Agora Verkehrswende

Transforming Transport to Ensure Tomorrow's Mobility

12 Insights into the *Verkehrswende*

SHORT VERSION

Imprint

Transforming Transport to Ensure Tomorrow's Mobility

12 Insights into the *Verkehrswende*

A discussion of the most important challenges facing the decarbonisation of the transport sector and the transition to sustainable mobility
(short version)

This document offers key insights into how we can enable the *Verkehrswende*, or transport transformation. The Executive Director of Agora Verkehrswende is solely responsible for the contents of this publication. The Scientific Advisory Board bears no responsibility in this regard.

The full version of this study is available at:
www.agora-verkehrswende.de/en/publications/transforming-transport-to-ensure-tomorrows-mobility/

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Preface

Kindergarten. Zeitgeist. Sauerkraut. Many German words have entered the English language over the years. One of the more recent additions is *Energiewende*. Germany's sweeping programme to phase-out nuclear power and transition to clean energy has proven so popular internationally that this neologism has been catching on. However, another German word of crucial importance to the clean-energy transition is less well known abroad: *Verkehrswende*, or transport transformation, which refers to both the decarbonisation of the transport sector and transition to sustainable mobility. One reason why the word remains obscure is fairly simple: the *Verkehrswende* has barely begun.

The 12 insights contained in this report outline the steps Germany will need to take to accomplish this transformation. They offer less a finished strategy than a map and compass for future work – a map, because they describe the fields and topics that must be navigated on the way to developing a sustainable transport sector; and a compass, because they point to the ultimate destination: namely, the elimination of fossil fuels by 2050. This year may still seem far off, but Germany urgently needs to ramp up its decarbonisation efforts now to meet its own climate targets and those set forth by international agreements. And as the fraught discussions concerning the future of coal in Germany have made abundantly clear, countries that cling too long to the status quo have a much harder time introducing renewables down the line.

The transport transformation involves much more than switching to clean energy in the transport sector by adopting electric vehicles. If it is to succeed, it must be accompanied by changes in the transport system and in people's travel behaviour. As such, public acceptance may well play a bigger role than the nuts and bolts of decarbonisation. Indeed, the transformation of the transport sector will set in motion structural changes that are far more complicated than those associated with the clean-energy transition in the power sector. That's why it requires the support of government and the population at large. Right now, it seems, important stakeholders still need convincing. Among other things, they need to be persuaded of the social and economic value of the *Verkehrswende* beyond mitigating climate change, a subject addressed by this report.

Germany's 2050 Climate Action Plan has set national targets based on the ambitious goals of the Paris Agreement, including Germany's first-ever benchmarks for the transport sector. The task now is to find the best path for achieving these targets – and then to begin the journey. We invite you to join in the discussion.

Given the rapid changes to transport technologies, these 12 insights will no doubt need revising over time. Who three years ago could have expected vehicle battery prices to fall so quickly? And who today can, with any certainty, predict the future importance of privately owned cars?

What will international discussions have to say about the *Verkehrswende* several years from now? Our hope is that, *as Germany begins to transform its transport sector, the pivotal role of sustainable mobility will become apparent for the success not just of Germany's clean-energy transition,* but of similar programmes everywhere.

Your ideas, comments and criticisms are welcome. Let's work together to transform the transport sector today, thus ensuring tomorrow's mobility.

Christian Hochfeld
Executive Director of Agora Verkehrswende on behalf of the entire Agora Verkehrswende team
Berlin, September 2017

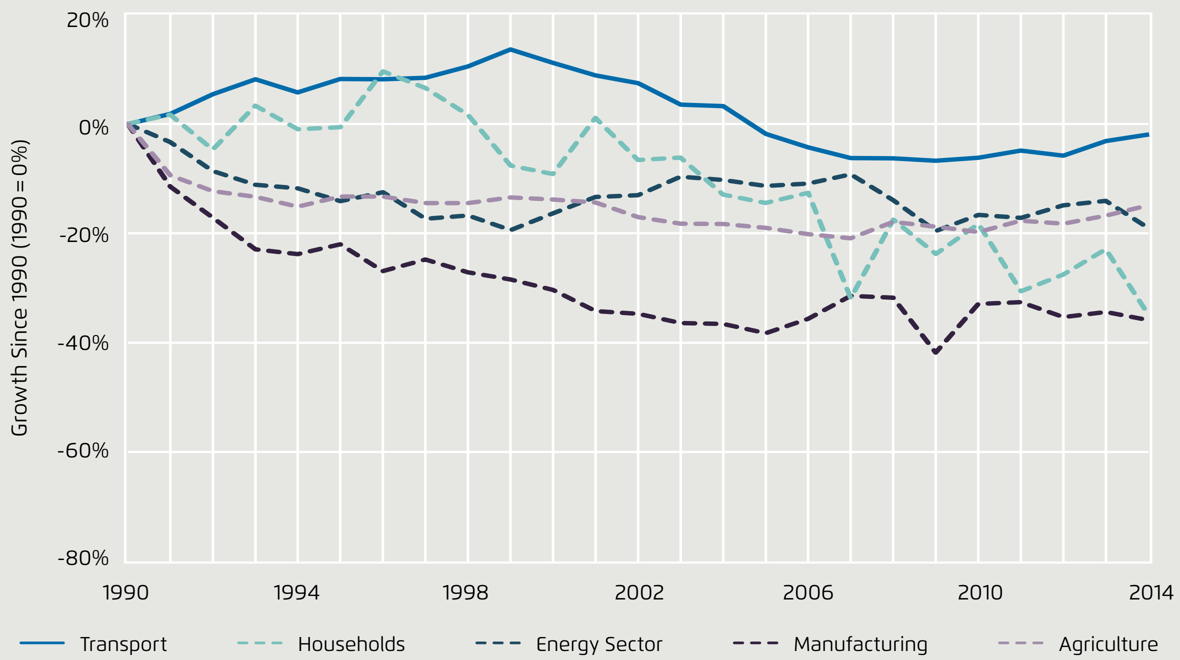
Contents

Intro-
duction

Transforming the transport sector is crucial for the success of the clean-energy transition.

Our economic prosperity is heavily dependent on the transportation of people and goods. Yet for all its benefits, transportation can have negative impacts on human health and quality of life. At present, the German transport sector consumes more energy than any other part of the economy and is second only to the energy industry in greenhouse gas emissions. As such, it plays a pivotal role in the clean-energy transition and the effort to mitigate climate change. Neither of these projects will succeed in the absence of significant changes in the transport sector. To date, the transport sector has made no contribution to the attainment of Germany's emissions targets. While significant emissions cuts have been achieved in other sectors of the Germany economy, greenhouse gas emissions in the transport sector remain stuck at their 1990 levels. This contravenes the spirit of the Paris Agreement that was struck in December 2015. It also violates the climate protection resolutions adopted by the German government, including its 2050 Climate Action Plan, which has set the goal of making Germany "nearly independent of fossil fuels and hence greenhouse gas neutral by 2050". In specific terms, emissions in the transport sector are to be reduced 40 to 42% relative to 1990 levels by 2030. The discrepancy between objectives and reality reveal the enormous need for political action. Indeed, in the absence of a dramatic transformation in the transport sector, the clean-energy transition – and, by extension, our efforts to protect the climate – are destined to fail.

Greenhouse gas emissions since 1990 by sector — Figure 1



Source: Data from Umweltbundesamt: Nationaler Inventarbericht 2016, p. 73

Insight
01

Transforming transport requires decarbonisation and sustainable mobility.

Energy is a limited resource. This is no less true of renewable energy than it is of fossil fuels. There are technological limitations to the amount of energy that can be obtained from sunlight, wind, biomass and hydropower. But even if this weren't the case, a massive expansion of renewables would bring undesirable consequences for people and the environment. As the number of wind turbines increases, public support for the further expansion of renewables is likely to decline. Accordingly, carbon-neutral energy needs to be used efficiently, not only to ensure continued public acceptance for the energy transition, but also to minimise generation costs.

The fact that the amount of renewable energy will be limited for the foreseeable future has consequences for the transformation of the transport sector. It means that replacing combustion engines with electric motors is not enough. Lowering energy usage and covering the remaining demand with carbon-neutral energy will be essential. Hence, the transport transformation necessarily rests on two pillars: the "mobility transition" and the "energy transition in transport".

The first pillar, the mobility transition (known in German as the *Mobilitätswende)*, will ensure declining final energy consumption in the transport sector without restricting individual mobility. Advancements in technology have increased mobility options and made multimodal travel – the use of multiple types of transport for a single trip – easier. Energy policies and general societal trends will make it possible to activate latent potentials to reduce, reorganise and improve transport. Mobility will take on a new character in cities and rural areas while also supporting the goals of climate protection.

Yet ensuring a high level of personal mobility while reducing overall traffic volumes will depend on adopting the right political framework. Fortunately, new technologies give policymakers the ability to align the transport sector with climate goals more effectively than ever before. With the right policies in place, it should be possible to reduce energy consumption in the transport sector by around 25% by 2050. When one adds the effect of efficiency increases, achieving a 50% reduction in energy consumption by 2050 in relation to 2005 levels is an attainable goal.

The goal of the energy transition in transport *(Energiewende im Verkehr)* is to assure that the remaining energy consumption in the transport sector is carbon neutral. This is primarily a technical challenge. Yet surmounting it will require the right political guidance.

Most studies conclude that the broad-based electrification of the transport sector will be crucial for the attainment of carbon reduction targets. Yet meeting these targets will require several other components: namely, an integrated, electricity-based mobility system that encompasses various modes of transport; infrastructure for the low-carbon generation of electricity, hydrogen and electricity-based fuels; and the adoption of sustainable transport principles. By 2030, 20% of all road vehicles – 100 million cars alone – must be electric-powered. However, in view of the many uncertainties involved with introducing new technologies, alternatives should not be ruled out today. Accordingly, regulations must be informed by technological openness.

