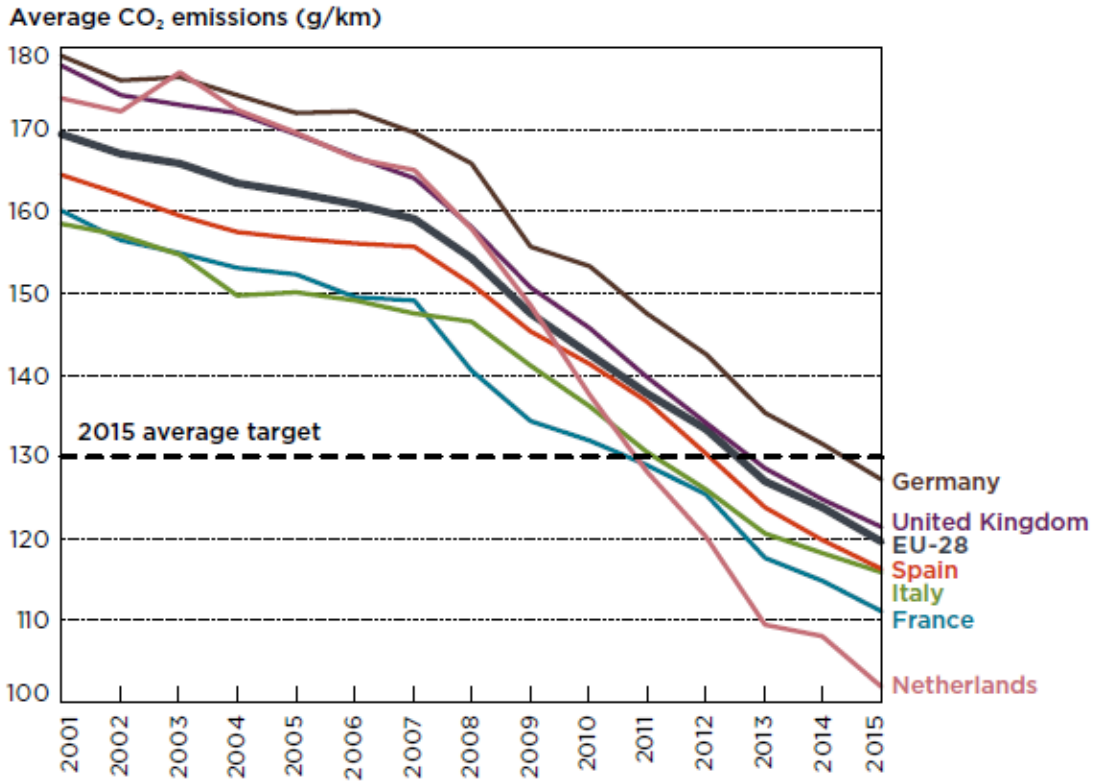
In addition to emissions standards (and/or zero-emission vehicle mandates – i.e. requiring that a certain percentage of new vehicles are zero-emission) for light duty vehicles, similar policies are needed for heavy-duty vehicles. However, as zero-emission technology for these vehicles, particularly for heavy trucks, is far less well developed than for cars and is expected to be more challenging, similar regulation for heavy vehicles will lag behind, roughly by one decade.

Make zero-emission vehicles an affordable choice through better taxation

While vehicle regulations will increase the number of zero-emission vehicles that can be bought, the total cost of owning (and operating) an electric vehicle is still higher than owning and operating a diesel or a petrol vehicle, as a result of the high cost of zero-emission vehicles. Therefore, vehicle regulation alone does not guarantee that consumers will buy zero-emission vehicles. Although it is expected that within 5 to 10 years, electric cars will be cost competitive over the vehicle's lifetime taking account of the cost of purchasing and running the vehicle, the higher purchase price of such vehicles will remain a barrier for many consumers. This is related to the fact that, when purchasing a vehicle, people only take account of the fuel costs for only the first few years, not the whole lifetime of the vehicle.

In order to overcome this barrier countries, such as Norway and the Netherlands, have already introduced strong incentives for zero-emission vehicles in their vehicle taxes (purchase taxes, annual circulation taxes and company car taxes). These examples show that this can be very effective. In Norway the 2017 market share of electric cars in new cars sales was already 39%, more half of those being fully electric. The tax incentives in the Netherlands have not only increased the share of electric vehicles but also reduced the emissions of new conventional vehicles. Such incentives significantly improved the country's performance compared to other EU countries; in 2003, the Netherlands had one of the highest average CO_2 emissions of new car, but by 2012 the figure was one of the lowest of all of the EU Member States, as illustrated in Figure 6. However, very recently, the CO_2 emissions of new cars increased again as the government has scrapped many of the tax incentives.

