POSITION PAPER

28 February 2018

BusinessEurope position on low-emission mobility

KEY MESSAGES

1 Business at large recognises the need to transition to low emission mobility both in Europe and globally, with transformations occurring that affect all value chains.

2 Regardless of the mode of transport, all technologies, fuels and efficiencies should be able to compete with each other to achieve low-emission mobility in Europe. If we know where we want to go, everyone should be allowed to be part of the solution on how to get there.

3 An integrated approach is required, with impact assessments covering environmental costs and benefits, job implications and security of supply. It is therefore important to think about how to shift to a low-emission mobility economy without negatively impacting Europe's competitiveness and adding geopolitical risks.

4 In order to stimulate rather than stifle innovation, new legislation should focus on applying the Innovation Principle and sufficient financing should be made available to create a critical mass for new ideas.

5 Given the scale of the challenges, which are environmental, socio-economical and geopolitical in nature, it is crucial that business and other stakeholders are intensively included into the low-emission mobility policy pathway to safeguard public acceptance and European competitiveness. International cooperation is also a must.

KEY FACTS AND FIGURES

The transport sector contributes EUR 548 billion or 4.8% to the EU's GDP	Transport adds more than 11 million direct jobs and 11.4 million in transport service-related sectors. 12.6 million of these are in the automotive sector	The automotive sector invests EUR 50 billion annually in innovation, more than any other sector

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1. INTRODUCTION

Context and objective

The transport sector in both Europe and the rest of the world is going through huge transformations. These range from alternative fuels such as hydrogen, biofuels and (bio-)gas to the use of low-carbon technologies in the production of conventional fuels, and from alternative powertrains in both conventional combustion engines and electrification to connected and automated transport (CAT) and new shared mobility models. Such transformations are happening simultaneously but are often treated in silos.

In the last few years, the European Commission rolled out a number of initiatives[1] that have triggered an intense debate on how to make mobility more efficient and less emitting. Furthermore, other elements such as how to fundamentally change the end-user behaviour are also seriously considered. While these debates are still ongoing, there is a general understanding that the transition to a low-emission economy in Europe can only be achieved if Europe's industry remains a frontrunner and that the focus on innovation and competitiveness remains a key pillar of such a transition.

This holistic position paper proposes some general and mode-specific policy avenues to reap the full benefits of the on-going transformation. It also lists the technologies, fuels and engine efficiencies that can get us to a low-emission economy, though the list is non-exhaustive as new solutions might arise in the future.

The need for low-emission mobility

The EU Member States have ratified the Paris Agreement and agreed to a 2030 Framework in which they commit to cut greenhouse gas emissions by at least 40% by 2030 compared to 1990 levels. Being the most ambitious climate target amongst the major economies in the world, it is meant to be a target for which all sectors of the economy have to do their part. For the industry, power and aviation sectors, which together account for 45% of the EU's GHG emissions, the EU Emissions Trading System (EU ETS) is Europe's main tool to reach their cost-effective emissions reductions of 43%.

Transport, which accounts for almost a quarter of total EU emission, is part of the proposed Effort Sharing Regulation[2] that will have to reduce emissions by 30% by 2030 based on 2005 levels, together with other important sectors such as agriculture, buildings and waste management. Towards 2050, the European Commission has pledged a 60% emissions reduction in the EU transport sector.[3] Figure 1 shows a breakdown of GHG emissions between the different modes of transport.

[1] Including the 2011 white paper on transport, the 2016 Commission strategy for low-emission mobility, and the November 2017 Clean Mobility Package

[2] Apart from intra-EEA flights from aviation

[3] EC, 2011. White paper – Roadmap to a Single European Transport Area

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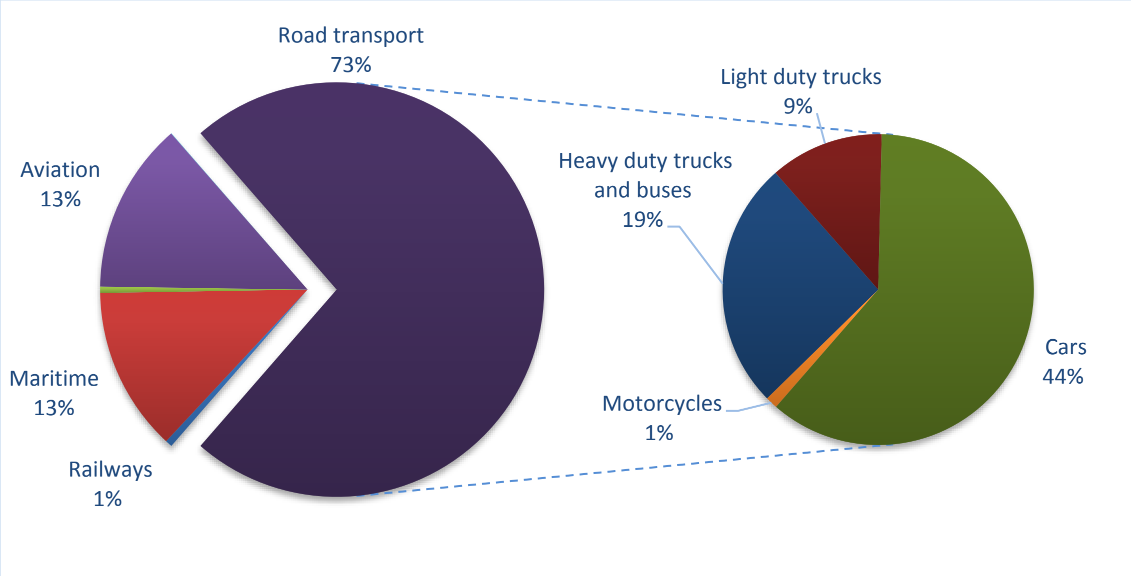
Figure 1 - Share of transport greenhouse gas emissions in 2015 by mode of transport (%)



Source: European Environment Agency. Note that the definition of "payload" is not aligned across sectors and that therefore data might include inaccuracies.

Despite technological advances to reduce emissions (average new car emissions have been reduced by 36% since 1995), progress on cleaner transport has been offset by a growing demand. The European Commission estimates that by 2050 passenger transport will grow by more than 50% and freight transport by 80% compared to 2013 levels. Energy consumption in the transport sector will likely move away in part from passenger vehicles towards aviation, maritime and long-distance transport. Furthermore, even when assuming aggressive electrification scenarios, the International Energy Agency (IEA) expects the majority of vehicles sold in Europe by 2030 to still include an internal combustion engine.[4] Therefore, technological improvements to the internal combustion engine that allow for alternative fuels and engine efficiencies remain important as well.