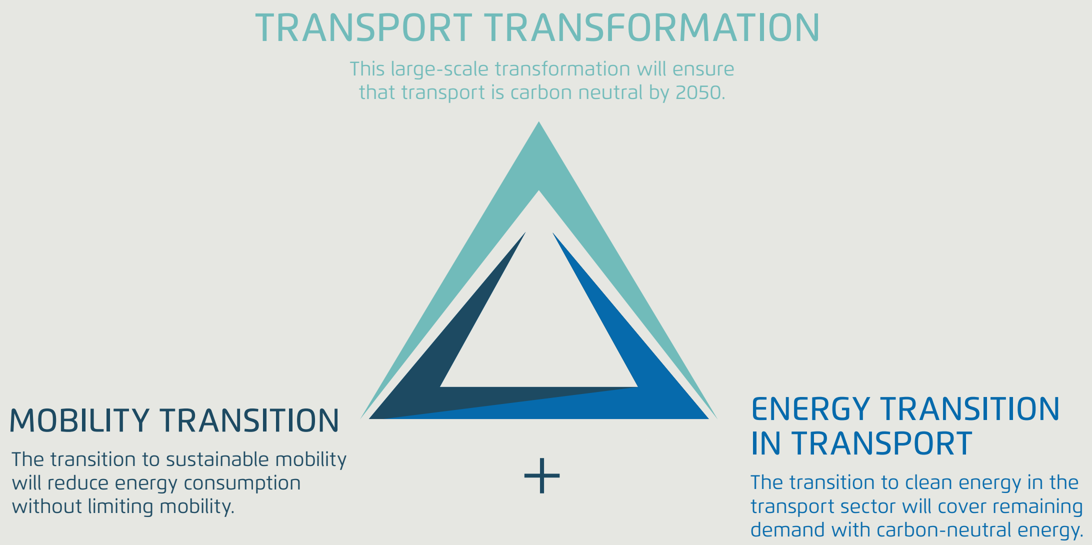
Of course, the primary task of policymakers is not to determine which technologies to use. That's the job of supply and demand. But government policies can provide a regulatory framework that promotes a carbon-neutral transport sector – e.g. by instituting CO_2 standards for vehicles. Clearly, technological advances alone will not generate sufficient CO_2 reductions. Future infrastructure investments must be designed to reduce emissions, and the government must send targeted signals to transportation users that steer their behaviour in the right direction. Decision-makers have at their disposal various instruments for this purpose: levies, surcharges, restrictions and standards based on the polluter-pays principle, and funding programs based on the burden-sharing principle. What does not work is to rule out incentives, declare standards unacceptable or give priority to balanced budgets. This will hogtie government action.

The transport transformation is a long-term task that spans multiple areas of the economy. Such a task requires cohesive policies. This means that policymakers at various levels of government, from the EU level to local municipalities, must coordinate their activities. The same goes for policy-making across economic sectors; they, too, must be harmonised for policy initiatives to be effective. Germany could send an important signal if government officials were to agree soon on a general strategy for transforming the transport sector. A smart strategy would define vital structural cornerstones, policy instruments, reforms and targets. A crucial goal is to reduce emissions in the transport sector by 40 to 42% by 2030, a target that has been embraced by the federal government.

A general strategy is all the more important considering this transformation is not just about traffic and the environment. It's also about German industry, jobs, economic vitality and public health. The longer Germany hesitates while other countries push ahead, the more it will fall behind and the less time it will have to prepare for unavoidable structural change. And without a transformation of the transport sector, Germany stands to lose its attractiveness as a site for industrial production.

The transformation of the transport sector will require new cooperative impetus at the international level, especially in Europe. The digitalisation of the transport sector and adoption of electric powertrain technologies will only be possible if imports of certain raw materials (i.e. lithium, cobalt) or of carbon-neutral electricity-based fuels increase on a massive scale. To avoid shortages or monopolies, international cooperation is urgently needed, especially during market ramp-ups of new transport technologies. Such cooperation will create the basis for the development of extraction and processing capacities in foreign countries while also ensuring that demand peaks do not drive up prices, thus slowing the transformation. This need for cooperation thus makes the transport transformation an element of international security and peace efforts.

The geometry of the transport transformation | Figure 2



Authors' figure

Insight
02

Efficiency is the guiding principle of the transport transformation.

The transport transformation involves structural change that will have major impacts on people's everyday lives. Accordingly, the principle of economic efficiency should guide the policies adopted to usher in this structural change. In specific terms, this means that decarbonisation should be undertaken in the most efficient way possible. Whenever new policies are devised, policymakers should seek to conserve limited resources, including environmental resources, the financial resources of public and private actors, and public acceptance for change. In this way, the transport transformation is not only a technical challenge, but a socio-political one as well.

The imperatives of the clean-energy transition cannot run roughshod over public preferences. While Maximising efficiency should be the principle that guides the transformation of the transport sector, but it should not be elevated to dogma. When designing policies, we must carefully study and consider opportunities for reducing costs. If the goal of maximising technical efficiency runs up against the limits of public acceptance, then next-best solutions will need to be found.

Providing possibilities for people to satisfy their mobility needs without making long trips using motorised transport is the most efficient means of transforming the transport sector. For fewer kilometres travelled means less energy consumed and a lower environmental impact. Functional zoning (for decades the dominant paradigm in urban planning) and ongoing efforts to make far-off places easier to reach will not abet this transition. Restructuring for efficiency will require time and the political resolve to pass legislation that is no longer focused on eliminating obstacles to vehicle traffic.

New information and communication technologies promise to generate rapid increases in the efficiency of transport. Individuals now have a compelling and practical alternative to private vehicle ownership thanks to the digital networking of non-motorised forms of transport, public transportation, and car- and ridesharing services. Driverless vehicles can also have a positive effect on the environment, provided they are used efficiently. With digital technologies, various means of transport can be better utilised and the traffic system can be made more intelligent. This will result in efficiency gains while also undergirding economic growth.

The efficiency rule should also be applied to vehicles, even if it does not suffice to achieve the aims of the transport transformation. According to EU law, energy efficiency is defined as "the ratio between performance output and energy input". Accordingly, a vehicle engine with higher horse power but the same fuel consumption as its predecessor is more efficient. However, such an engine still emits the same amount of CO_2. Thus, when it comes to vehicle technology, the efficiency rule must be supplemented by another: namely, the economy rule. The economy rule dictates that we should use available energy in a frugal manner, and not just efficiently. Indeed, for the transport transformation to succeed, we will need light-weight vehicles built for low-energy use, not high performance and speed.

The economy rule also applies to battery-powered vehicles. It is true that electric motors are more efficient than combustion engines, but they do vary in the amount of electricity they use depending on their design, power and weight.

The energy consumed in an immediate sense to propel a vehicle is only one part of the story. It is crucial to consider the entire process by which energy is obtained, transported and consumed, i.e. from *well to wheel.* Vehicle efficiency *(tank to wheel)* and fuel production *(well to tank)* are, by themselves, insufficient measures for judging climate impacts. What really matters is the efficiency of the system as a whole.

At least for now, electricity is the sole energy carrier that can be produced on a wide scale in Germany using renewable energy sources. For the foreseeable future, electricity driven vehicles are therefore the only option for climate neutral transport. Although electric motors generally convert energy more efficiently than combustion engines, electric vehicles are only emissions free if the electricity used to power them is generated completely from renewables.

The share of renewables in the German electricity mix is now around one-third, and thanks to the government's promotion of renewable electricity, this share is still growing. As the production of electricity from renewables increases, electric-powered transport will become more efficient, and the amount of GHG emissions it creates will decline until it eventually reaches zero. Direct electricity use is the key for the transformation of the transport sector. Should this option not be possible – whether due to technical limitations or a lack of political willpower – other, less efficient solutions will have to be considered.

In such an event, internal combustion engines in road traffic cannot be ruled out, although they are less efficient than electric motors. However, combustion engines can only be an option for the transport transformation if they are operated with climate-neutral fuels that are produced using green electricity. The production of electricity-based fuels itself requires a great deal of energy, however, making it significantly less efficient than direct electricity use.

Carbon-neutral transport with combustion engines, therefore, is at an efficiency disadvantage both in terms of well-to-tank and in terms of tank-to-well, which speak against their use. Their deployment for long-term climate change mitigation would only be acceptable under a regulatory framework that requires fuels for such vehicles to become gradually more carbon-neutral.

While Germany has adopted an ambitious legal framework for the power sector that sets forth a clear and comprehensive route to decarbonisation, such a framework does not yet exist for vehicle fuels. The development of such a framework is one important task in the effort to bring about the transformation of the transport sector.

Efficiency gains and growth stimulus from intelligent networks — Figure 3

Efficiency gains	€ billions	Growth stimulus	€ billions
Fuel and time savings thanks to intelligent traffic management (M2M, traffic guidance systems, GPS connectivity, etc.)	4.4	New services based on smart mobility solutions (e.g. apps for multimodal transport)	1.1
Reduced travel distances and costs thanks to smart logistics (automated traffic flows based on sensor data and centralized IT functions)	3.6	New logistic services, including services based on smart logistic infrastructure	0.9
Total annual savings	8.0	Total annual growth	2.0

Beckert, B.: Gesamtwirtschaftliche Potenziale intelligenter Netze in Deutschland, 2012, p. 32

Insight
03

In cities, the mobility transition has already begun.

For more than a decade now, private vehicle ownership has been on the decline in German cities among the younger population. More people are getting around by bicycle, on foot, with public transport and through carsharing.

The paradigm of the "car-friendly city" – a product of the post-war era – has been on the decline for years. One reason is a change in values. For instance, more than three-quarters of Germans surveyed today want to live in cities and communities where owning a car isn't a necessity. The dominant concern now is to have a liveable urban environment that is friendly to humans, and not to cars. Denser housing combined with mixed-use urban development reduces transport distances – and, by extension, CO_2 emissions.