Figure 6 - Passenger cars: CO_2 emissions of new passenger cars by Member State (ICCT, 2016)



Different means of purchasing or financing vehicles also has the potential to change the way people consider costs. Financial arrangements that spread investments over time can help consumers to spread the cost of purchase, thus reducing the amount that has to be paid immediately. Private lease and car sharing are good examples where consumers do not pay the investment cost at once. National and local governments can support this by fiscal means or other privileges.

Another way of changing the relative price of zero-emission vehicles compared to petrol and diesel vehicles is to increase fuel taxes. Higher fuel taxes stimulate people to buy more fuel-efficient or even zero-emission cars and to drive petrol and diesel cars more efficiently, and perhaps even to reduce the amount they use their car. When fuels are taxed according to their potential for releasing CO_2 emissions, a shift to low carbon fuels, such as biofuels and synthetic fuels, can also be stimulated through fuel taxation. Changing the levels of fuel tax will affect all vehicle types: passenger cars, buses and heavy goods vehicles. Basing fuel taxes on a fuel's potential to release CO_2 would particularly affect diesel, which in many countries is taxed too little compared to petrol based on its carbon content. Energy taxes which make biofuels and synthetic fuels more attractive can contribute to reducing CO_2 emissions from the transport modes that cannot yet shift to zero-emission vehicles, such as the long-distance road transport of heavy goods, as well as those vehicles in the existing car fleet that use petrol or diesel.

Ideally, the EU's minimum tax rates for fuel should be increased to levels that make a difference in order to avoid significant differentials between prices in neighbouring countries, as otherwise people will simply drive across the border to fill up on cheaper fuel. Similarly, it would be beneficial to harmonise vehicle taxes at the EU level to prevent people buying cars more cheaply in neighbouring countries.

Make the use of zero-emission vehicles the logical and attractive choice through local incentives

The attractiveness of zero-emission vehicles is not just dependent on their purchase cost. Local incentives and privileges such as lower parking charges and (temporary) access to bus lanes or environmental zones, can be an effective way to kick start zero-emission vehicle sales in the short-term. For example, environmental zoning, where only zero-emission vehicles are allowed in a zone, can be a strong instrument for trucks supplying stores and supermarkets in city centres. Attention should, however, be paid to the harmonisation of the requirements: it will not benefit truck drivers, and therefore the shops that they supply, if various municipalities set different requirements.

Increase the visibility of zero-emission vehicles through green public procurement

Green public procurement – effectively giving more credit for greener vehicles in the public procurement process – can also contribute to increasing the number, and therefore the visibility, of zero-emission vehicles. This can be done for cars and vans, but also for trucks, buses and all kinds of machinery, including street sweepers, and is especially relevant for companies offering transport services. Due to the strong competition in the market, many transport companies are not able to pay the additional cost of zero-emission vehicles and/or low carbon fuels. With green public procurement these additional costs can help a company to win procurements, and so increase its turnover. Public authorities are very suitable to initiate the use of low and zero-emission vehicles, particularly in niche markets.

Green public procurement initiatives can be combined with pilots or demonstration projects to test the vehicles, proving to a larger audience that their use is possible. Pilot or demonstration projects might especially be relevant for zero-emission vehicles, which are being introduced onto the market, such as larger electric trucks and hydrogen trucks. Pilots with buses have helped the sector to gain experience with these new technologies in the daily operation of public transport companies.
For example, the launch of hydrogen fuel cell vehicles in Japan in 2014 was very effective, mainly because of public procurement that was responsible for 60% of the 1,500 vehicles ordered in two months.

Support and guide the development of the required energy infrastructure

The availability of the required charging and fuelling infrastructure is clearly fundamentally important, otherwise owners will not be able to recharge or refuel their vehicles. Car buyers will not choose an electric or hydrogen vehicle unless there is a guaranteed availability of sufficient charging/fuelling infrastructure. The harmonisation and standardisation of charging infrastructure is also important in order to ensure that any vehicle can be charged or fuelled at any charging or filling station. This will avoid the need for people to have multiple adapters in order to be confident of being able to charge an electric vehicle.

The EU level is the appropriate level to set high level ambitions for the coverage of networks, for example by requiring a minimum amount of charging points, and by focussing on the realisation of corridors (e.g. on the TEN-T network). This will enable cross border mobility for vehicles using other types of energy carriers than petrol or diesel. While the development of infrastructure in urban areas is especially relevant for passenger transport, the TEN-T network is more relevant for long-distance heavy goods transport. At the same time, distribution companies often have their own infrastructure on site. This results in other challenges compared to passenger transport: capacities and charging/refuelling times are more important, because the impact on daily operations should be as limited as possible.

At the local level, authorities are responsible for the allocation of space to infrastructure, such as parking spaces and fast charging stations, and also for the procurement or tendering of charging networks. Harmonisation of these processes will benefit the efficiency of the process, which will result in economies of scale and limit the administrative burden for suppliers.

