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Challenges of Electrification of Heavy and Long-haul Traffic

The transport sector's share of total GHG emissions in Germany was as high as 18 percent in 2015, thus accounting for the second largest volume of emissions, topped only by the energy sector. Moreover, with respect to national climate protection goals, little has been achieved in the transportation sector to date. Final energy consumption has increased from 600 TWh in 1990 to 730 TWh today, and renewable energies as a share of the total energy supply has been stagnating for several years at around a meagre 5 percent (BCG 2018). Given the transport sector's large share of total emissions and the slow progress made to date, realising the national climate goal of cutting total emissions by between 80 and 95 percent with respect to 1990 by 2050 crucially depends on developments in the transport sector. The most promising way of reducing emissions in the transport sector is the continuous substitution of fossil fuels with the increasing amount of emission-neutral electricity generated by renewable energies (30 percent in 2016). Although a purely power-based energy supply in the sector seems improbable and technology neutrality is a central principle in the process of fostering sector coupling, most studies focus on electrification as a key strategy for reducing GHG emissions in the transport sector.

One strategy for reducing emissions in the transport sector is the ongoing substitution of fossil fuels with emissions-neutral electricity generated from renewable energies (about 30 percent of the electricity mix in 2016). Although a purely electricity-based transport energy supply seems unlikely, electrification, or the coupling of the electricity sector with transport in all technology scenarios, is still playing a key role in the reduction of GHG emissions in the sector.

There has been a focus to date on progress towards and the cost degression of battery technology and the slow, but steady proliferation of electric passenger cars and hybrids in many developed countries (see Figure 1). Less attention has been paid to heavy transport: aviation, shipping and road freight transport. Given forecasts that air travel demand will double by 2050 and the persistent trend towards growth in road freight transport, reducing emissions in those segments of the transport sector is becoming increasingly crucial to the mitigation of climate change. Compared to the passenger car segment, however, there is still a great deal of uncertainty over which technologies are the most cost-efficient, and forecasts are very mixed. This article aims to provide an overview of the different alternative technologies available and the key technological challenges in aviation, shipping and road freight transport.

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ELECTRICITY GENERATION TECHNOLOGIES

The usage of Power-to-X (PtX) fuels is the most energy-intensive type of electrification. Accordingly, future power demand, and thus future power imports, crucially depends on the share of vehicles running on synthetic fuels in the transport sector. To achieve the 95 percent goal, both the BDI-study and the Öko-Institut study deem the use of PtX necessary, making it the largest line item contributing to electricity demand in the 95 percent scenario of the BDI with 124 TWh in 2050. Decisive factors in this increase are aviation and shipping, which still run on conventional fossil fuels in the 80 percent trajectory. To realise the 95 percent goal, fossil fuels would have to be fully substituted by synthetic fuels.