New digital technologies and electric vehicles have opened up new options for cutting emissions. But the right political support is needed to harness latent potential in this area. The digital transformation can support integrated traffic planning while blurring the boundaries between public and private transport – without creating restrictions to personal mobility.

Public transport already offers considerable environmental advantages over other forms of motorised transport. Accordingly, we need to expand public transport while making it even more environmentally friendly through increased electrification. Yet we also need to interlink public transport with other mobility options, including car- and bikesharing, ridesharing, and long-distance buses, in order to create comprehensive "mobility networks". These networks blur the lines between public and private transport and enable users to determine an optimal combination of various mobility options without relying on vehicle ownership.

A key factor for ensuring public use of such mobility networks is the nationwide expansion of mobility services. They must be made available not only to the inhabitants of big cities but also to people who live in suburbs and small towns. To achieve this, public transport systems require a stable foundation, especially when it comes to funding. This might necessitate the reform of municipal transport financing laws or the introduction of a local public transport tax.

The rise of the liveable city paradigm involves replacing car-oriented urban infrastructure with roads and pathways for bicycle and pedestrian traffic. With the right kind of urban infrastructure – such as a dedicated pathways for bike and foot traffic – the share of non-motorised transport in cities can be increased to over 50%. Improvements are even possible in the freight transport sector by harnassing the potential offered by electric and electric-assisted cargo bikes.

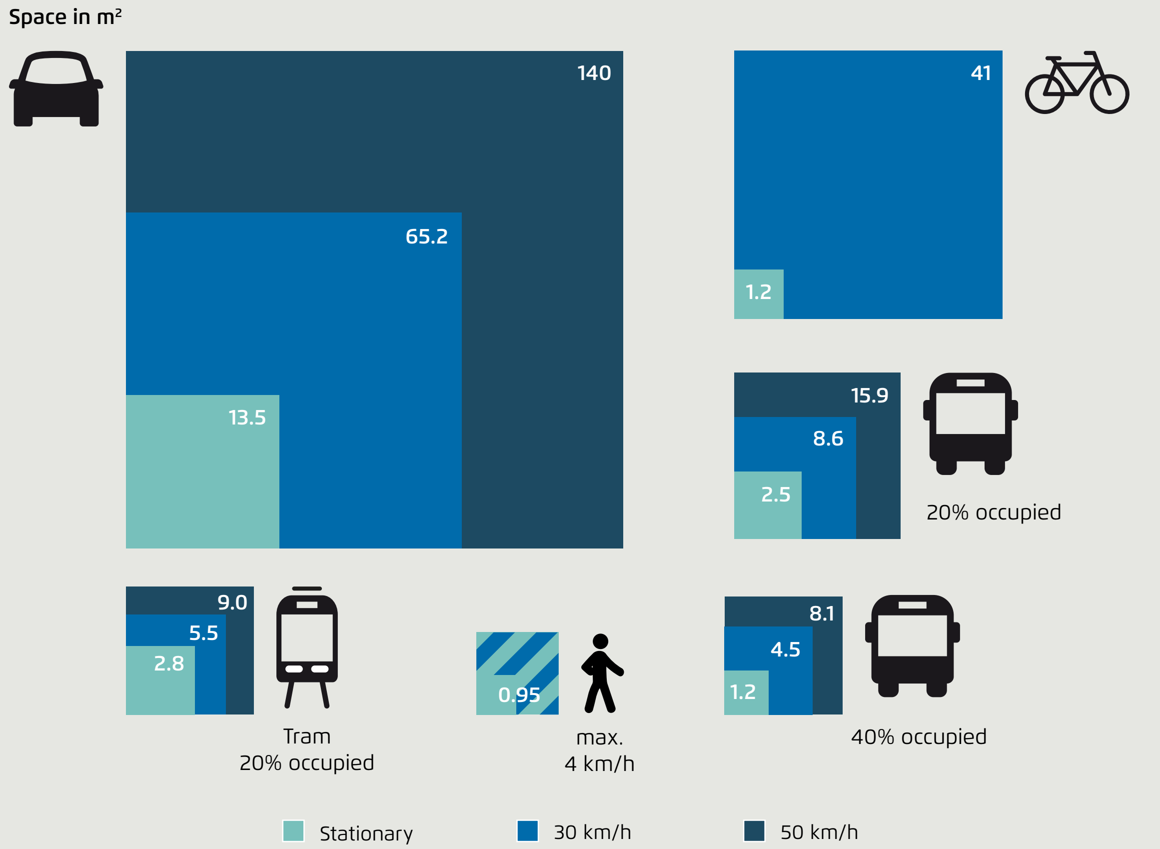
Parked vehicles negatively impact public space, due to the massive amount of room they require. Taking a cue from other European cities, we should grant German municipal authorities greater freedom to determine local parking management policies. Higher parking fees – both for resident permits and short-term parking – would enable space to be reclaimed for the public good. Another important instrument to free up space is the promotion of car- and ridesharing. Empirical studies have found that a single carshare vehicle can replace 8 to 20 private cars in inner-city areas.

Freight transport in Germany is predominantly performed with diesel vehicles, which release high levels of harmful emissions. Diesel trucks in urban areas also impair the flow of traffic and represent a safety hazard. Sustainable approaches to city logistics represent a possible solution in this area. Typically, these approaches involve streamlined collection points for goods outside urban areas, reducing the number of trips into the city. Electric vehicles and electric-assisted cargo bikes can then be used to make individual deliveries to end customers. Municipal policymakers have options for keeping freight traffic out of sensitive areas: they can institute diesel driving bans for heavy freight vehicles, or enact truck routing systems.

Transforming urban transport will depend on enlightened planning and guidance at the municipal level. In general, city planners understand the specific challenges facing their city, and they are aware of viable solutions to resolve them. What stands in the way of transformation is generally not a lack of knowledge, but rather practical challenges. The implementation of transformative policies requires alliances between policymakers, local administration, the private sector, the citizenry, academia and the media. Furthermore, the German government and the EU need to reform existing traffic and transport regulations so that municipalities have greater freedom of action.

However, what cities need most of all is legislative stability. Germany should pass so-called experimentation clauses that facilitate municipal action, especially for testing temporary or flexible policies. Germany's road traffic regulations must be amended to enable innovation without a time-consuming repurposing of public policy.

Space requirements of different types of transport at different speeds — Figure 4



Authors' figure based on M. Randelhoff: Vergleich unterschiedlicher Flächeninanspruchnahmen nach Verkehrsart. URL: www.zukunft-mobilitaet.net/78246/analyse/flaechenbedarf-pkw-fahrrad-bus-strassenbahn-stadtbahn-fussgaenger-metro-bremsverzoegerung-vergleich/. Last accessed on: 14.03.2017

Insight **04**

Rural areas will also benefit from the mobility transition.

For the majority of rural residents, cars are the number one means of transport, and they are likely to remain so for the foreseeable future. The immense challenge now is for policymakers to develop climate friendly alternatives to conventional cars. One solution is to increase efficiency through technological improvements. Another is to shift transport demand to more environmentally friendly mobility options. The trend toward more flexible working hours and living arrangements has resulted in individuals commuting ever greater distances. Subsidies such as commuter allowances and tax benefits for company cars – which increase the amount of harmful emissions released into the atmosphere – only exacerbate this negative trend.

Demand for public transport is low in rural areas, in part because it is difficult to interlink with other forms of transport. The resulting lower availability and quality of public transport means it is difficult to compete with private vehicle ownership. Rural residents are thus likely to remain reliant on privately owned cars.

To ensure that car use meets climate change mitigation targets, the government must do more to promote electric vehicles. Concerns about the limited range of battery electric vehicles are unfounded: using current technology, electric vehicles can service 80 to 87% of all journeys made by rural and suburban residents. Detailed studies of typical driver profiles show that battery life is sufficient for longer commuter routes as well. The lack of recharging stations, a reoccurring problem in cities, plays much less of a role outside city centres, as electric cars can easily be charged at home. Once Germany's new legislation to promote electric cars comes into effect, people will be able to charge their cars at the workplace, as well. Moreover, energy generation at home provides additional benefits. For example, rooftop solar panels can produce energy for charging vehicles at home.

There is considerable potential to shift from cars to alternative means of transport that are not only better for the environment, but also reduce commuter traffic. On average, 30% of rural commuters need no more than ten minutes to get to work. Some 29% of commutes are shorter than five kilometres and 20% are between five and ten kilometres. What is more, 70% of workers living outside urban centres travel by car to work, regardless of commuting times. For such short distances, alternatives such as bicycles or pedelecs are good options for reducing the volume of commuter traffic and the environmental damage it causes.

Pedelecs – bicycles equipped with electric motors – allow riders to cover more ground in a shorter time. Studies show that cycling 15 kilometres with a pedelec bike is for most people an attractive alternative to using a car – and also cheaper. Businesses have already made good progress in managing new transport solutions such as pedelecs. For some time now, firms have offered company bicycle policies to encourage more workers to ride.

If more people are to commute to work using bicycles or pedelecs on a regular basis, however, they will need pleasant, uninterrupted bike paths, express lanes and secure bike parking.