Decarbonise the energy mix

A shift to electric- or hydrogen-powered vehicles will only be zero-emission if the electricity and hydrogen used is produced from renewable energy sources. This is covered by existing and new policies for decarbonising the energy sector and therefore not addressed in more detail here. The additional power demand is significant (the electrification of all cars would increase the total power demand by about 15% to 20%), but can be covered by the potential increase in renewable power production.

However, the uptake of zero-emission vehicles does not just provide challenges but also opportunities to the energy sector. More innovative technologies such as smart charging can both benefit the electricity sector as well as the cost of electric driving. However, government action is required, such as adjusting grid and electricity price related regulations, agreements with network operators at the local level and requirements for in-car technologies to allow for a vehicle-to-grid and grid-to-vehicle interfaces.

Even in a sustainable mobility system, a significant amount of liquid and/or gaseous fuels will be needed, as concluded by the Öko-Institut's Vision Scenario for 2050. Therefore, and for limiting global warming to 1.5 to 2°C, there is also a clear need for decarbonising these fuels. The main options are biofuels and synthetic fuels, both of which need to be produced sustainably. Policy to ensure that synthetic fuels are sustainable needs to learn lessons from the way in which biofuels policy has developed.

Past policies on biofuels have demonstrated that sustainability concerns need to be properly addressed in regulations by means of strict sustainability criteria and by focusing on advanced biofuels produced from waste and residues. This should avoid negative indirect land use change impacts. Targets for the share of renewable energy in the energy consumption of the transport sector (renewable energy mandates) or targets for reducing the GHG-intensity of fuels can be effective instruments to increase the share of renewable energy in the transport sector. A CO_2-based approach might be preferred over volume-based targets. The effectiveness of the approach will be improved by including the CO_2 impacts of different fossil fuel sources, as it will also affect the use of high carbon fossil fuels (e.g. tar sands). Often targets are translated into renewable energy mandates for fuel suppliers at the national level to require them to ensure that a certain share of the fuel that they sell is renewable.

Renewable energy mandates can provide investment security boosting investments in production facilities for sustainable, next generation, low carbon fuels. Those mandates have also increased the relevance of harmonising fuel specifications at the EU level. Fuel specifications create clarity for fuel suppliers on what requirements need to be met, while on the other hand creating clarity for vehicle manufacturers on the quality of fuels that will be used in their vehicles. They also ensure that the fuel that drivers use to refuel their cars in different locations is of a similar quality.

Ensure waste prevention and battery re-use

While they enable zero-emission mobility, electric and hydrogen vehicles bring additional environmental challenges relating to vehicle and battery production and disposal. Addressing this requires a policy framework for battery end-of-life processing, including re-use and recycling requirements. Without a well-developed approach, the production of high numbers of electric vehicles may lead to serious environmental and social problems later on when they need to be recycled. Such a framework should preferably be developed at the EU level. Other environmental and social issues with respect to battery production also require policy attention (e.g. the mining of lithium and rare earth metals), for instance by developing sustainability criteria in regulation or industry standards.

3.4 What are the further considerations in delivering a sustainable mobility sector?

There are some further considerations that also need attention from policymakers. A policy strategy for a sustainable transport future requires clear choices. Some argue that such a strategy should be based the principles of technology neutrality and cost-effectiveness and therefore mainly consist of generic policies. However, these principles are often not well defined or even misused.

Take care when talking about 'technology neutrality'

'Technology neutrality' can be a useful principle if interpreted as meaning that governments should preferably not specify the technology that should be used, but rather set the overall aim or target that needs to be achieved. This is true for the regulation of both vehicles and energy, as well as requirements in tenders supporting green public procurement. However, when interpreted as meaning that policies should not discriminate or promote technologies it is useless. In that meaning, technology neutrality can never be an aim. The current policy framework is not 'technology neutral' and there is no need for future policies to be technology neutral either. Policies aimed at contributing to a more sustainable transport system by definition need to promote (at least indirectly) low carbon technology and transport modes, and the infrastructure and services that contribute to the transition that is needed.

Consider 'cost-effectiveness' only when it is appropriate to so do

A similar discussion takes place around the principle of 'cost-effectiveness'. In general, it is clear that achieving a sustainable future with the lowest costs to society is to be preferred. However, this principle cannot be applied in every stage of innovation and for all kinds of policies. A too strict use of the principle of cost-effectiveness can hinder a timely preparation for a long-term transition. For example, pilots or public authorities acting as launching customer for innovative technologies can be very important and valuable contributions to the long-term transition, even if the costs are higher than the direct societal benefits.

Involve people to enhance confidence and encourage the change

A long-term transition as needed in the transport sector cannot be fully predicted. The development of the performance and cost of technology, such as electric vehicles and low carbon fuels, the way concepts like 'Mobility as a Service' can be turned into practice and the extent to which people will change their behaviour: all are, in a way, uncertain. This is a challenge for policymakers, but also for other stakeholders. On the one hand, policymakers should give investors long-term certainty, but at the same time the strategy should be adapted when technologies, costs, demand or parameters

develop differently compared to what had been originally expected. Fiscal incentives, for example, should not be fixed for a long period of time but be frequently adjusted to take account of market developments.