Just like in Europe, mobility's emissions around the world are growing. The IEA expects global transport emissions to rise from 7.5 gigaton (Gt) today to 9.4 Gt by 2040.[5] Demand, especially for road transport in developing countries, is expected to double. Therefore, increased transport emissions are a global issue, not just for Europe.

Other emissions are also important. All pollutants, including SO_x, NO_x and PM emission reductions should be considered, as well as noise[6], as they can have significant environmental and health effects (noting that such pollutants are not only transport-related). Fortunately, there have been considerable decreases between 2000 and 2015 in the EU28 such as for SO_x (72%) and NO_x in road transport (25%), but much work still

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[4] The IEA in its 2017 World Energy Outlook (WEO2017) expects oil to remain the dominant fuel under all of its three scenarios for Europe's future growth of transport demand
[5] IEA, 2016. World Energy Outlook 2016
[6] Reference is made to the European Noise Directive (2002/49/EC), as well as the obligation of Member States to implement Noise Management Action Plans in urban areas

needs to be done as concentrations continue to exceed EU limit values in large parts of Europe, in particular in urban areas.[7] The inclusion of all emissions and noise is therefore important to assess potential trade-offs between GHG emissions and other pollutants and technologies. This is also required to decide how to properly account for the environmental and climate impact of different technologies and to direct public investments.

Finally, it is important to note that the transport sector continues to work and commit to reduce its emissions:

- The automobile industry is aiming to decrease CO_2 emissions per car by 42% in 2021 compared to 2005 levels, and NOx from trucks and buses will decrease by 83-86% by 2030 compared to 2015 due to continuous fleet renewal.[8]
- The shipping industry under the coordination of the International Maritime Organisation (IMO) will decrease sulphur (SOx) limits in fuel oil from 3.5% mass by mass (m/m) to only 0.5% m/m starting 1 January 2020.
- The International Civil Aviation Organisation (ICAO) put in place its Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), requiring airlines to stabilise their emissions after 2020. Furthermore, average aviation fuel consumption decreased from 85 kg/passenger in 1992 to 54 kg/passenger in 2015, and participating airports in the Airport Carbon Accreditation programme have reduced their carbon footprint by more than 202,184 tonnes of CO_2 in 2016-2017.
- The 28 European members of the Worldwide Railway Association (UIC) have collectively committed to reduce CO_2 emissions per passenger kilometre and ton/kilometre by 50% by 2030, and are well on track to meet this target.[9]
- Europe's power sector has committed itself to supply carbon-neutral energy "well before" 2050[10] and thus can make an important contribution to the decarbonisation of transport.

[7] EEA, 2017. Air quality in Europe — 2017 report.
[8] Aarhus University, 2015. No. 219: Projection of SO2, NOx, NMVOC, particles and soot emissions - 2015-2030. URL: https://goo.gl/zJzgCU (in Danish).
[9] UIC, 2017. URL: https://uic.org/energy-and-co2-emissions
[10] Eurelectric, 2017. Press release: Eurelectric commits to carbon neutral power 'well before' 2050

2. ACHIEVING LOW-EMISSION MOBILITY ACROSS MODES

Guiding principles for a smart EU policy framework

- **Stimulate technology and fuel neutrality**. In order to ensure an effective, gradual and sustainable transition towards a low-emission transport sector by 2050, all technological options and fuels need to be allowed to compete for reducing emissions in the different transport modes applicable. The mode and type of transport depends on the solutions that are available, reliable and affordable. The efficiency of mobility also needs to be increased, as it minimises resource inputs and harmful outputs. Neutrality also requires a close cooperation of the value chain, many parts of which have strong roots in Europe, and the need for a true single market for transport. The removal of remaining regulatory, administrative and technical barriers in all modes of transport is crucial.

- **Make impact assessments (IAs) a must-have**, especially to understand the socio-economic impacts of the transition to a low-emission mobility economy. In particular, there is still a lack of clarity on what the net effect of the transition will be on jobs, with some expecting a net increase while others expecting a net decrease. Job displacements are inherent to economic transitions, but in order to truly get society onboard, workers whose jobs are at risk to be displaced in one sector need to have the opportunity to be reemployed elsewhere as soon as possible. Forward-looking re-training policies are crucial in this context. Impact assessments can also look at other areas, such as the effect of public finance for low-emission mobility on tax levels, or the competition effects for biomass sources between new users (transport) and conventional users (e.g. chemicals).

- **Think outside of the box**. Low-emission mobility in Europe will not only be achieved with new powertrains, engine efficiencies and new fuels, but by connecting all the dots through an **integrated approach**. The final section of this paper will describe a range of promising practices to further reduce emissions, such as connected and automated transport (CAT), European Modular Systems (EMS), the collaborative economy, altering end-user behaviour, new mode designs and weights, and dynamic route planning. The way the different modes of transport work together through these practices or “intermodality” needs to be further understood. It is therefore crucial that policymakers and stakeholders keep a close dialogue with business and other stakeholders on how regulation can facilitate, rather than stifle the shift towards low-emission mobility practices. Manufacturers, fuel companies, governments, transport operators and consumers must all play their part in this integrated approach to reduce emission efficiently. Furthermore, public authorities have an exemplary function in achieving low-emission mobility, for instance by being first movers on renewing public fleets allowing new technologies and fuels to reach the necessary critical mass. Such practices have allowed the aviation sector, among others, to adopt more biofuels into their flights.

- **Maintain security of supply and strive for more energy independence**. Policymakers should consider how to manage the implications of a surge in demand for each new technology or fuel. For example, the increased demand of electric vehicles requires more flexibility or should be well integrated with -the power system. Advances in this field (such as smart charging of vehicles and by integrating batteries in the grid)[11] could eventually reduce Europe's dependence on energy imports. For instance, 88.2% of Europe's oil is currently still imported, and most batteries for electric vehicles in Europe are produced in China. However, even if Europe wants to start producing its own batteries, fuels and fuel cells, this will require large amounts of precious materials. As most reserves of these precious commodities are located in third countries, it is important for Europe to think about how to shift to a low-emission mobility economy without shifting its competitiveness and geopolitical risks.

- **Stimulate rather than stifle innovation in Europe**. In order to shorten payback periods related to investments in new infrastructure and vehicles, a positive, stable regulatory and fiscal framework with at least a 10-year visibility is firstly needed. New legislation should as much as possible focus on applying the Innovation Principle to stimulate innovation, and apply equally to the entire EU in order to prevent internal market distortions. They should also be coherent with existing legislation. Secondly, relevant funding needs to be allocated to innovation along the entire value chain. Examples include the development of fuel efficiency and new shared mobility services, the adoption of alternative fuels and power sources in the transport sector, but also infrastructural and digital solutions such as 5G networks to enhance logistical efficiency. Financing of innovation through Horizon 2020, the European Investment Bank (EIB), the Connecting Europe Facility (CEF) and European Fund for Strategic Investments (EFSI) as well as other funds needs to be encouraged and reinforced. Such infrastructural financing and investment should aim to build on the user-/polluter-pays principle in order to achieve true-cost pricing. Finally, it is still sometimes the case that R&D funding in certain industries (e.g. in the shipping sector) is not pooled, preventing some technological advances from being made. This requires action from the industry itself, not policymakers.