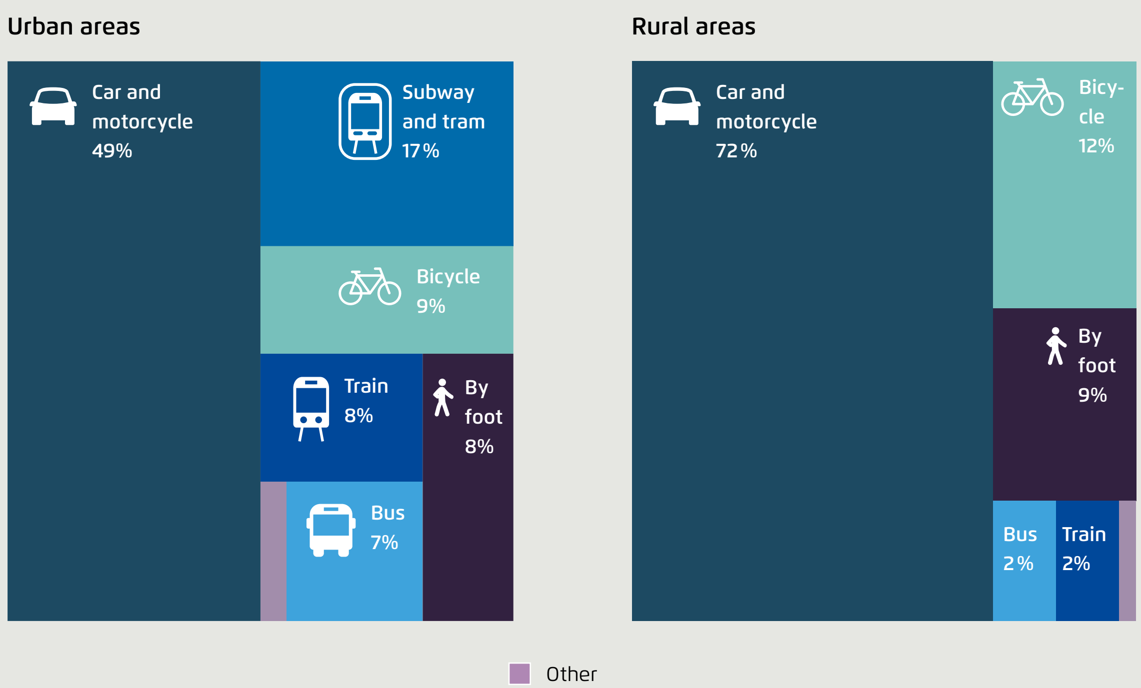
The infrastructure of regional public transport networks also plays a decisive role in commuter behaviour. In regions with good route coverage, commuters take public transit more often. If networks are well connected, people tend to use them more frequently.

New approaches are essential for an effective expansion and modernisation of current transport services across Germany. Public transport services in most rural areas are often rigidly organised, characterised by long waits and gaps in service. Multi- or intermodal trips are almost impossible, making travelling by public transport less efficient and less convenient in rural areas. As a result, cars remain the primary choice for the majority of residents regardless of age group.

Students and trainees are the most frequent users of public transport services in rural areas. Indeed, school transport is a major revenue source for public transport in rural areas, and many schedules and routes reflect this. Nevertheless, the number of students is on the decline. If this demographic trend continues, an important source of funding for rural public transit could dry up. Given this current situation, it is time to rethink and redesign rural mobility. Current demand for regular bus service can be met by using smaller vehicles instead of larger (but mostly empty) coaches. Such vehicles could be used flexibly on demand and deploy smart routing systems to improve existing services. For instance, advancing already existing dial-a-ride services based on digital technologies would be a more efficient way of handling lower demand for school transport while increasing public interest in new transport services. What is more, it would keep costs down when demand is low. In areas with low demand and high operating costs, an alternative like this would improve mobility for rural residents and safeguard the budgets of transport companies.

Another prospect for the future of mobility in rural areas is the implementation of driverless cars. Once market-ready automated vehicles are available, they might represent an affordable and attractive way to expand public transport services even in low demand areas. Bookable anytime, anywhere, they provide most of the flexibility of owning a private car. A number of pilot projects and citizens' initiatives have also found that transport services such as bike- and carsharing are feasible if they reflect local demand, and that they are especially desirable for recreational trips.

Modes of transport used by urban and rural commuters — Figure 5



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URL: www.zeit.de/feature/pendeln-stau-arbeit-verkehr-wohnort-arbeitsweg-ballungsraeume. Last accessed on: 15.03.2017

Insight
05

Driverless vehicles are ideal for shared use.

Digitalisation is rapidly changing the transport sector. Today, it already influences which modes of transport are used and combined, which routes are taken and which mobility services are on offer. Nevertheless, as new trends such as automotion are just about to emerge, digital transformation still seems to be in its infancy. However, technological advances have the potential to make the transport sector much more climate friendly – yet tapping into this potential will require policymakers to adopt legal frameworks that promote beneficial changes in mobility behaviour. In the absence of the right policies, new mobility options, such as vehicle automation, could undermine the effort to reduce carbon emissions in the transport sector.

Thanks to automation, driverless cars are expected to operate more efficiently, travel closer to other cars and make traffic more fluid. This could help to reduce energy consumption and CO_2 emissions. A fleet of driverless vehicles, available on demand everywhere and at short notice, could lead to a fundamental reassessment of private vehicle ownership. A large-scale increase in shared vehicles would reduce the total number of vehicles on the road while also slashing carbon emissions in the transport sector. It would also give municipalities more room to determine land use and urban development. Automation is likely to have similar effects on transport in rural areas. Driverless vehicles have the potential to bring new transport options and improve mobility in less densely populated areas.

Vehicle automation will not necessarily lead to positive outcomes, however. For instance, it might inadvertently generate more traffic. Automated vehicle owners could program their cars to circulate in cities without any passengers in order to avoid parking fees. Alternatively, eliminating the burdens of driving may make people more willing to commute longer distances, as the time inside the vehicle can be used productively. It is also possible that individuals will shift from traditional forms of ecomobility to affordable door-to-door services provided by fully automated fleets.

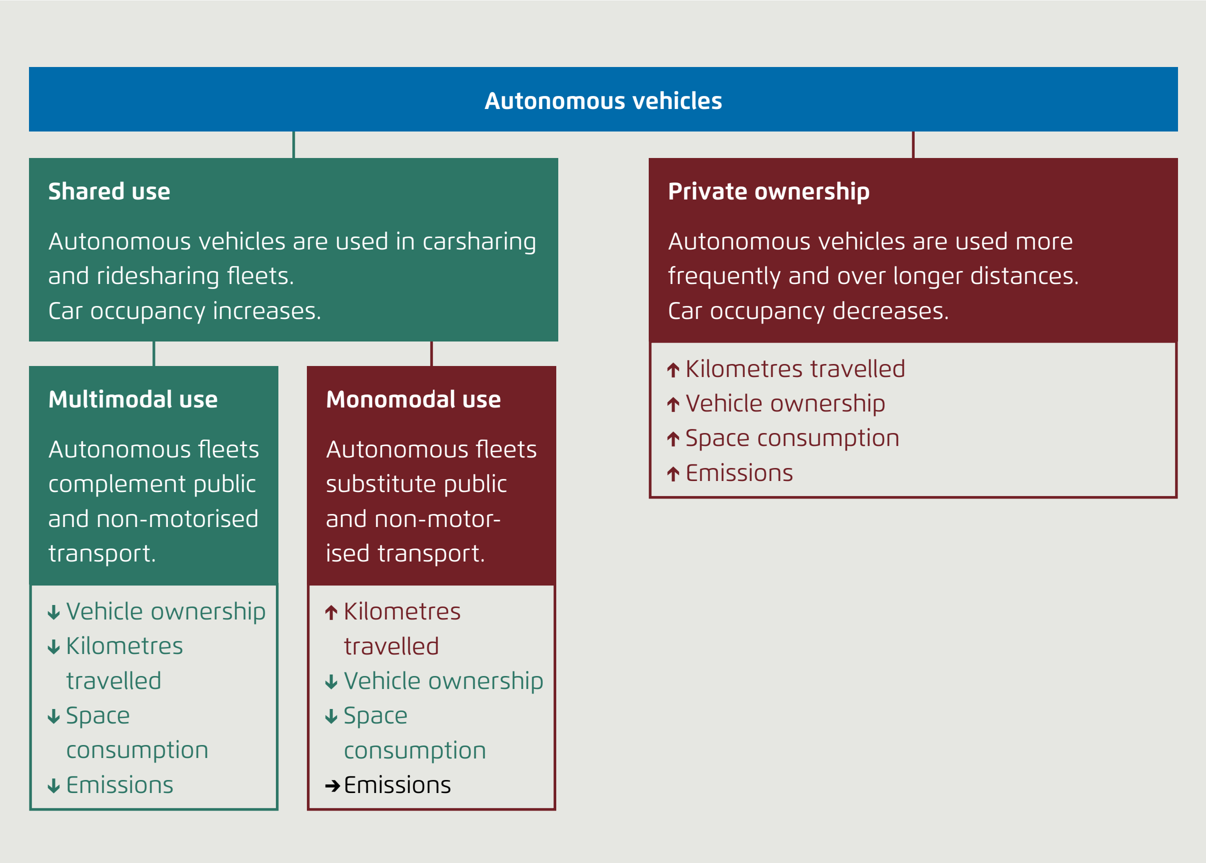
If today's mobility structures and ownership rates remain the same, then vehicle ownership and mileage statistics are likely to increase. Should a multimodal integration of driverless vehicles within a high-performance transport system succeed, the quality of mobility can be maintained or even increased without motorised private transport – not least because public transit will also benefit from increasing vehicle automation, becoming more efficient and convenient. The transport system of the future must include road and rail transport with intelligent infrastructure and traffic control systems (for road signs, parking spaces, light signals and the like). Combined with big data applications, such a system can guide traffic proactively while seamlessly linking multi- and intermodal trips. This can contribute to sustainable mobility behaviour and reduce traffic-related CO_2 emissions while also decreasing the need for traffic infrastructure. An undervalued benefit of a connected transport system is the new potential for shaping traffic policy. Dynamically priced low emission zones and toll systems that vary based on traffic levels, time of day, CO_2 emissions, air quality, and other factors could be used to steer climate friendly transport.