For individuals it is not always clear how they will be affected by new developments and a first reaction is often resistance. A famous example is the Stockholm congestion charge that was first introduced as a temporary measure and faced fierce public resistance. Just before the trial, only a third of the population supported its implementation. However, in a referendum after the trial period, a majority voted in favour of the scheme, after having experienced its benefits, and after that, the public support increased to about 70%. A similar pattern has been seen in London, Oslo, Singapore, Milan and Rome. Beforehand people tend to be very negative about congestion charge schemes, but that shifts once they see the benefits and get used to it.

Change, by definition, has losers and winners and it often harms vested interests. Therefore, many policies aimed at reducing emissions or changing investments have to overcome strong resistance. People and politicians are often afraid that change will limit their freedom, be harmful to the economy, be costly or reduce the number of jobs. In general, the following principles can help to make policies more appealing and attractive and to deal with public resistance:

- involve people in developing alternatives;
- start with a trial (such as the example of the Stockholm congestion charge);
- combine carrots and sticks, i.e. incentives and disincentives;
- be transparent on the use of revenues;
- take a step-by-step approach so people have time to adapt, can get used to changes and see the benefits;
- ensure that people have sufficient time to adapt their behaviour before a scheme is implemented;
- ensure that all involved are aware of the scheme's requirements sufficiently far in advance;
- avoid that any particular group is unreasonably affected.

Europe: front-runner or lagging behind?

Europe is often mentioned as a frontrunner in sustainable transport and innovation but when taking a closer look this needs to be nuanced. The EU was indeed the one of the first to introduce CO_2 standards for new cars and has currently, in terms of targets levels, the strictest standards for cars and vans. However, compliance and enforcement in the EU is generally weaker than in the USA and Canada. Therefore decreasing target levels are not translated into similar real world emission reductions. On the other hand, where the EU has only recently announced CO_2 standards for trucks, Japan, the USA, Canada and China have already had such standards in place for several years.

That lagging behind is not without risk can already be seen in various niche markets. The market share that Tesla achieved in luxury cars is significant and impressive. In the USA, in the first quarter of 2018, the Tesla model S was sold more than Mercedes S Class and Porsche Panamera together and the number was even twice that of all BMW 6 and 7 series together. In Europe, Tesla's Model S also outsold the luxury flagships of Mercedes-Benz, BMW and Audi in Europe.

In the market for electric buses, the situation is even more astonishing. According to Bloomberg (2018b), China had more than 380,000 (about 99%) of the 385,000 electric buses on the road in 2017, 17% of the country's entire fleet. Every five weeks, 9,500 new electric buses were added, the equivalent of the entire London bus fleet. For comparison, the European front-runner is the Netherlands with less than 300 electric buses. The market for electric buses is therefore highly dominated by Chinese manufacturers.

As almost all countries in the world have ratified the Paris Agreement and set ambitious reduction targets, the market for electric vehicles is expected to grow very fast in the next decade. A recent analysis showed that the automotive industry has invested seven times more in e-vehicle production in China than in Europe. China has secured € 21.7 billion of investment in the past year to manufacture electric vehicles while Europe secured only € 3.2 billion. Overall. Only a third more cars are produced in China than in Europe, so market size does not explain the difference in investments (23.5 million passenger cars were manufactured in China in 2017, compared with 17 million in Europe). Such examples illustrate that lagging behind is possibly much more risky than being ambitious and trying to take a frontrunner position.

4 What are the benefits of a truly sustainable mobility sector?

A transition to a sustainable transport sector has many impacts on society. The most important ones are discussed in this chapter. First of all, such a transition contributes to a healthier and more attractive environment, particularly in cities, as discussed in Paragraph 4.1.
The transition also has many impacts on costs for users, industries and society as a whole, which are discussed in Paragraph 4.2. Last but not least, the transition will also affect employment, as discussed in Paragraph 4.3.

4.1 Improved health and attractive urban space

One of the significant benefits of the transition to a sustainable mobility sector will be on human health. Vehicles that are powered by electricity emit no pollutants when they are used, while those powered by hydrogen emit nothing more than water. Both electric and hydrogen powered vehicles are also quieter than petrol and diesel vehicles, particularly in urban areas where driving speeds are relatively low and therefore the engine is the main source of vehicle noise. Extensive use of these vehicles, either privately owned or shared, driven or automated, will lead to substantial improvements to the urban environment, as air and noise pollution will both reduce significantly.