- **Enhance international cooperation**. Achieving low-emission mobility is not just a challenge for Europe. Standards around mobility are best to be coordinated and standardised with Europe's main trading partners, especially for modes of transport that compete with each other on a global basis. Europe should also cooperate with its trading partners and other countries to reduce mobility-related emission that take place globally, such as in shipping and aviation.

- **Enforce existing regulation** and make this more focussed on technology and fuel neutrality. Furthermore, ensure that all the elements of Europe's energy and climate policies (such as the EU ETS directive, effort-sharing regulation, renewable energy and energy efficiency directives) form a coherent whole. This creates a more equal level playing field between the different transportation modes and could incentivise firms and individuals to choose the most sustainable mode.

[11] Eurelectric, 2015. Smart charging: Steering the charge, driving the change.

3. MODE-SPECIFIC NEEDS FOR ACHIEVING LOW-EMISSIONS

Road transport

- At least in the beginning, **dedicate significant (public) investments to the development of appropriate fuelling and charging infrastructure**. It would then become more realistic for enterprises and citizens to embrace low emission technologies and fuels. When the time comes to renew one's vehicle or fleet, a strong and established infrastructure would give security and reliability in the decision to bet on these technologies. It is important to find the right balance between public support to bring down technology costs and to put in place the right infrastructure in order to minimise the costs for society and maximise the climate change mitigation impact.
- **Further invest in sufficient maintenance and expansion of Europe's roads and related facilities**, such as secure truck resting areas. EU studies show that Europe's main roads are challenged by congestion every single day, adding EUR 110 billion annually to the EU's fuel bill and increasing CO_2 emissions accordingly.[12] This is especially important when considering the continued growth in long-haul freight traffic.
- **Align definitions** (e.g. for "advanced biofuels", but also "near zero emission", "low emission" and "clean" vehicle) as much as possible, and update relevant legislation to ensure real emission reductions.

Aviation

- The use of alternative fuels for aviation are **subject to tighter rules** than for other modes of transport to ensure safety of the operations. For example, very low temperatures while flying at 10 to 20 kilometres altitude could make fuels freeze or change their performance in another way. Because of these more stringent requirements and other specificities, alternative fuels need to be defined more carefully so they can be used in aviation. Furthermore, aviation is more restricted by weight limits and power needs than are other modes of transport. This makes it necessary to overcome the current difficulties with applying full electrification (due to the need for carrying onboard large batteries) or carrying large amounts of alternative fuels needed for take-off and landing.
- Airlines and fuel producers **need long-term regulatory certainty**, including but not limited to which raw materials can be used to produce biofuels and which cannot. Such certainty is critical to invest hundreds of millions in sustainable jet fuel development and manufacturing. In particular, having a list of allowed and prohibited materials that will not change every few years will be of great service for this purpose.
- For successful technological innovation, there needs to be a **sufficient supply of raw materials** within the EU that can be dedicated to aviation. The link with availability is oftentimes missing in policy debates. Policymakers are encouraged to create a roadmap and define market measures to ensure that enough raw materials are available and can be transformed into sustainable aviation fuels, without creating competitive distortions with other users of the bioeconomy.

[12] JRC, 2012. Measuring road congestion. JRC scientific and policy reports

- **The Single European Sky (SES) should be implemented as soon as possible** as it can help reduce the environmental impact per flight by 10%. The modernisation of the European Air Traffic Management (ATM) systems can reduce intra-EU flights by 10 minutes on average, saving 12 million tons of CO_2 assuming a growth to 20 million flights annually.[13]

Maritime

- Ship emissions are an important concern in harbours. In order to fulfil the emission control areas (EMAs) and regulations of the International Maritime Organisation (IMO), there should be a **clear drive to stimulate a range of technologies** in order to reduce levels of NOx, SOx and particle matter in addition to CO_2.
- Attention should also be paid to the sector of domestic navigation on internal waterways. Policies targeting fleet renewal and the use of alternative fuels could help cut emissions in this sector.
- In order to take emission reductions to the next level, it is important that **all stakeholders**, be it regulators, equipment manufacturers, fuel producers, yards and the shipping companies **work closely together**. This was one of the cornerstones behind the success of the 0.5% sulphur legislation agreed by the International Maritime Organisation (IMO) to take effect in 2020. All parties need to work together to find the appropriate solutions at a much earlier stage. The use of carrots and incentives by the legislators are much more productive than sticks and fines.

Rail

- About 60% of Europe's rail network and 85% of rail traffic is done with electrified trains, the rest mostly with diesel-fuelled locomotives. Electrification is an important objective for the sector, but could be difficult in places where the network is not used at full capacity. Therefore, in cases where electrification is not cost-effective, other options such as powertrain efficiencies, gasification or new hydrogen systems should be considered.

[13] IATA, 2013. The blueprint for the Single European Sky

4. KEY TECHNOLOGIES AND COSTS

This final section provides a non-exhaustive list of technologies, fuels, engine efficiencies and other practices that will be further developed to achieve a low-emission mobility in Europe, namely:

- Biofuels
- Connected and automated transport (CAT)
- Electric batteries
- Engine efficiencies
- Hydrogen and synthetic fuels
- Natural and renewable gas
- Other:
    - Altering end-user behaviour
    - Dynamic route planning
    - European Modular Systems (EMS)
    - Fleet renewal
    - New mode designs and weights
    - Collaborative economy

Where possible, the key cost components and avenues for cost reductions are also discussed.