Smartphones are a key technology for the digitalisation of the transport sector. They are enabling and driving the development of collaborative mobility services, in part because of their GPS functionality. Smartphones make users part of a connected transport system that provides pertinent information about their mobility choices in real time. Smartphones can be used to link public transit to new mobility services – carsharing, bikesharing, ridesharing and so forth – and in this way promote the nationwide availability of integrated mobility. Many still underestimate the potential of smartphones for research and planning. The use of mobile devices enables the detailed analysis of mobility behaviour as well as needs-oriented traffic planning. As transport systems have been more automated and connected, questions related to the ownership, use and confidentiality of these data have become increasingly relevant. The answers to these questions will mainly decide on the trust and acceptance of users and the innovation potential of new technologies and mobility services.

Hence, the main objective must be to provide clear information to passengers, manufacturers and operators about how personal data will be used. For instance, users must be informed about the scope of data collection and use. The sharing of source maps, timetables, price information, real-time weather data and accident alerts would create a level playing field while promoting new, innovative mobility services. Public data availability and the use of big datasets could, in Europe alone, prevent 629 million hours of traffic jams. This could reduce energy use in motorised private transport by around 16% while generating economic savings of around 28 billion euros. To unlock the potential of transport data applications, the adoption of an Open Data law would set forth uniform standards while also assuring data availability at an online portal.

The development of innovative products and services often hinges on an ability to experiment with new solutions in real-world settings. In order to abet the rise of new mobility services, policymakers should rethink regulations in the transport sector. Not least, this could pave the way for partnerships between transport sector companies and new mobility service providers.

Usage forms and possible effects of vehicle automation — Figure 6



Authors' figure based on Michael Glotz-Richter

Insight

06

Electrification is key to an energy transition in transport.

Despite more efficient traffic planning and new mobility behaviour, reliance on motorised vehicles will remain high in the coming years. Accordingly, if the transport sector is to become essentially CO_2 free by 2050, traditional technologies must be replaced by alternative powertrain technologies. This is all the more necessary given the growing global demand for automobiles. By 2050, the number of vehicles on the road could increase from 900 million to around 2.4 billion. This trend is only compatible with current international climate targets if the share of emission-free vehicles increases considerably in passenger and freight transport.

German politicians understand the challenge. The 2050 German Climate Action Plan calls for the decarbonisation of the transport sector and for Germany to be a leading manufacturer of electric vehicles. Moreover, it aims to reduce the cost of hydrogen while improving its availability.

Various combinations of powertrain and fuel technologies are conceivable as part of the transition to carbon-free fuels. Electric vehicles are by far the most promising candidate for ushering in a clean transport sector. Battery electric vehicles (BEV) that are driven with wind and PV power are particularly advantageous because they use renewable electricity directly without transforming it into other forms, thus avoiding conversion loses. Indeed, battery electric vehicles represent the cheapest decarbonisation option with a view to energy efficiency and the supplemental costs that would result for the economy. The cost accounting on which this assertion is based takes into account all costs from today until 2050 for energy supply, petrol stations, charging station infrastructure and vehicle purchase.

Electrification can be a means of decarbonisation not only for passenger cars but also for light utility vehicles, particular for short trips in urban settings. Smaller trucks can use the same energy supply and powertrain concepts as passenger vehicles. Pure electric engines are now even a possibility for larger truck models. Beyond climate considerations, reducing noise and air pollution is an important motivation for the electrification of buses and light utility vehicles.

High purchase costs, concerns about limited ranges and a lack of charging opportunities are the main obstacles today that keep people from buying electric cars. The high purchase cost of fuel cell electric vehicles is a decisive impediment to their adoption, as is the absence of fuelling station infrastructure, which is a long way from covering the nation.

However, technological advances are likely to reduce the importance of these factors in the coming years. Battery prices and the associated costs for new electric vehicles are now expected to fall much more dramatically than predicted just a few years ago. At the same time, the costs for cars with internal combustion engines have been rising, due to stricter emission standards. Potentially electric car prices will be able to compete with traditionally powered vehicles somewhere between 2023 and 2030. Concerns about the range of electric vehicles may also prove unfounded. Several major car manufacturers have stated that by 2020 their vehicles will have ranges exceeding 400 kilometres.

For Germany to meet its ambitious carbon reduction targets of 40 to 42% relative to 1990 levels, as set forth by the 2050 Climate Action Plan, more than technological advances will be needed, however. The federal government must introduce effective and efficient policies to increase the market share of electric vehicles. Regulations must be robust yet open enough to permit innovation. At the same time, regulations must be geared toward feasible, effective and cost-efficient technologies.

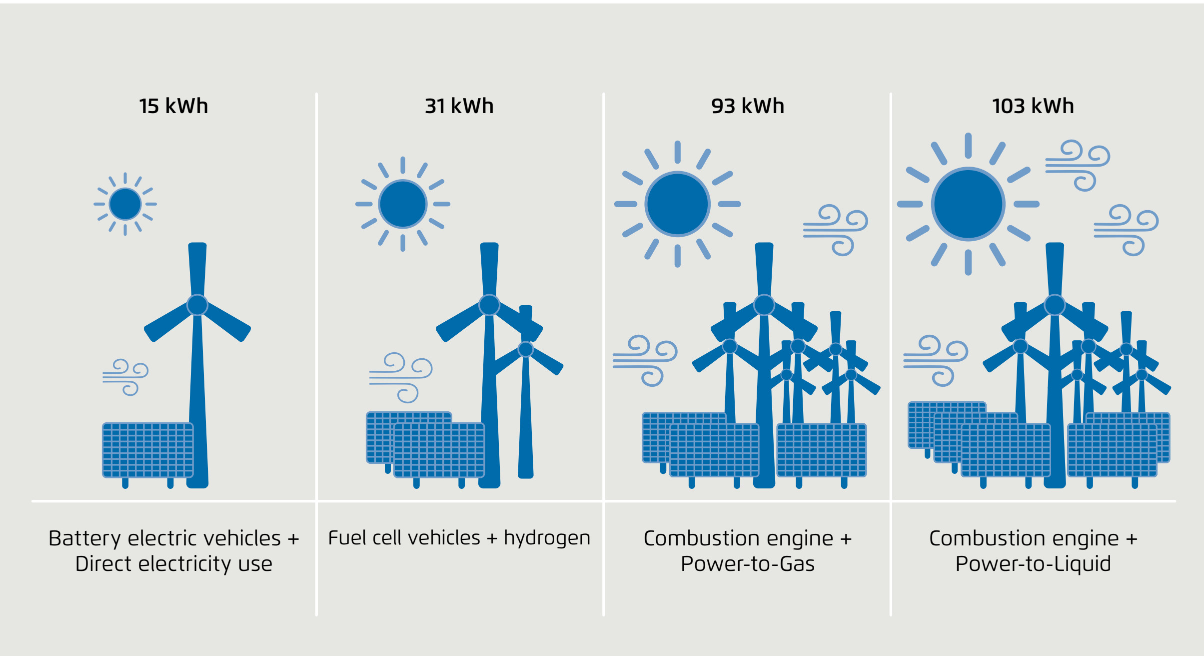
One way to get electric vehicles on the market more quickly is to tighten CO_2 standards for passenger cars and utility vehicles at the EU level. Should EU regulation not be enough for Germany to reach its climate targets in the transport sector, further national measures will be required. One strategy that could be considered is a reform of the motor vehicle tax.

The rapid expansion of charging infrastructure is another prerequisite for the adoption of electric vehicles, for commuters will hesitate to purchase an electric vehicle if they cannot charge it reliably. The establishment of a suitable nation-wide network of publicly accessible charging stations is the stated goal of the German federal government. In the long term, however, charging infrastructure should not rely on public funding alone. Policymakers should seek above all to provide a stable legal framework for private investment. This also applies to hydrogen fuelling stations, as fuel cell vehicles could play an important role in the future.

An additional challenge relates to the resource and environmental effects of alternative vehicles. Numerous raw materials needed for battery production – such as lithium, graphite and cobalt – are mainly mined outside of the EU. As a result, new import dependencies could arise. Production bottlenecks and the dominant market position of producer countries can have a major impact on battery prices. What is crucial is whether dependency on these resources can be reduced in the future and whether environmentally friendly and economic recycling techniques can be developed. In this way, the rise of electric vehicles must be accompanied by a comprehensive environmental and resource strategy.

When discussing the undesirable consequences of widespread electric vehicle adoption – e.g. battery disposal problems – it is important to keep in mind that "business as usual" with combustion engines and fossil fuels poses its own set of negative environmental and resource impacts.

Electricity demand of transport sector in relation to technology scenario (per 100 km) Figure 7



Authors' figure based on DLR et al.: Erneuerbare Energien im Verkehr, 2015, p. 15

Insight
07

Carbon-neutral fuels can supplement wind and solar energy.

The shift to alternative powertrains represents an important contribution to the decarbonisation of the transport sector, but it's not enough. For one reason, experts believe that ships and airplanes will continue to require liquid or gas fuels for the foreseeable future.

As the transport sector becomes increasingly decarbonised, vehicles must be powered directly by electricity from renewable sources or from liquids or gases converted from renewable electricity and from certain biofuels with low greenhouse gas emissions. Compared with fossil fuels, natural gas produces less CO_2 and thus has the potential to decrease GHG emissions, but this won't be enough for a thorough decarbonisation of the transport sector. Natural gas is only a bridge fuel, and must be gradually replaced by synthetic methane or other synthetic fuels.

The best option for powering the transformation of the transport sector is the direct use of electricity from renewables. Battery electric vehicles offer the greatest efficiency advantages. However, alternative fuels in liquid or gas form that are produced using renewables can serve as an important supplementary energy source, particularly in air and seaborne transport.