Vehicles using biofuels or synthetic fuels that are similar to current fossil fuels will still emit air pollutants and will be noisy, but the use of these vehicles will be limited to inter-urban routes. There will also be indirect health benefits, as the adverse health impacts of the worst of climate change will have been avoided, as long as the production of electricity, hydrogen and other energy carriers has been decarbonised.

In addition to not being exposed to health-damaging levels of air and noise pollution, cities will also be more pleasant, and safer, places to live as a result of being designed to support public transport, cycling and walking, and no longer being dominated by infrastructure designed for private, motorised transport. Road transport accidents in cities will have declined significantly, particularly if the vehicles used in cities are either fully automated or fitted with devices to prevent collisions. As roads will be less busy, people will be able to access services and employment and educational opportunities that had been previously restricted to them, as a result of the existence of busy roads. The urban space will be more open to socialising and recreational activities, thus improving the social cohesion of cities.

Less room needed for parking and roads also has significant economic benefits. By replacing space-inefficient private car transport by alternatives, lots of scarce and expensive urban space becomes available for houses, shopping, leisure or parks, improving the quality of urban living. An apartment building with no or few parking places, can house more apartments and has a lower price per apartment.

The modal shift in favour of public transport, cycling and walking will contribute to improvements in peoples' health in other ways. Regular cycling can improve cardiovascular fitness, muscle strength and flexibility, as well as improving mental wellbeing and reducing anxiety and stress. Increased walking is also similarly beneficial. Public transport can also be considered to be an 'active mode'. Public transport users need to walk (or cycle, if cycling is well integrated with public transport) to and from bus stops and train stations, so undertake more physical activity than they would simply sitting in a

car. Hence, the move to a sustainable mobility system will be an important element in countering the increase in obesity, and the associated diseases, that is currently being seen in many countries.

While such changes will require investment, as noted already, there will be significant cost savings as a result of there being no health-damaging air or noise pollution, as well as the improved physical and mental health from more liveable cities and more active travel. Many of these savings will be in other sectors, e.g. in the health sector, rather than in the transport sector, but overall there are likely to be benefits to the economy of the transition to a sustainable mobility sector. For example, analysis of the long-distance cycling commuter routes in the region around Copenhagen has estimated that the network will bring socio-economic benefits to the region, as a result of improved health and other benefits for cyclists. These benefits more than cover the costs of constructing and maintaining the network.

4.2 Reduced costs, improved productivity and improved social equity

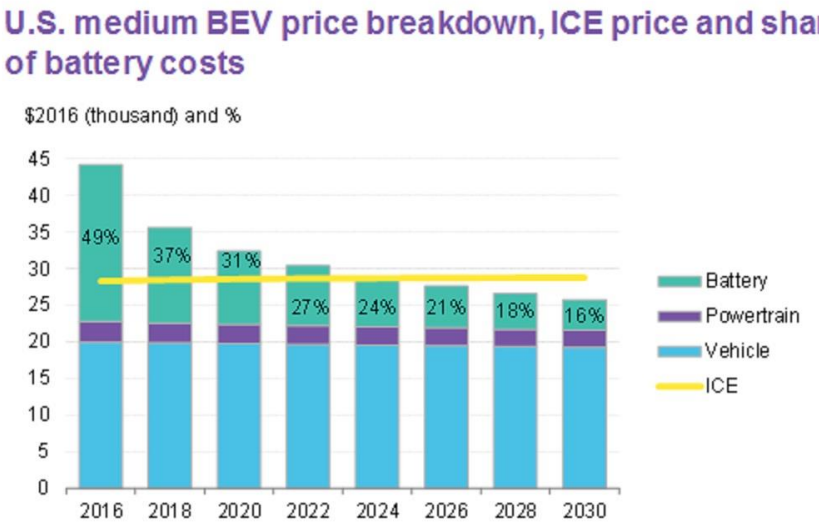
A shift to zero-emission vehicles and to smart, multi-modal transport will have large impacts on costs for consumers, industry and society as a whole.

Reduced costs of electric vehicles

A first cost impact is expected from the transition to zero-emission vehicles. The purchase price of such vehicles is currently high compared to that of diesel and petrol vehicles. However, this is already changing, particularly for electric cars. As demonstrated in Figure 7, currently the cost of manufacturing the battery used in an electric car is a significant proportion of its total production cost. However, battery costs are declining significantly to such an extent that by 2024 the cost of manufacturing an electric car is expected to be similar to that of a petrol or diesel car, which should be reflected in the price of the respective vehicles. In the medium-term, therefore, this suggests that the costs of an electric car will not be an issue. However, in the short-term, the higher initial investment costs will remain a barrier for many people, which could be addressed by fiscal incentives and/or offering financial arrangements spreading the cost of the investment over time, as noted in the previous chapter.