Biofuels and biomethane/syngas

Environmental benefits

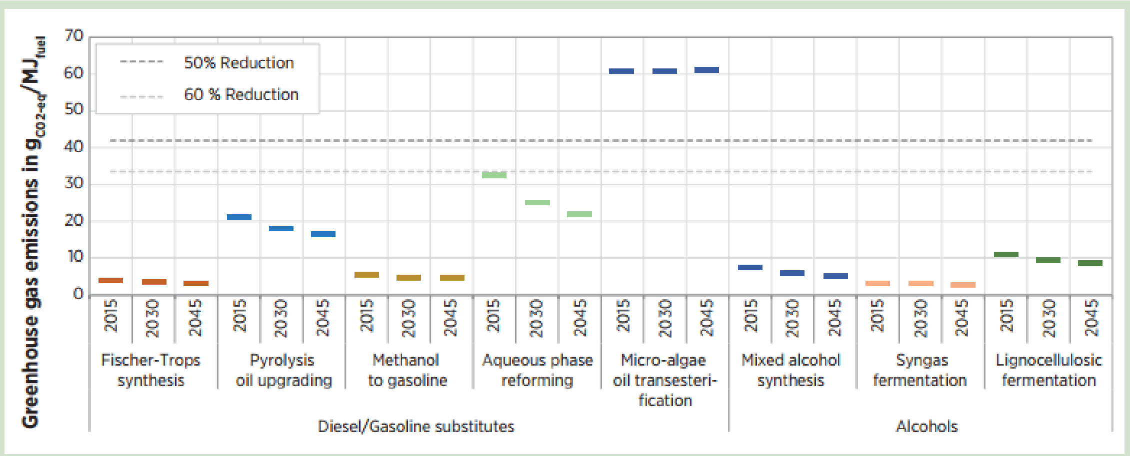
Biofuels are in most cases renewable matter blended with conventional fuels such as gasoline or diesel. Conventional examples are **first-generation ethanol** (produced from fermenting sugar cane, corn, wheat and sugar beets) and **first-generation biodiesel** (from vegetable oils, rapeseed, soybean and palm). **Advanced (second- and third-generation) biofuels**[14] are not in direct competition with food production or land-use because they are produced from non-food materials, such as bio-based materials and waste (such as straw, forest residues, sawmill by-products and waste cooking oil).

Another type of advanced biofuel is **biomethane as gaseous waste-based fuel and syngas fermentation**, which is produced from unavoidable waste streams of non-renewable origin. These can be used through carbon, capture and use (CCU) technologies, including waste processing gases and exhaust gases, with substantial greenhouse gas savings potential. CCU would in this case biologically convert the carbon to products through gas fermentation. According to the Renewable Energy Agency (IRENA), most advanced biofuels can eventually fully replace conventional fuels in engines if, for example, issues of availability and compatibility are solved. Such biofuels can have pathways of achieving emissions of about 3-33 grams of CO_2e per megajoule of fuel ($g_{co2\text{-}eq}/MJ_{fuel}$) combined with high conversion efficiencies. For most

[14] There is still not a clear definition of "advanced biofuels" and this needs to be clarified as soon as possible together with industry players

advanced biofuels, this means at least a 60 % GHG emission reduction can be achieved compared to conventional technologies (see figure below). In the aviation sector, some commercially viable options of sustainable aviation fuels (SAFs) are already available, such as hydro-processed esters and fatty acids (HEFA).[15] Under current EU regulation on blending limits, up to 40% CO_2 reduction can be achieved by mixing SAFs. This can potentially be increased to 80% by 2050 with technological advances in new fleets that allow for higher blending levels and increased production capacity developments.[16]

Figure 2 - Emission reduction potential by type of advanced biofuel



Source: IRENA Innovation Outlook: Advanced Liquid Biofuels (2016)

<u>Cost components</u>

A key cost saving element of biofuels is that many advanced biofuels can be supplied ("dropped") into the existing car fleet and infrastructure in the future, even when switching to 100% drop-in biofuels and with the necessary advanced to car engines. Therefore, the IEA's 2016 World Energy Outlook (WEO) estimates 65-90% of the levelised costs[17] of advanced biofuels to be dependent on the feedstock used (IRENA thinks it's 40-70%). Capital costs for first-generation ethanol constitute only 5%of total costs in the EU.

For advanced drop-in biofuels, the main challenge will be to overcome the issue of availability. Availability of biomass is restricted because of the limited amount of available land and water. While biomass is used to produce fuels, it is also used by a range of sectors active in the bioeconomy. Global production capacity for advanced biofuels was about 1 billion litres in 2015, with Europe accounting for about a third. However, more than half a million tonnes of dry matter are necessary for a bio-refinery to produce 150,000 tonnes of lignocellulosic ethanol annually. This requires significant capital investment costs that are much more substantial for advanced than for conventional biofuels (see Figure 3 below). It also requires competition for biomass to be optimised throughout society, in particular by ensuring an equal level playing field for users competing for the same raw materials.

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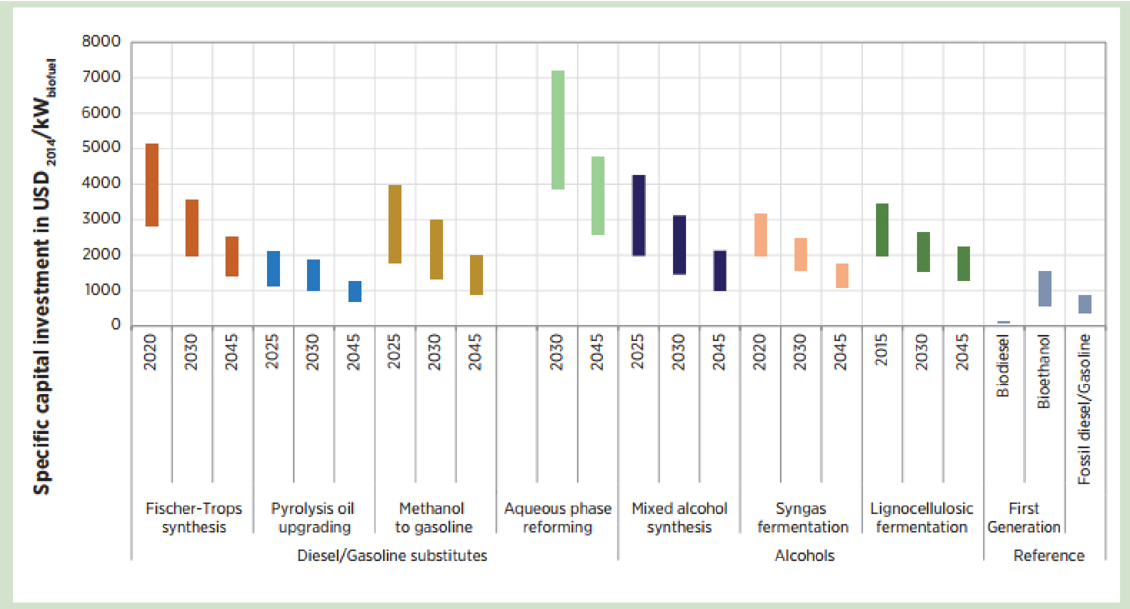
[15] IATA, 2017. Fact sheet – alternative fuels. URL: https://goo.gl/MNiqXz
[16] IATA press release, 5 June 2017. Governments Need to Support Production of Sustainable Aviation Fuels
[17] Levelised costs are used as a proxy for the price that biofuels (or any energy source in general) must receive from the market to break even over its lifetime