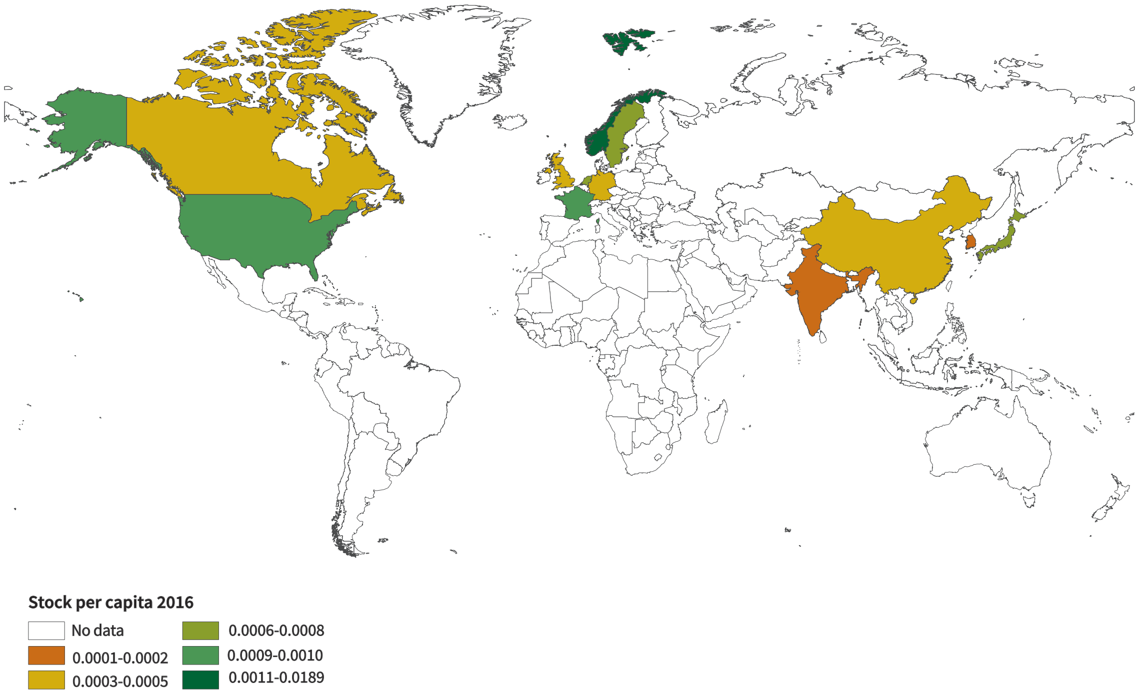
However, the electrification of the transport sector does not necessarily mean a reduction of GHG emissions. This only occurs if electrification and the expansion of renewable energies, or increasing their share of the electricity mix, go hand in hand. Fuel cell vehicles, for example, would only be less harmful to the climate than conventional cars if no more than 300 g CO_2/kWh were to be emitted in the power generation process - in the case of synthetic fuels, the corresponding threshold is even lower. The share of renewables in total electricity generation is currently 30 percent, while brown and hard coal make up another third. With this power mix and average emissions of 527 g CO_2/kWh, the use of fuel cell vehicles as well as synthetic fuels would not make sense from a climate protection perspective. Battery-powered electric cars, on the other hand, are already less emission-intensive than conventional cars with internal combustion engines (ESYS 2017).

CHALLENGES FOR EMISSION REDUCTION IN HEAVY AND LONG-HAUL TRANSPORT

Aviation

At present, emissions from aviation account for only a small proportion of the total volume of emissions, accounting for 3 percent of greenhouse gases in the EU. However, the International Air Transport Association predicts that the number of air travelers world-

Figure 1
Worldwide Stock of Electric Cars 2016



Only data according to the Electric Vehicles Initiative (EVI) is shown here.
Source: IEA (2017) - International EV Outlook 2017.

wide will double from 4 trillion to 7.8 trillion per year by 2036 (IATA 2017). Since 2012, the European Emissions Trading Scheme (EU ETS) has also included aviation, albeit geographically limited to the area of the European Economic Area. Under the EU ETS, airlines are required to monitor, report and verify their GHG emissions (MRV system: Monitoring, Reporting, Verification) and receive a certain amount of CO_2 allowances.

So far, airlines have been limited in their ability to meet these levels of emissions, primarily through improvements in energy efficiency and CO_2 mitigation measures. Since there is no substitute with the same speed and flexibility as aviation, technological innovation is needed to reduce emissions from aviation (European Commission 2016). The solution to changing the electricity mix, as in the case of road traffic, and directly electrifying the air traffic is difficult to transfer to aviation. For example, the challenge of increasing the limited range of battery-powered vehicles in passenger cars is an insurmountable obstacle to the required distances in air traffic. The simplest solution would be to combine biofuels or synthetic fuels with the fossil fuels used to date. However, the production of biofuel quantities needed for a fuel blend with a biofuel content of 10 percent may cause adverse effects such as crop and drinking water shortages in potentially endangered regions. For synthetic fuels to be an option for reducing emissions, it is necessary to accelerate the expansion of renewable energies to meet the demand of the electricity sector and generate enough surplus electricity to produce large quantities of synthetic fuels. In addition to the substitution of fuel, the International Air Transport Association has proposed various modifications to aircraft design. These include improved engine fans to reduce fuel burn and blended wing body configurations to improve aerodynamics (IATA 2017). Finally, it is important to keep an eye on the emergence of a new type of air traffic: urban air traffic is still in its infancy, but could be introduced more widely by 2020. This transport mode is intended for short distances in urban areas (Agouridas 2017). It is to be operated purely electrically, so that its contribution to GHG emissions will primarily depend on the electricity mix.