While the cost of manufacturing an electric, diesel or petrol car is expected to be comparable by 2024, the total lifetime costs of electric cars will be comparable to the total lifetime costs of petrol and diesel cars much sooner. This is because the energy (i.e. electricity) and maintenance costs of electric cars are much lower than those associated with diesel and petrol cars. Hence, the total cost to the car's owner over the entire vehicle lifetime of electric car is expected to become lower than that for diesel and petrol cars even sooner.

Figure 7 - Anticipated evolution of the production costs of electric cars (by the vehicle, powertrain and battery) in the USA compared to petrol or diesel cars (i.e. ICE cars)



Source: Bloomberg New Energy Finance, EPA, ICCT, FEV, ONRL, IDL. Note: Estimated pre-tax retail prices

A similar trend is to be expected for zero-emission technology for other vehicle types, such as trucks and buses.

In addition to the vehicles, significant investment will also be needed in energy infrastructure, although these costs and investments are expected to be much lower than those needed for vehicles. The high investments that are needed will also result in a high number of jobs, particularly in vehicle development and the roll out and the servicing of new energy infrastructure and related payment and information services.

Reduction of health costs and increased productivity

The health benefits discussed in the previous section will also entail significant cost savings. Less air pollution, less noise and lower numbers of casualties will significantly reduce the adverse health impacts and related costs that we currently experience. Currently, the health related costs of transport are in the order of € 0.5 trillion a year, which is about the same as the total GDP of a country like Belgium or Poland. A significant reduction of the health impacts will therefore give large savings.

Furthermore, the larger share of active modes (cycling and walking) can be a significant contribution to fighting obesity and other health problems that result from too little physical exercise. As the cost of obesity in the EU is estimated to be already about € 70 billion a year and those of physical inactivity at € 80 billion a year, the benefits from reducing obesity and improving physical activity can also be very high.

Other savings result from reduced congestion. Even more important is that when travel time can be used for working or other useful things, travel time will no longer be regarded as 'time losses'. Policy evaluations of strict CO_2 standards or road pricing show that these types of policies result in net cost savings for society. In addition, road pricing and other fiscal measures generate revenues for making investments in a better and more sustainable transport system.

Another cost saving is related to parking. Less parking space in urban areas means lots of scarce and expensive urban space becomes available for other uses, resulting in significant cost savings.

Improved social equity

Last but not least, cost impacts also have equity impacts. Policymakers tend to focus on car users, but many households do without a car. A recent study by the Dutch Statistical Agency CBS (CBS, 2018) showed that even in a relatively rich country like the Netherlands, more than a quarter of all households do not own a motor vehicle. In the lowest income group, this share is as high as 46%, while for low-income groups in the most urbanised areas, up to 63% have no motor vehicle.

Compared to investments in motorways, more people are able to benefit from investments in public transport and cycling infrastructure. In general, one can expect that the transition to a sustainable transport system as proposed will generally also improve social equity, because mobility options for people without a private car, who are more likely to be on lower incomes, will improve. In addition, urban planning aimed at densification and mixing functions will enable all people, including those who cannot afford to buy or drive a car, to more easily access jobs, medical care and other destinations.

The introduction of road pricing may also improve social equity. A study in the USA commissioned by National Transportation Policy Project concludes that pricing would benefit those with lower incomes because higher-income individuals tend to drive the most and are more likely to travel on congested routes, and thus would pay most of the tolls. Various other studies have come to similar conclusions, although some also note that although lower income groups spend on average less on charges, this is a larger share of their total income. A review study by Levinson (Levinson D., 2009) concludes that "*there are certainly potential issues with equity associated with road pricing, but that those issues can be addressed with intelligent mechanism design that provides the right incentives to travellers and uses the raised revenues in a way to achieve desired equitable ends. These include cutting other taxes and investing in infrastructure and services.*"

4.3 Increased number of sustainable and healthy jobs

The many jobs in European car manufacturing and vehicle component industries are often used as an argument against policies such as strict vehicle emission standards. Although the relationship is not obvious and most studies show that stricter standards would increase rather than reduce the number of jobs, the argument still plays a key role in political decision-making.

The challenge with identifying the number of jobs associated with transport, and how this might change in the future, is the need to rely on high level statistical data based on traditional definitions of industrial sectors. For example, in reviewing the reports that have estimated the number of jobs associated with cycling, UN Environment noted that studies used a range of sources for their estimates. National statistical data were often used to estimate the number of jobs relating to manufacturing and retail, while regional surveys and local case studies were used to estimate the number of other types of cycling jobs, e.g. those relating to tourism and bike share schemes. In the reports that estimate the number of jobs in 'sustainable transport', the type of jobs considered to be a 'sustainable transport' job is varied, and depends on the report. The jobs considered range from the design and manufacture of electric cars and trains and the construction of infrastructure for sustainable transport, to the operation of public transport, bike and car sharing schemes, the local authority officers responsible and a range of jobs associated with 'sustainable' tourism. It is therefore difficult to state with confidence the number of existing jobs associated with transport, let alone how these might change for all of the different types of job in the future.