On the use of engines, low blend levels with conventional fuels typically lead to costs in terms of fuel additives [US$ 0.60-1.30 per liter of gasoline equivalent (lq-eq)] as well as the infrastructure cost for delivering different fuels, which are relatively low. They do not incur extra costs for existing combustion engines or other powertrains. For high blend levels[18] of ethanol and methyl ester biodiesel, it is however estimated that US$ 400-700 in additional costs should be factored in per conventional combustion engine.[19]

As technologies develop and efficiencies in engines improve, IRENA expects capital investment costs to reduce from USD 2,000-7,000/$kW_{biofuel}$ today to USD 700-2,000/$kW_{biofuel}$ by 2045. This might still be insufficient at an oil price of USD 80/barrel, but most advanced biofuels pathways would be able to directly compete by 2030 or 2045 if the oil price surpasses USD 100/barrel. This should be viewed against the 60-95% GHG emission reduction potential that most advanced biofuels have over fossil fuels.

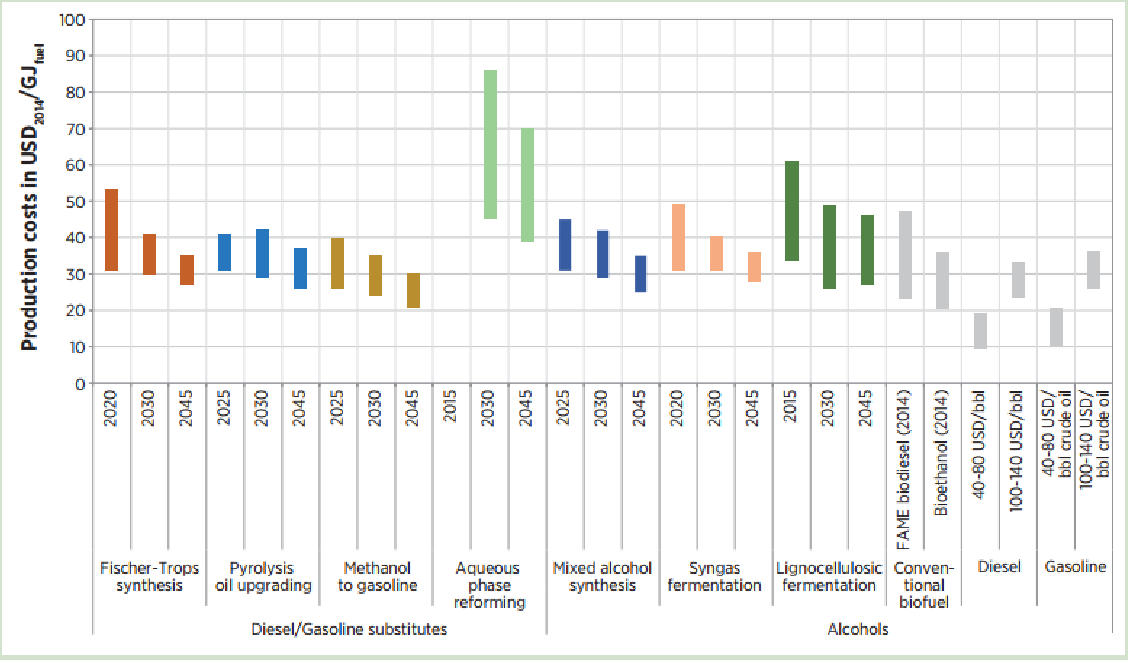
Figure 3 - Capital investments by type of biofuel



Source: IRENA (2016)

18 High level blend levels of biofuel in most of today's internal combustion engines are 10% or more volume for ethanol and 30% volume for methyl ester biodiesel
19 International Energy Agency, 2016. World Economic Outlook 2016.
20 EIA, March 2017. Study of the Potential Energy Consumption Impacts of Connected and Automated Vehicles

Figure 4 - Fuel production cost comparison



Source: IRENA (2016)

Connected and automated transport (CAT)

Environmental benefits

Digitalisation of transport is providing several new ways to further reduce emissions. One rapidly advancing technology in this regard is that of **autonomous mobility**, in which modes of transport are capable of sensing their environment and navigate partly or fully autonomous from human intervention. Another promising development is that of **connected mobility**, in which modes of transport are communicating with outside entities. Examples include vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I), but can be imagined for any device entity possible under the Internet of Things (IoT). For road transport, the U.S. Energy Information Administration (EIA)[20] estimates that connected and automated vehicles (CAVs) could reduce fuel consumption by up to 44% for passenger vehicles and 18% for trucks, though this might be fully or partly offset by an increased vehicle use of those currently unfit to drive such as the elderly, disabled, and adolescents. CAVs could also reduce congestion in cities. For example, as every vehicle would be able to communicate and drive autonomously, they could engage in **vehicle platooning** (typical application for trucks on highways).[21] This is when the vehicle at the front of a string of cars controls the speed and direction, and all vehicles behind it respond to the lead vehicle's movements as they can precisely match its

[20] EIA, March 2017. Study of the Potential Energy Consumption Impacts of Connected and Automated Vehicles

[21] ACEA, 2016. What is truck platooning?

braking and acceleration. Such ideas reduce air flow between vehicles, which can reduce GHG emissions by 2-8% for the lead vehicle and 8-13% for the following vehicles.[22]

For rail, CAT technologies are seen as enablers to reach the sector's ambitious targets by optimising energy consumption and acquisition, as well as improving its interconnectivity with other transport modes, so-called "intermodality". For shipping, automation can improve voyage execution and can increase short sea and inland waterway vessel journeys. Going one step further, the first test pilots for autonomous ships are already underway in Norway. For aviation, optimised 4D trajectories can enable better weather information, predictions and flight plan reconfigurations, a necessity as extreme weather events are becoming more pronounced due to climate change. This makes CAT pivotal for increasing network resilience and minimising air traffic management (ATM) disruptions, in turn preventing CO_2 increases.[23]

Costs

The costs for CAT technologies are difficult to estimate, but major cost components will likely be related to the required investments in **vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), high-speed internet and 5G technology**. These are crucial as they allow for the optimal utilisation of fleet management tools and thus more efficient transport flows and better capacity utilisation of mode fleets. Another cost component lies in **cybersecurity**, which becomes pivotal as increased automation leads to an increased exchange of large amounts of data. Luckily the rollout of such technologies will be needed across all sectors and hence costs can to a significant degree be shared by society.