If the transport sector were decarbonised for the most part using electricity-based fuels (e.g. hydrogen, power-to-gas and power-to-liquid), power demand in the transport sector would greatly exceed Germany's gross power generation in 2016. A decarbonisation strategy that relied mostly on direct electricity would require less energy. But even in this case, electricity demand would be very high, consuming nearly all of Germany's current power production. Accordingly, the German government's development pathway for the expansion of renewables is unlikely to be sufficient. Two consequences can be drawn from this: First, the use of carbon-neutral fuels should be reserved only for modes of transport that are unable to use electricity directly. Second, while carbon-neutral fuels represent a necessary supplement to direct electricity use for individual modes of transport, they are not a practical option for every segment.

All evidence indicates that Germany will be unable to produce the additional electricity needed for a mass rollout of synthetic fuels. The expansion of wind turbines and photovoltaic systems has already reached the limits of public acceptance. Coupled with concerns about production costs, this is a sure sign that electricity-based fuels will also have to be imported. As a consequence, Germany must push for carbon-neutral renewable electricity both in and outside its borders. In this connection, sustainability standards should be drafted and internationally ratified as soon as possible. As of today, little is known about sustainable production capacities for these fuels, and commercial production is still being tested. This underlines the importance of using such fuels only when no alternatives are available. Recent experience with biofuels shows that underestimating sustainability can lead to an overly optimistic assessment of a fuel's potential.

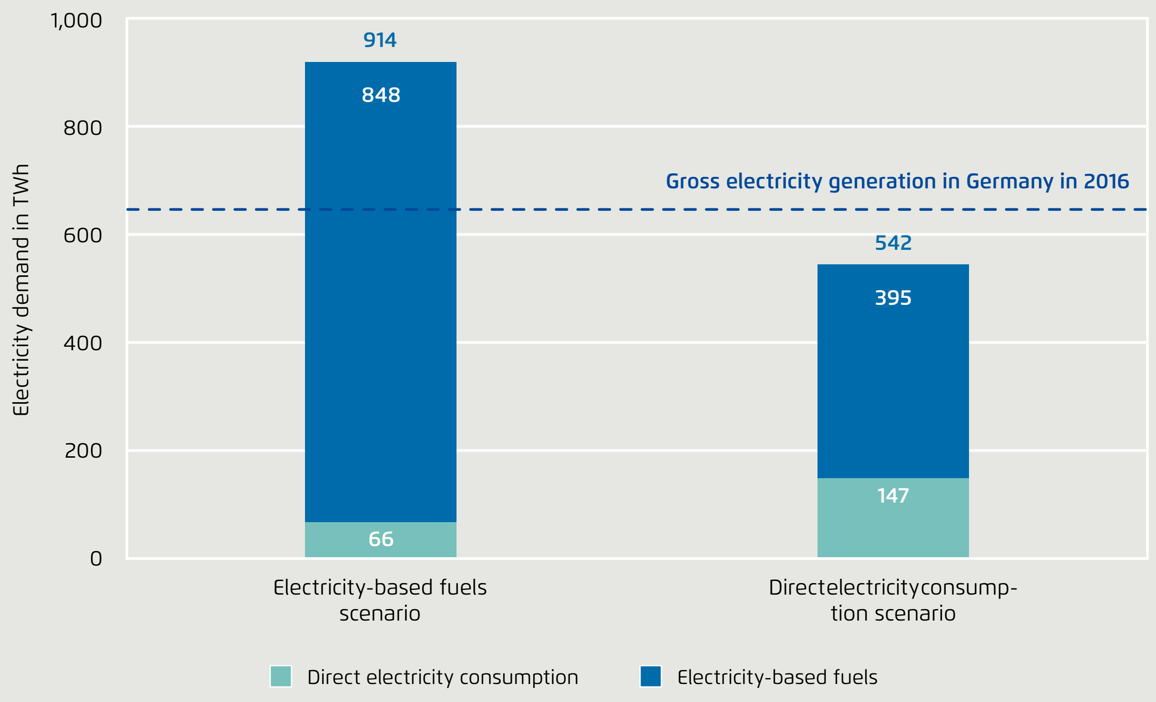
Biofuels are used in Germany as an additive in fossil fuels. The share of renewable energy in the final energy consumption of the transport sector in 2015 was just over 5%, with biofuels making up the largest share. If they are to contribute to the complete decarbonisation of transport sector, their production will have to ramp up considerably without undercutting essential environmental and sustainability goals. From today's perspective, however, this does not seem realistic. Their large land requirements and low efficiency both undercut potential benefits.

Biofuels from cultivated biomass offer neither the quantity nor quality of energy needed to represent a viable alternative to fossil fuels. Biofuels from waste and residual products are different from biofuels from cultivated biomass in that they do not compete with agricultural land for human food and livestock feed. Globally, second-generation biofuels from agriculture and forestry waste products will only be able to cover a small fraction of energy demand in the transport sector.

Biofuels, carbon-neutral fuels and hydrogen all raise problems as a potential source of propulsion energy. Each one raises questions related to infrastructure, technology support schemes, import dependencies, production potential and economic costs. These issues must be analysed as part of the energy transition in transport in order to identify comprehensive strategies and to minimise the societal costs of switching to climate-neutral fuels.

More coherent legal frameworks are an additional requirement for the replacement of fossil fuels with electricity and climate-neutral fuels. For example, tax on diesel is 18.41 euro cents per litre less than tax on gasoline, even though the combustion of 1 litre of diesel emits more CO_2 than a litre of petrol (2.65 kg versus 2.37 kg). The oft-cited benefits of diesel for the climate are entirely because diesel engines are more efficient than petrol engines. The uniform taxation of diesel and petrol based on its energy and CO_2 levels would be an important first step towards the complete replacement of fossil fuels with climate-neutral electricity.

Electricity demand of transport sector (including international air travel from Germany and sea travel with German ports) in relation to decarbonisation strategy — Figure 8



Authors' calculations and figure based on Öko-Institut: Renewability III, p. 20, and AGEB: Stromerzeugung nach Energieträgern 1990–2016. URL: www.ag-energiebilanzen.de/index.php?article_id=29&fileName=20170811_brd_stromerzeugung1990-2016.pdf

Insight

08

The freight sector needs an improved rail system and climate-neutral roads.

The freight transport sector is growing, and with it, CO_2 emissions. Freight traffic now accounts for just over one-third of emissions in the transport sector. The decarbonisation of freight traffic can be achieved only if final energy demand drops significantly and fossil fuels are replaced by wind and solar power and by carbon-neutral fuels.

Rail freight is less energy intensive and more environmentally friendly than road freight. Accordingly, we should encourage a shift from roads to rails in freight transport. For this to occur, however, advances are needed in rail logistics, infrastructure, financing and noise abatement.

Due to the dominance of just-in-time production processes, many companies today are no longer able to fill an entire train with goods. High demand for single-wagon transport encourages combined transport and wagonload freight, in which cars and wagon groups are put together at railroad yards. This bundling is still too expensive and slow compared with road transport. However, automation and digitalisation can decrease costs, increase efficiency and make rail traffic a more appealing option. Companies without their own direct rail connections must rely on logistics centres. These centres enable intermodal transport chains based on flexible combinations of wagonload freight.

The growth potential of rail is large, yet existing capacities must be better used by expanding the rail system and avoiding hub bottlenecks. Top priority should be assigned to enlarging the main corridors that lead from the ports along the German North Sea and in Antwerp, Rotterdam and Amsterdam.

One reason why more freight traffic hasn't shifted from roads to rails is the uneven cost burden. This is particularly visible in the differences in fees levied on rail lines and trucks and in taxes on electricity and diesel.

Although railways are better for the environment than road transport, they must be made better still. The electrification of rail lines is a key challenge. Only 59% of rail lines are electrified at present; this figure needs to be increased. If good arguments speak against electrifying certain sections of track (for example, because they are used infrequently), hydrogen- or battery-powered trains are good alternatives. The public acceptance of freight lines can be improved significantly if trains are equipped with modern braking systems that make rail traffic much quieter.

Even if rail capacity in Germany increases markedly and all goods suited for rail are carried by rail, current growth forecasts predict that by 2050 rail freight will make up no more than 30% of Germany's total freight transport (in tonne-kilometres). A complete decarbonisation of freight traffic will require a significant shift from road transport to railways together with the development of efficient, carbon-neutral trucks.

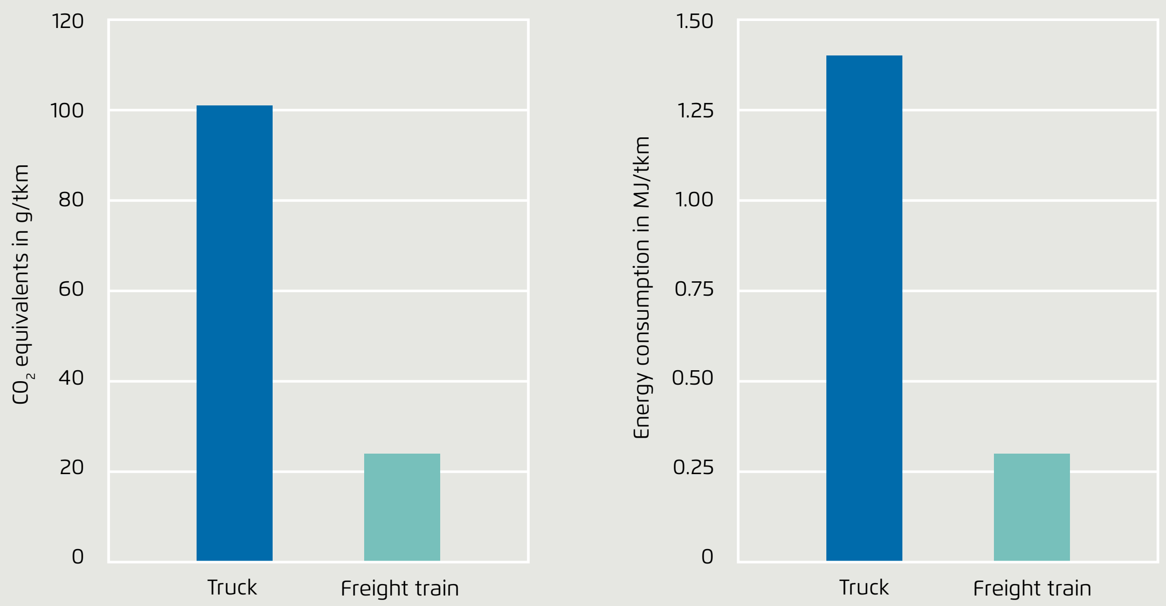
The clean-energy propulsion option that will dominate heavy long-haul trucking is still unclear. Until we know which technology will come out on top, we should take advantage of the various options for making trucks more efficient, including better powertrains, better aerodynamics, less rolling friction, lighter construction, speed limits and optimised auxiliary consumers. By introducing these and other measures – including in particular binding CO_2 targets for trucks – semi-trailer trucks could be made up to 40% more efficient. In the future, additional efficiency gains might be obtained through platooning (i.e. the coupling of multiple semi-autonomous trucks on highways or when trucks align in a close group to reduce wind drag).