A number of reports have tried to identify the net impact of the transition to a sustainable future or a low carbon transport system, i.e. whether the total number of jobs will increase or decline. These tend to focus on the most significant sectors that are identified in statistics, such as manufacturing and retail. The International Labour Organisation have looked at the effect globally on jobs across different sectors from the transition to a green economy. They estimated that, by 2030, there would be a net increase of 18 million jobs globally in sectors involved with the production and use of energy, resulting from, among other things, an increase in electric vehicle production, which more than compensated for job losses in other sectors, such as fossil fuel extraction and refining. They also estimated that there would be six million new jobs created from the recycling, remanufacture and repair of goods resulting from the transition to a circular economy. While not specifically focusing on the transport sector, such a high-level study suggests a potentially positive picture.

More transport-specific reports also suggest that there would be job gains from the implementation of sustainable transport policies. A study for Germany, undertaken for the Federal Environment Agency (Federal Environment Agency (Umweltbundesamt), 2013), estimated that increasing the modal share of public transport by 10% by 2030, would increase employment in the transport sector by 5.3%, while a similar set of measures to increase cycling and walking would increase employment in the sector by 4.2%. This was due to public transport and cycling activities being more labour-intensive than those associated with other transport modes.
A report for the European Cyclists' Federation (European Cyclists' Federation, 2014) estimated that a doubling in the modal share of cycling would lead to an additional 400,000 cycling jobs in the EU, in other words a cycling job for nearly everyone in Malta. The report also noted that the manufacture and sale of bicycles, and the construction of cycle-specific infrastructure, are more job intensive (measured in terms of jobs per every € 1 million of turnover) than similar activities for other modes. Hence, with similar levels of economic performance, there would be more jobs.

Looking more specifically at the employment implications of reducing the CO_2 emissions of cars, CE Delft and TNO (CE Delft and TNO, 2017) estimated that making the relevant EU Regulation more stringent would have a positive impact on employment of between 0.04 and 0.15%. The study concludes that many of the additional jobs are created in the electricity supply sector and in the motor vehicle supply chain, but the net increase in employment also reflects additional effects caused by the net cost savings that are expected as the cost of owning a car will decrease due to the regulation. As a result, consumers can spend more on other goods and services, leading to an increase in output and employment in those other sectors. The study concludes that the largest impacts are to be expected with the most stringent target levels that were investigated.

A report for the European Climate Foundation estimated that the transition to electric vehicles will result in a net increase of 260,000 jobs in Europe by 2030, as a result of an increase in the number of jobs associated with producing renewable energy and putting the necessary charging infrastructure in place. After 2030, it estimated that a decline in jobs in the manufacture of motor vehicles and in the production of fossil fuels would be more than compensated for by an increase in the number of jobs in other sectors. These increases would occur in the production of electricity and hydrogen, the manufacture of electrical equipment and, particularly, in related services (see Figure 8).

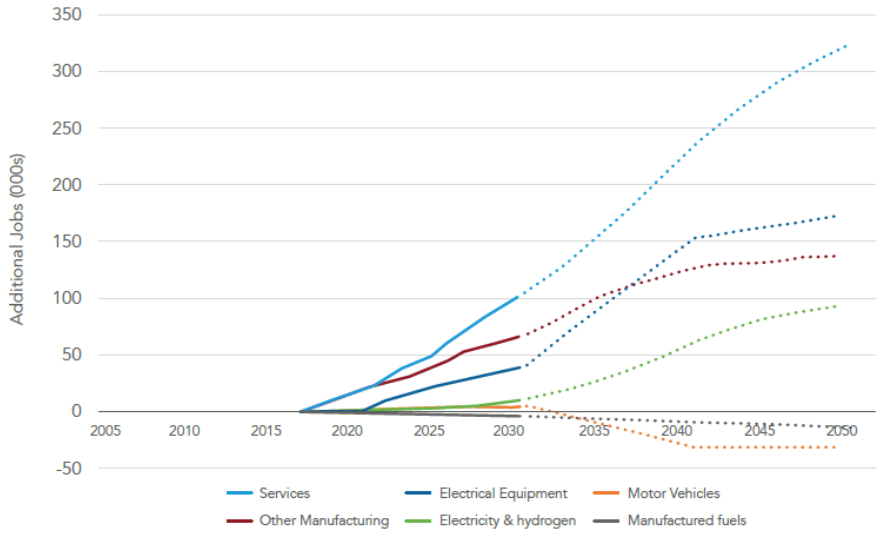
However, these reports do not consider the implications of digitalisation and automation on jobs in the transport sector in the longer term. The European Climate Foundation did note that this was considered a potential issue, particularly in relation to the service industry. Clearly, even in the sustainable mobility vision set out above in which automated vehicles complement other modes of transport, if commercial companies or public authorities operating public transport services can safely automate the operation of a vehicle and save money, they will do so. Hence, automation is likely to lead to less demand for vehicle drivers at least. However, the complexity of automated vehicles will

lead to jobs in the servicing and maintenance of such vehicles (including their software), while there will also be jobs involved in managing the system within which automated vehicles operate.
The integration of the transport and energy systems, and an increased reliance on telecommunications infrastructure and operations, are also likely to lead to a need for more technical jobs to ensure that such systems continue to work together.