Electric batteries

Environmental benefits

Electric batteries have a significant potential to shift Europe towards low-emission transport by diversifying the fuel mix. Cars, light -duty vehicles, busses and trains can be created with different degrees of electrification, such as **battery electric vehicles** (BEVs) and **plug-in hybrid vehicles** (PHEVs). Many studies have been published around the possible future market penetration of BEVs and PHEVs, whose results differ based on key assumptions on technological breakthroughs in batteries in terms of higher efficiency, lower cost and larger ranges, versus whether or not other technologies will develop at a faster phase than battery technology.[24] Depending on the energy source used for charging, any production phase emissions could be more than offset during the use phase. Furthermore, a potentially novel way of transferring power to the battery is by doing so from the road to the vehicle while the vehicle is in motion. Such **Electric Road Systems (ERS)** or "eHighways" are currently being piloted in Sweden and Germany and could be an important piece of the puzzle for achieving affordable decarbonised freight transport. In terms of air pollutants (the major ones being direct emissions of NOx, SOx, PM) and noise, for BEVs these are very small to non-existent. BEVs do generate non-tailpipe PM emissions.

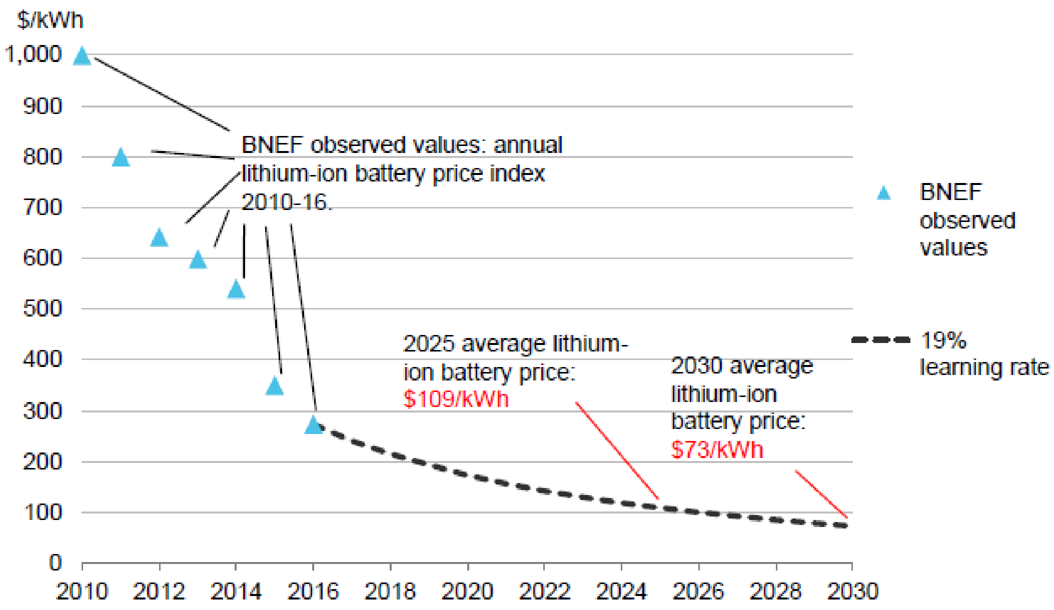
[22] For more details, please refer to the SARTRE project: http://cordis.europa.eu/result/rcn/58617_en.html
[23] European Commission, 2017. Connected and automated transport – studies and reports
[24] For a recent literature review, please see ERTAC (June 2017)

As for **trains**, electrification is already a mature technology as 60% of Europe's rail network is powered by electrified trains. **Hybrid aircrafts** are still in a fundamental research phase and would need significant advances in battery density to become commercially viable, but there are advances being made for short-haul flights of up to 1,000 miles (1,600 kilometres). CO_2 emissions could then be cut by about 70% compared to average airliners today, as well as noise.

Costs

The key cost components for BEVs and PHEVs are the battery pack, followed by car fleet renewal, charging infrastructure, and BEV production platforms, which differ substantially from those of internal combustion engines (ICEs). Key cost reductions can be achieved between now and 2025 through **economies of scale**, **technological advances** that improve cell capacity and yields, **segmented powertrain strategies** by industry, and **commercially viable deployment of charging infrastructure**, such as destination charging at work facilities, parking places and private residences.[25] This in turn requires investments and a new way of billing for electrical consumption. If these cost segments are addressed, the costs of a battery pack could drop from US$162/kWh today to US$73/kWh in 2030, this latest assumption supposing some technical breakthroughs (figure below).

Figure 5 - Lithium-ion EV battery pack prices, historical and forecast



Source: Bloomberg New Energy Finance (2017). Note: Prices are an average of BEV and PHEV batteries and include both cell and pack costs. Cell costs alone will be lower. Historical prices are nominal, future ones are in real 2016 U.S. dollars. Key assumption: The learning rate (the price decrease for every doubling of capacity) is 19 %.

[25] For more details on possible cost savings for electric vehicles, please refer to the publication by the Amsterdam Roundtable Foundation and McKinsey & Company, 2014. Electric vehicles in Europe: Gearing up for a new phase?

Furthermore, as more and more people start to use electric vehicles, so-called **sector coupling** (transport and energy) and smart grid solutions could help to improve flexible and cost-efficient electric vehicle charging. Key cost savings can therefore be brought about until 2050 by using BEVs as energy storage, and balancing electricity supply and demand in vehicle-to-grid (V2G) applications. For sector coupling via electrification to become widely adopted however, a key challenge to overcome would be the basic need for a vehicle to be ready and charged when required.

On Electric Road System (ERS), their cost depends on the ERS technology used but range between EUR 250,000 and EUR 5 million per two-way kilometre of road.[26] The German Ministry of Transport provides an average estimate of EUR 2.2 million per two-way kilometre[27] as well as EUR 50,000 per truck in additional vehicle costs (this number is expected to decrease to EUR 19,000 by 2050).[28] This needs to be put into perspective: The general construction costs per two-way kilometre can amount to several million euros[29] so the additional cost of ERS could be considered relatively manageable (and goes down with economies of scale). Furthermore, it is not necessary to rollout ERS everywhere: For example, 60% of all heavy-duty vehicle emissions in Germany occur on only 2% of the total road network.[30]

Engine and tyre efficiencies

<u>Environmental benefits</u>

Alongside emerging new technologies and fuels, continuous technological up-scale of existing technologies will be key for the coming decades. This is also crucial in order for new fuels to be adopted by engines (fuel switching), for example for synthetic fuels and advanced biofuels. Furthermore, research into "advanced combustion engine" (ACE) is being undertaken. There is still potential to reduce emissions from the ICE with technologies like steel pistons with nanoslide cylinder coating, more compact and lighter construction of the engine, application of new materials such as chromised timing chains, and low-temperature combustion.