As with passenger cars, the most efficient and economical option for decarbonisation is the direct use of electricity from sun and wind. However, despite technological improvements, batteries in 2050 will be unlikely to deliver the ranges typically required in long-distance freight traffic. This limitation can be overcome with hybrid trucks that run on overhead contact lines as well as carbon neutral fuels. However, overhead lines would need to be installed internationally to enable cross-border freight traffic.

From a macroeconomic perspective, the most affordable option is to combine overhead contact lines with carbon-neutral P2L diesel and/or batteries for sections of road outside the overhead system. The largest difficulty consists in the coordination of international funding and in the construction of a Europe-wide overhead contact line infrastructure. By contrast, a solution with P2L diesel as a drop-in fuel would face fewer obstacles to implementation.

Trucks powered by liquefied natural gas (LNG) that can use liquefied P2G methane in the future offer both opportunities and risks for the transformation of the transport sector. While LNG trucks produce fewer emissions than their diesel counterparts, natural gas is a fossil fuel and, as such, can at most serve as a bridge technology. However, if liquid natural gas were to be replaced at some point with P2L methane, then these vehicles could make a significant contribution to reducing emissions. In any event, investment in LNG vehicles and fuelling stations will lower the chances of implementing fuel cell solutions in electric vehicles and hybrid trucks that rely on overhead lines. The questions surrounding LNG show that the German federal government and the EU Commission must develop a harmonised European policy.

Comparison of specific emissions and energy consumption of trucks and freight trains in 2014 Figure 9



Authors' figure based on Umweltbundesamt: Vergleich der durchschnittlichen Emissionen einzelner Verkehrsmittel im Güterverkehr. URL: www.umweltbundesamt.de/themen/verkehr-laerm/emissionsdaten. Last accessed on: 02.02.2017

Insight
09

The power system and transport sector benefit from sector coupling.

Electricity from wind and solar power is projected to become the main energy source for future transport. But national CO_2 emissions will decrease only if additional amounts of renewable electricity are generated. Accordingly, it is crucial for the clean-energy transition to keep pace with the transformation of the transport sector.

Current scenarios predict that by 2050 electricity demand in the transport sector will increase significantly. The amount of demand growth actually witnessed will depend in no small part on the extent to which electricity is used to produce synthetic fuels. Given the upper limits to the volume of renewable energy that can be generated in Germany, it appears likely that Germany will become reliant on imports of electricity and/or electricity-based fuels.

Due to the increased demand for electricity in the transport sector, overall electricity consumption in Germany will tend to increase rather than decline. Against this backdrop, the German government's targets for reducing power consumption appear unrealistic. By 2050, the German government hopes to reduce electricity consumption by 25% (over 2008) while also increasing the share of renewable energy in the power mix to 80%. These goals are incompatible with the additional demand projected for the transport sector. Clearly, the expansion of renewable energy needs a significant boost if climate targets for 2050 are to be met.

The growing share of renewables in the power mix is increasing the need to make the consumption of electricity more flexible. Smart charging and bidirectional charging are two ways to promote improved coordination between supply and demand. Smart charging and bidirectional charging can also promote the closer integration of the transport and power sectors (this integration is referred to as "sector coupling" in German). This will enable power demand in the transport sector to be more closely aligned with the expansion of power generation capacity.

The power system will benefit from smart charging if charging takes places when additional supply is available and, more importantly, when power can't be transported elsewhere because of limited power grid capacity.

In the case of bidirectional charging, energy is fed back into the grid from an electric vehicle's battery. While bidirectional charging is already technically feasible today, we still lack viable business models for its commercial implementation. Bidirectional charging converts electric vehicles into temporary batteries, providing energy when wind and solar power are in short supply and demanding energy when there is excess production. As this technology is developed further, it will be important to ensure that bidirectional charging does not harm vehicle batteries. Furthermore, it is important for planners to make sure that newly installed charging infrastructure is compatible with the use of this technology.

A clear technical and legal framework should be established so that power providers and grid operators can create commercial incentives for customers to engage in charging behaviour that is beneficial to the power system. Furthermore, there is a need to expand power distribution grids while keeping future requirements for quick charging stations in mind.

A disadvantage of creating cost incentives for charging at specific times of day is it can lead to increased demand at night for cheap electricity from lignite-fired power plants, which are heavy emitters of CO_2. This problem illustrates the importance of ramping up renewable-energy capacity installation while also reducing coal-based power production.

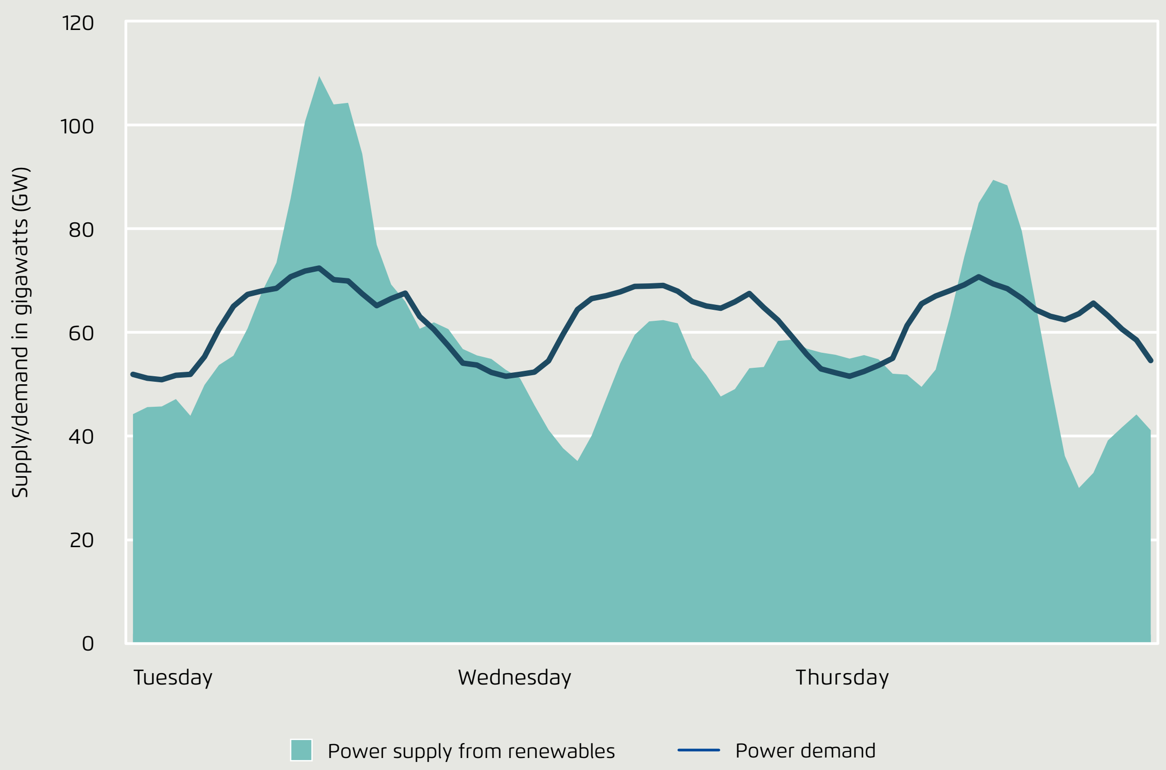
Home battery units charged by roof-top solar panels are another option for overnight charging and for decreasing dependence on conventional power plants. The energy stored in batteries at home can be used to partially charge electric vehicles overnight. (Even partially charged batteries can be an important factor for the short distances cars typically travel on any given day.)

Household generation of power using rooftop solar is an appealing option for many people and can help to speed up the energy transition in transport. In the future, second-life batteries – batteries whose performance no longer suffices for supplying propulsion energy to vehicles (their original purpose) – could be used in households. Currently, however, there are no economic policies or regulations governing the use of second-life batteries in households.

Another storage option for flexibility is the production of hydrogen using excess power. Hydrogen can then be used directly or converted into methane or liquid fuel for vehicles. Once Germany's energy transition has reached a point where renewable energy is the principal source of power, reconversion from stored hydrogen could be used to balance out seasonal differences in electricity production. This can be crucial on days or during weeks when neither wind nor solar power supply sufficient energy levels.

With existing technology, however, the total efficiency of hydrogen production, storage and reconversion amounts to no more than 40%. One additional point to consider is that, in a post-fossil economy, the chemicals industry will also require large quantities of hydrogen and carbonated compounds such as electricity-based methane.