Shipping

Against the background of increased demands on environmentally-friendly and low-emission engines, shipping is also facing new challenges. Due to stricter regulations in the emission control areas of Europe, North America (from 2020) as well as some Asian cities, drives with liquid natural gas (LNG), as well as with electric propulsion, have increasingly come to the fore. In addition to the potential to reduce sulfur dioxide emissions by up to 100 percent using LNG compared with diesel engines, it is also possible to reduce carbon dioxide emissions by approximately 20 percent (World Ports Climate Initiative 2016). The global LNG fleet initially grew slowly, among other things, due to the significant cost of retrofitting existing engines. In 2016, for example, only 90 ships were registered worldwide, but by the end of 2017 this figure had already risen to 119 (The

Maritime Executive 2018). Another hurdle to LNG is the inadequate tank infrastructure in many ports.

In addition to the regulation of pollutant emissions, EU ports have been required to report CO_2 requirements for large seagoing vessels since the beginning of 2018 (VDMA 2017). This MRV system was introduced in parallel to the international maritime organisation (IMO) measure that has also been in place since 2018 and requires shipping companies to draw up a monitoring plan. By monitoring CO_2 emissions and introducing new technologies in the field of powertrains and fuels, emissions can be reduced by up to 75 percent (IMO 2009). Electric mobility in shipping has been playing an increasingly important role for some time now. Inland waterway transport in particular has benefited from the development of electric ships such as in ferry operations. In addition, a few ocean-going vessels are to some extent already being developed with fully electric drives. In the EU, this is particularly important in the field of short sea shipping. Due to high costs and the lack of a secure nationwide shore power supply, the majority of purely electrically powered ships can be operated, but only in conjunction with, for example, synthetic fuels or liquefied natural gas. There are also challenges in securing the power supply and dealing with power outages on board.

Road Freight Vehicles

At present, road freight transport accounts for one third of total energy demand in the transport sector. As the major energy sources are petroleum derived fuels (97 percent), global road freight transport is a major contributor to global CO_2 emissions. Since 2000, there has been an upwards trend in emissions from road freight transport, accounting for 8 percent of the increase in global emissions from fuel combustion and thwarting efforts to mitigate climate change. Total emissions due to road freight vehicles amounted to about 7 percent of aggregate CO_2 emissions from total energy use (IEA 2017). Currently, unlike China, the United States and Japan, there is no binding limit for CO_2 emissions from heavy goods transport in the EU. In 2019, like ship and air traffic, an EU-wide MRV system will be introduced for manufacturers of trucks weighting for than 7.5 tonnes, which will boost competition to increase energy efficiency. This should serve as a basis for further regulations, for which first drafts have been announced this year (European Commission 2017).