Further efficiencies can be achieved for some applications of gasoline, LPG and diesel engines through **downsizing** by increasing power density. Other pollutants such as NOx from diesel engines can be reduced by replacing liquid urea injections with other fluids (such as ammonia) in the exhaust pipeline.

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[26] For a detailed overview, see Siapartners, 2016. Insight – Electrified road freight transport – evaluating the possibilities of external electric power systems for road transport
[27] Bundesministerium für Verkehr und Digitale Infrastruktur (BMVI), 2017. Machbarkeitsstudie zur Ermittlung der Potentiale des Hybrid-Oberleitungs-Lkw
[28] Umwelt Bundesamt, 2016. Erarbeitung einer fachlichen Strategie zur Energieversorgung des Verkehrs bis zum Jahr 2050
[29] A 2013 study by the European Court of Auditors (ECA) found that EUR 3.058 billion was spent on about 400 km of road, which is about EUR 7.6 million per kilometre. There can be significant differences between countries. Source: ECA, 2013. Are EU Cohesion Policy funds well spent on roads?
[30] Siemens, 2015. Electric roads for heavy duty vehicles

In addition, the European Commission report about **tyre** labelling estimates that if all tyres were to reach a fuel efficiency class B by 2030, the potential energy savings could amount to 256 PJ, which corresponds to a greenhouse gas emissions reduction potential of 18.6 Mton CO2 annually.[31]

Costs

The cost components of technological up-scaling of ICEs and ACEs are unfortunately uncertain.

Hydrogen and synthetic fuels

Environmental benefits

Hydrogen produced via water electrolysis is a promising extension of the electric route. Instead of a battery, modes would use a fuel cell to power the electric motor. Because fuel cells are able to store more energy in less weight than batteries, they can be used for heavy payloads and long distances as they offer a better range (already more than 500 km) and relatively shorter refuel time (similar to gasoline/diesel regarding quick charging points). It is particularly relevant for vehicles with operational constraints, such as taxis and buses in urban areas, medium- and heavy-duty vehicles for long-haul routes, ships, and can be a cost-effective alternative to diesel-powered powertrains on rail networks that are not fully utilised (and hence uncompetitive for batteries). Hydrogen could help store low-carbon and/or renewable energy thanks to water electrolysis. Even if the hydrogen is produced with natural gas, fuel cell electric vehicles (FCEVs) during the use phase emit 20-30% less CO_2 than conventional powertrains.[32]

Another example is **synthetic fuels**, which is a combination of hydrogen from water and carbon from carbon dioxide to form hydrocarbon chains to produce substitutes for gasoline, diesel and natural gas. The carbon dioxide that is used as an input in the production of the fuel is more than the combustion of the carbon dioxide, potentially creating a net-zero emission potential effect.

Costs

Hydrogen produced via water electrolysis can be used for long-term energy storage and thus for enabling the large-scale integration of renewable electricity into the energy system. Just like batteries, it can therefore be used for **sector coupling** and may even offer more flexible and easier plannable mechanisms. Due to their long ranges, fuel cell electric vehicles (FCEVs) may require fewer charging stations than for batteries. That is why less than 10% of costs likely lie in refuelling infrastructure. 90% of costs (and thus cost savings) lie in production, storage and distribution, series development, production lines and new business models.[33] On storage, there is a need to compress hydrogen in a high-pressure tank to between 350 and 700 bars to achieve a vehicle range of at least

[31] European Commission, 2017. Assessment of the need to review Regulation (EC) No 1222/2009 of the European Parliament and the Council on the labelling of tyres with respect to fuel efficiency and other essential parameters
[32] McKinsey, 2017. Hydrogen: The next wave for electric vehicles? URL: https://goo.gl/NP4wg4
[33] McKinsey, 2017. Hydrogen: The next wave for electric vehicles?

500km. Large-scale production of hydrogen will become viable with more widespread use, and rising carbon prices might make it profitable to produce hydrogen from fossil fuels. As hydrogen can be produced from a variety of sources through a variety of methods, cost will come down with hybrid and decentralised solutions.

Synthetic fuels can be used in regular combustion engines and rely on existing infrastructure. Since they have the same characteristics as their fossil counterparts, they offer a stable pathway to store and transport renewable electricity produced on overcapacity. However, synthetic fuels currently require significant amounts of energy during the production phase. Making such fuels cost-competitive requires a sufficient amount of renewable electricity as well as affordable electricity prices. In addition, low CO_2 prices in Europe also represent a barrier to the adequate development of renewable hydrogen.

Natural and renewable gas

Environmental benefits

Natural gas vehicles (NGV) can be an efficient alternative for light, medium- and heavy-duty vehicles due to technical and economic reasons.[34] Furthermore, **compressed natural gas** (CNG) is used for light-duty vehicles such as passenger cars, light commercial vehicles and for medium-duty vehicles such as buses, trucks and dustcarts. **Liquid natural gas** (LNG) on the other hand is a solution for long-distance freight and ship transport. NGVs can reduce CO2 emissions by up to 23% compared to conventional fuels, NOx by up to 70%, and has lower PM emissions. Furthermore, by blending natural gas with 20% '**renewable gas**' (such as biogas from manure and waste, or the conversion of surplus renewable electricity to green hydrogen and biomethane), GHG emissions are reduced by 40% compared to oil-derived fuels. By using **biomethane**, CO2 emissions could be similar to a battery electric vehicle (BEV) using renewable electricity. Finally, **bio liquified petroleum gas** (bio-LPG) made from renewable crops and waste feedstocks is growing. It has the same properties as conventional LPG, but can also reduce GHG emissions significantly, and the infrastructure is well-developed.