In the longer-term, therefore, the transition to a low carbon economy or a green economy is expected to increase employment. This needs to be seen separately from the automation of the transport system, which is likely to happen with or without the achievement of a truly sustainable mobility sector. The extensive automation of the transport system will lead to job losses and some job gains, similar to what is already happening and expected to continue in many other sectors. The net effect will depend on the scale and impact of automation. This will be a challenge for society as a whole and is not particularly related to transport.

The challenge from the perspective of jobs in transport is not in delivering a low carbon, sustainable mobility sector, as reports suggest that this will increase the number of jobs. The challenge is in ensuring that the automation of the transport sector is consistent with the delivery of a sustainable mobility sector, including in relation to the employment opportunities that it provides.

Figure 8 - The employment impact per sector in the Europe of the transition to low-carbon cars (thousands). (Dashed lines reflect the increased uncertainty after 2030) (ECF, 2018)



5 Recommendations

Table 2 provides an overview of the policy measures identified, at the EU, national and regional/local level that are needed to support the achievement of a truly sustainable mobility sector. In many cases, the effectiveness and contribution of policies increase when they are combined, e.g. improving cycling and public transport combined with parking policies and urban road pricing.

In this long list of measures, most can be regarded as 'no regret' policies that are beneficial in any scenario. At the same time, some other policies should be considered with more care, e.g. because of the risk of potential lock-ins or technology choice that may turn out to be suboptimal in the long-run. This is particularly the case for:

- governmental policies for making 'Mobility as a Service' a seamless system;
- green public procurement;
- fiscal incentives and other types of support for private lease and car sharing to spread investments in zero-emission vehicles.

Table 2 - Overview of policies at EU, national and regional/local level

Policy measure	EU	National	Regional/ local
USER BEHAVIOUR			
Urban planning			
Urbanisation, densification and mixing functions, preventing urban sprawl			x
Planning new houses around nodes of public transport, preferably near city centres			x
Create space for public transport, shared transport, cycling and walking			x
Create space for freight consolidation centres on the outskirts of cities			x
Change in infrastructure investments			
Excellent cycling infrastructure including bicycle parking	x	x	x
High quality and high capacity public transport	x	x	x
Transition to Mobility as a Service			
Governmental policies for delivering 'Mobility as a Service', a seamless system		x	
Co-financing pilots	x	x	x
Supporting and facilitating new mobility services			x
Commuting and business travel			
Set fiscal policies that support sustainable business travelling and commuting , e.g. removing tax exemptions for the reimbursement of commuting costs		x	
Parking policies that discourage private car use			x
Improving public transport and cycling routes to work locations			x
Pricing policies			
Road pricing, kilometre charging, motorway tolls		x	
Parking charges			x
Urban pricing policies, such as a congestion charge, urban road toll			x
Traffic policies			
Optimise waiting times, routing, comfort, ease of use and attractiveness for cycling and public transport			x
Lowering speed limits		x	x

Policy measure	EU	National	Regional/ local
Environmental zones			
Harmonisation of environmental zones	x	x	
Implementation of environmental zones and zero-emission zones			x
ZERO-EMISSION TECHNOLOGY			
Vehicle regulation			
Introducing or tightening of CO_2 emission standards in the short-term for cars, trucks, vans, buses and other machinery (and/or a zero-emission vehicle mandate)	x		
Vehicle and energy taxation			
Incentives in car taxes for zero-emission vehicles (purchase tax, circulation tax, company car tax)		x	
CO_2-based fuel taxes		x	
Harmonisation of car taxes and fuel taxes to avoid cross border effects	x		
Incentives for zero-emission vehicles			
Lower parking charges, (temporary) access to bus lanes, zero-emission zones			x
Fiscal incentives and other types of support for private lease and car sharing to spread investments in zero-emission vehicles		x	
Green public procurement: launching customer or innovations and mandatory zero-emission transport buses	x	x	x
Energy infrastructure			
Harmonisation and standardisation of charging and fuelling infrastructure (e.g. hydrogen)	x		
Set high level ambition for the coverage of networks	x		
Support smart charging by adjusting grid and electricity price related regulations, agreements with network operators		x	x
Sustainable fuels			
CO_2-based energy mandates, with sustainability criteria	x		
Circular vehicle production and battery re-use			
Policy framework for battery end-of-life processing	x		
Sustainability criteria for battery production in regulation or industry standards	x		

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