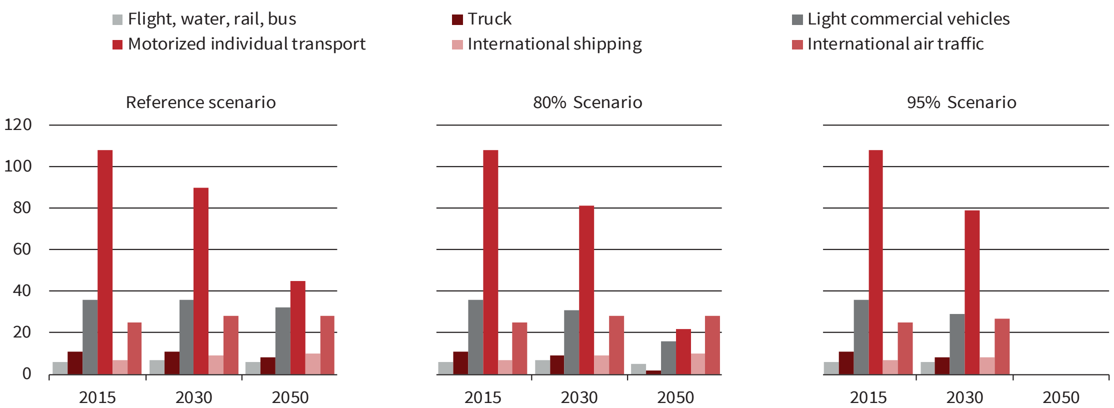
From today's point of view, no clear trend towards the domination of one technology in the road freight sector is visible. A study by the Boston Consulting Group entitled: 'Climatic Backgrounds for Germany' estimates the technology mix of the heavy goods traffic of the future for various climatic conditions (BCG 2018). For reduction scenarios of between 80 and 95 percent, the mix is very heterogeneous: among the predicted technologies are fuel cell vehicles, battery drives, truck overhead lines and CNG/LNG, but diesel and gasoline continue to play a central role too (see Figure 2). The various technologies differ in terms of their GHG reduction potential, costs and market maturity.

Since 60 percent of the emissions from German heavy goods traffic are generated on 2 percent of the German road network, the installation of overhead line infrastructure on the busiest motorway kilometers is ideal. In 2017, Germany and Sweden launched a joint pilot project, with the first test lines to be built by the end of 2018 in cooperation with Siemens. Even although, according to several studies, the construction of a catenary network is a cost-effective alternative from today's perspective, this option involves considerable risks. Investment decisions should be taken early, before the middle of the next decade - on the other hand, future cost degressions of alternative technologies could make them a more favorable alternative. In any case, overhead lines would only supply a small part of the entire road network, and would have to be supplemented on the rest of the network with drives via batteries, fuel cells or hybrids.

Figure 2

Greenhouse Gas Emissions by Transport Mode 2015–2050

Mt CO2-Equivalent



Source: Boston Consulting Group (2018).

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Despite the technical obstacles in the truck battery drive associated with the high energy density required, the big truck manufacturers presented their first models last year: MAN presented its e-truck in February 2017, which was followed by Tesla's 'semi-truck' in November of the same year. An advantage of battery technology is its significantly lower energy costs and far greater energy efficiency (85 percent) compared to diesel and gasoline (30 percent).

The fuel cell drive has faced quite high cost hurdles to date. Fuel cell trucks are also more emission-intensive than ordinary burners in the current German electricity mix. A central advantage over the battery drive with relevance to the truck segment, however, is about six times higher energy density per unit volume compared to batteries. Overall, there are now around 500 fuel cell trucks in various demonstration projects worldwide, but an early marketability appears to be hardly possible, due particularly to the problems associated with the tank size, high material costs and complicated tank processes.

CONCLUSION

Due to increasing demand for air travel and freight transport, the importance of emissions from air traffic, shipping and truck traffic in terms of climate change is growing. EU regulations are mainly limited to the MRV system without mandatory emission standards. However, long-distance and heavy haulage still faces fundamental technical challenges: far higher weights and longer distances often make solutions in the field of passenger cars difficult to transfer to this segment. From a technological point of view, the use of synthetic fuels to reduce emissions is conceivable, especially for aviation and shipping. However, this is a technology that is not yet ready for the market, which also requires large amounts of electricity for its production. To meet this increased electricity demand would either require a very expensive expansion of domestic renewable energies; or a sharp increase in electricity imports. The import of PtX fuels is also conceivable here. In truck traffic there is greater technological heterogeneity: studies predict a technology mix with lorry overhead lines for the most frequented routes in 2050, in combination with battery drives, fuel cell vehicles and CNG/LNG.

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