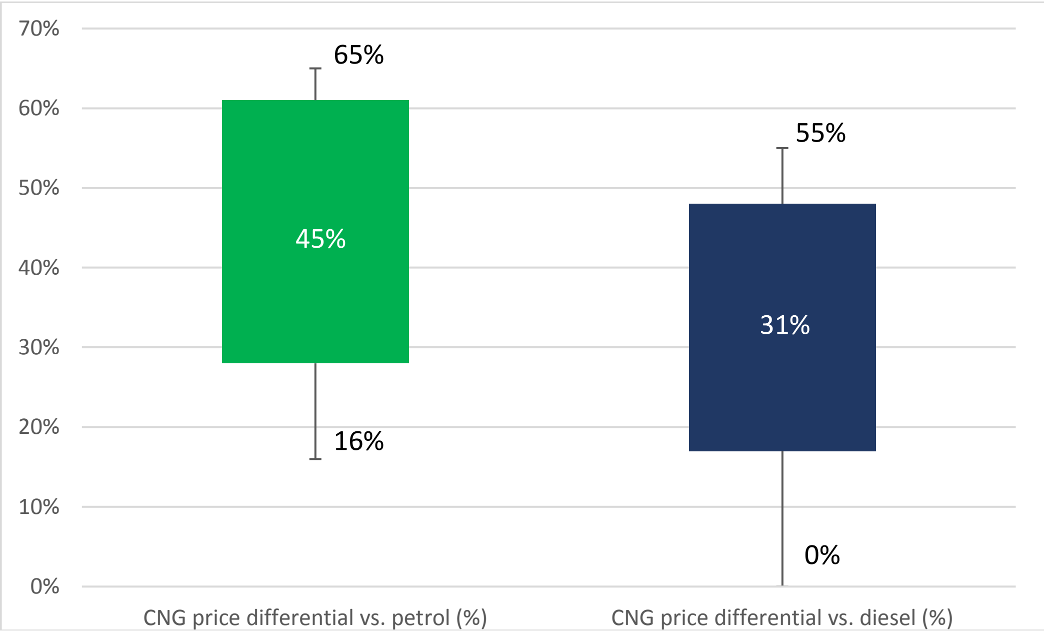
For **ships**, cleaner LNG could be a good solution to make ports, inland waterways and short-sea shipping as well as ferrying and fishing more sustainable. LNG has significantly lower emissions than both heavy fuel oils (HFO, with or without scrubber) and marine gas oil (MGO) in terms of acidification and effects related to particulate matter. The NOx and particulate mass emissions for both inland and sea ship engines running on LNG are generally more than 75% lower than for conventional diesel engines. Sea ships will also have a 90% lower SOx emission. The reductions are even higher when diesel engines using marine diesel oil (MDO), heavy fuel oil (HFO) and/or older diesel engines are replaced by gas engines. As for GHG emissions, large engines can reduce up to 15-20% GHG emissions with LNG. Lower noise emissions and engine vibration are also expected with ship gas engines.

[34] NGVA website, "CO2 & AIR QUALITY". URL: https://www.ngva.eu/co2-and-air-quality

Costs

Gas technologies have been developed for decades and can therefore represent cost-effective solutions to decarbonise and increase air quality in urban areas. Key cost components relate to the investment to infrastructure and a new car fleet. Extra costs for engine and vehicle adaptation and for the gas storage and feeding systems are in the range of 8-12% compared to equivalent gasoline passenger car, and in a range between 10-15% compared to diesel equivalents in the heavy-duty sector.[35] However, the average price of CNG in Europe is EUR 0.99/kg, which is 45% lower than petrol and 31% lower than diesel. Therefore, the extra capital expenditures can be balanced by the lower fuel operation costs of natural gas compared to gasoline and diesel (Figure 6).

Figure 6 - CNG price difference petrol and diesel



Source: NGVA Europe Statistics 2017.

Other

- **Altering end-user behaviour** can also have significantly positive effects by influencing the way we drive. For example, "slow steaming" (reducing the speed of a ship) by 10%, 20% or 30% could reduce baseline CO_2 emissions in the three main ship types (container fleet, dry bulk fleet, crude & product tanker fleet) by 13%, 24% or 33% respectively, while also reducing bunker costs.[36] Furthermore, landing and take-off (LTO) emissions for aircrafts can be reduced significantly if landings and take-offs are done more efficiently.[37] In addition, increasing the load factor of vehicles

[35] NGVA, 2017. Statistical Report 2017 – Natural & bio Gas Vehicle Association (NGVA) Europe. URL: https://goo.gl/ScacFB
[36] CE Delft, 2017. Regulating speed: a short-term measure to reduce maritime GHG emissions
[37] For example, see Koudis et al., 2017. Airport emissions reductions from reduced thrust take-off operations

by reducing the share of empty return journeys of trucks can decrease emissions as well.

- **Dynamic route planning** is a practice where transport modes can shorten their routes by taking others into account through shared information. For example, ships tracking the movements of other vessels can possibly shorted their average routes by 1% on average.[38]
- **European Modular Systems** (EMS) is a concept of allowing combinations of existing loading units (modules) into longer and sometimes heavier vehicle combinations to be used on some parts of the road network. This means that fewer trucks are required to transport the same quantity of goods, which in turn can lead to emission reductions. For example, some studies suggest that EMS can reduce GHG emissions by 10-25% per tonne-kilometre without compromising safety but can also reduce costs by up to 40%.[39]
- **Fleet renewal**. If improvements to existing model are limited, then renewing a mode fleet can be an option. For aviation, the largest emission reduction potential until 2030 will not only be in blending sustainable aviation fuels (SAFs) with original jet fuels but also through in fleet renewal**.** The latest Airbus A330 aircraft and Boeing 787 Dreamliner for continental routes are about 20% more fuel efficient than their predecessors. A Boeing 787 is even about 25-30% more fuel efficient than a 747. However, fleet renewal has a price tag for the consumer and on an annual basis could risk prematurely destroying valuable capital for business. Furthermore, there are socio-economic aspects: Since the financial crisis, the average age of the EU car fleet has risen from 8.5 years in 2008 to 10.7 years in 2015, with the oldest fleets found in Central and Eastern Europe.[40] Therefore, this is only an option in cycles and can vary depending on the mode and model.
- **New mode designs and weights**. Use of lightweight materials in transport, such as advanced high strength steel, aluminium, carbon fibres and plastics has significant potential to reduce CO_2 emissions and accelerate the transition to low emission mobility, decoupling transport demand growth from an increase in CO2 emissions. By making cars and vans lighter, conventional vehicles will use less fuel and emit fewer emissions in the use phase. Lighter electric vehicles can also travel further on the same amount of charge reducing vehicle-linked emissions. The technology for light-weight materials is developed, tested and available, though it is important to make sure that use phase emissions savings are not eroded by increased material production emissions.
- **Collaborative economy**, in which businesses and consumers grant each other temporary access to otherwise under-utilised physical assets, could reduce emissions such as through car sharing.[41] One example is Mobility as a Service (MaaS), which offers multimodal route planners and other services under one fare and on the same ticket. Such ideas could help promote and improving collective transport modes, in which the footprint per traveller can be much lower than in individual modes, whatever the type of energy used. In addition, they help to reduce congestion and reduce the need for parking.

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[38] Andersson and Ivehammar, 2016. Cost Benefit Analysis of Dynamic Route Planning at Sea
[39] Transport & Mobility Leuven, 2017. New integrated approach to reducing CO2 emissions from heavy-duty vehicles - Scenarios for 2030 (long haul and regional delivery cycles)
[40] ACEA, 2015. Average vehicle age. URL: https://goo.gl/Yyv41N
[41] See, for example, ITF-OECD, 2016. Shared mobility – Innovation for liveable cities