Scenario for power demand and generation in 2030 — Figure 10



Authors' calculations and estimates performed by Agora Energiewende

Insight
10

Rethinking the development and financing of transport infrastructure.

The transport infrastructure of the future won't just consist of roads, railways and bridges. It will also include electric vehicle charging points, filling stations for alternative fuels, and various types of digital infrastructure, including widely available high-speed internet. Decisions concerning future infrastructure investments have the potential to accelerate the transport transformation, or, alternatively, to entrench the existing transport system, which will make charting a new path even more difficult and expensive. There are two main challenges in this area: (1) to convert and maintain infrastructure such that costs are fairly distributed in line with environmental and social criteria; and (2) to find sources of financing that can make up for falling revenues from fossil-fuel and vehicle taxes.

The 2030 Federal Transport Infrastructure Plan (BVWP) is in urgent need of reform for Germany to meet its emission reduction goals. In its current form, the BVWP will only lead to annual CO_2 reductions of 0.4 million tonnes, yet reductions of 4.7 million tonnes are needed to adhere to the German government's 2050 carbon abatement targets. Accordingly, we believe the BVWP should be part of a transport transformation policy that takes economic, ecological and social factors into consideration while setting forth comprehensive measures for ushering in a transformation of the transport sector by 2030. In order to ensure public support, the development of this policy should enable the participation of the citizenry while also seeking to transfer decision making responsibility to the local level. This will undercut tendencies for the development of infrastructure projects of excessively large size.

The planning of transport infrastructure should be informed by the principle of "rail before road". When planning road infrastructure, alternatives to new construction or expansion should be considered to a greater extent. During planning a key priority should be given to the "big picture", including the integration of European-wide networks, as well as spatial and regional planning issues.

In this way, rail transport in combination with shared and multimodal mobility solutions will be important components of the transport infrastructure of the future. Yet we will also need new digital infrastructure, charging points for electric vehicles, and alternative fuel filling stations. The government will need to coordinate the widespread deployment of infrastructure for the charging of electric vehicles while also ensuring adherence to technical standards. In this regard, regulators will need to adopt common standards for cables and plugs while also ensuring an open market for competition and transparent billing methods.

The establishment of universal standards for the installation of overhead wires and hydrogen fuel infrastructure for heavy long-haul trucks is also likely to be an important issue. As part of the implementation of the EU Directive for the Deployment of Alternative Fuels Infrastructure, policymakers should consider whether it is expedient to provide subsidies for several alternative fuel types at the same time.

The expansion of digital infrastructure represents a cornerstone of the transport transformation. The widespread availability of high-speed broadband and mobile internet as well as the adoption of the 5G mobile internet standard will be an important springboard for propelling technology-based innovation in the transport sector. In particular, ubiquitous high-speed internet will help to enable semi-automated transport solutions, which could become fully automated at a later date. IT technology offers incredible latent potential for the transport sector, provided it is used in an intelligent way that conserves natural resources. An important insight is that dynamic control systems such as self-driving cars require reliable, real-time data transfer.

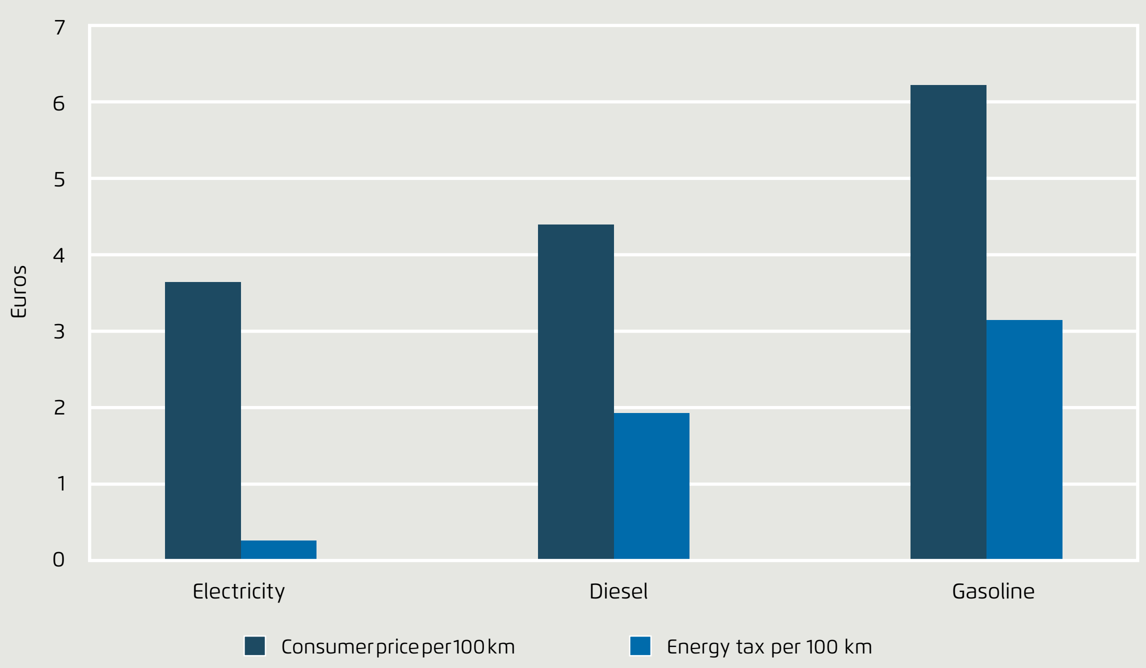
Among other things, infrastructure that is designed for connectivity would allow intelligent pricing systems for road use, enable the calculation of optimal routes based on one or several forms of transportation, and ease the scheduling of shared vehicle use. However, the potential offered by advanced IT systems can only be fully exploited if existing transport infrastructure such as traffic lights, traffic signs and public parking spots become more intelligent and are embedded in larger networks. Policymakers have a responsibility for enabling non-discriminatory access to electric-vehicle charging points and alternative-fuel filling stations.

Today, public investment in transport infrastructure is financed with proceeds from energy taxes. However, energy tax revenues are set to shrink with each passing year as the energy transition in transport continues and fossil fuel consumption declines. Accordingly, adequate funding for infrastructure projects is not assured over the long term, and new solutions for infrastructure financing need to be explored.

There are various arguments in favour of increasing the use-based financing of transport infrastructure as an alternative to the existing tax-based system. To support the transition to sustainable transport, we advocate the adoption of a toll that would be collected based on kilometres driven. We believe toll levels should be designed to reflect the externalities and infrastructure costs generated by each specific vehicle. Tolls should be variable in time and space in order to promote more efficient traffic flows. Furthermore, the toll system should be designed in a cost-effective way while also providing for reliable data security.

The expansion of electricity infrastructure has been financed to date with the so-called EEG levy and grid usage fees. Both of these surcharges are components of the electricity price, and they are primarily paid by household consumers. Road users who rely on fossil fuels do not make a contribution to the expansion of electricity infrastructure with their vehicle use. Additional research and debate are needed to clarify whether current burden-sharing arrangements for power-system financing should remain unchanged, or whether the overall system of taxes and levies for the transport and power sectors needs to be reformed.

Consumer prices and energy taxes per 100 km by automobile fuel source — Figure 11



Authors' figure (Consumption based on manufacturer's data of basic variant of VW Golf 02/2017 (12.7 kWh, 4.1 l, 4.8 l), www.volkswagen.de; energy tax, www.zoll.de; 2016 consumer electricity price, www.strom-report.de; 2016 diesel and gasoline consumer price, www.mwv.de)

Insight
11

The transport transformation can strengthen German industry.

The political goal of decarbonising the energy and transport sectors is closely associated with a technological revolution in the automobile sector. Indeed, the reign of the internal combustion engine appears to be coming to an end. The recent wave of innovation in the area of electric vehicles is being driven by numerous factors: alternative powertrain technologies have reached a state of market readiness; digitalisation is opening new doors in the transport sector; and in large cities, a growing number of people are now interested in driving cars without necessarily owning one.

These trends are having significant economic effects, particularly for Germany's export-oriented automobile industry. German companies will only be able to remain at the vanguard of the automotive industry if they lead the way in the decarbonisation of powertrain technologies and in the development of new mobility services. In a nutshell, German companies need to embrace the future and proactively shape it, rather than being forced to belatedly adapt in a reactive sense.

The German automobile sector's success in defending and expanding its international market shares will have direct impacts on domestic employment levels. We can expect the greatest number of jobs to be lost if the speed of structural change exceeds the ability and/or willingness of the automotive sector to adapt. Business and political leaders have been devoting particular attention to the manufacturing of powertrain technology, which currently employs some 250,000 workers domestically. The speed at which new powertrain technologies replace the internal combustion engine will be a critical determinant of the future of these jobs. While the structural changes that will be unleashed by the energy transition in the transport sector are not yet fully understood, it is clear that the production of electric powertrains is less labour intensive than the production of combustion engines and traditional gearboxes. It appears reasonable to assume that the negative employment effects associated with policy intervention to guide the transition to sustainable transport would be less severe than the consequences of being left behind in the international race to adopt new transportation technologies. This race is already underway in markets around the world, particularly in China. Against this backdrop, it would appear the greatest risk to German industry is posed by efforts to maintain the status quo.

The rise of electric vehicles is not only relevant for automobile manufacturing. Oil companies could begin to suffer earlier than expected from the success of battery electric vehicles. While new jobs will be created for the expansion and maintenance of power infrastructure and the production of electricity-based fuels, cost factors and public-acceptance issues suggest that alternative fuel production will primarily occur in other countries.

Economic effects will also result from changing patterns of mobility as part of the mobility transition: motorised transport will decrease while shared mobility and self-driving vehicles become more prevalent. For example, a recent study estimates that shared mobility and associated connectivity services and features could expand automotive revenue pools by some 30 per cent by 2030, or by 1.5 trillion dollars. This would have salubrious effects on employment.

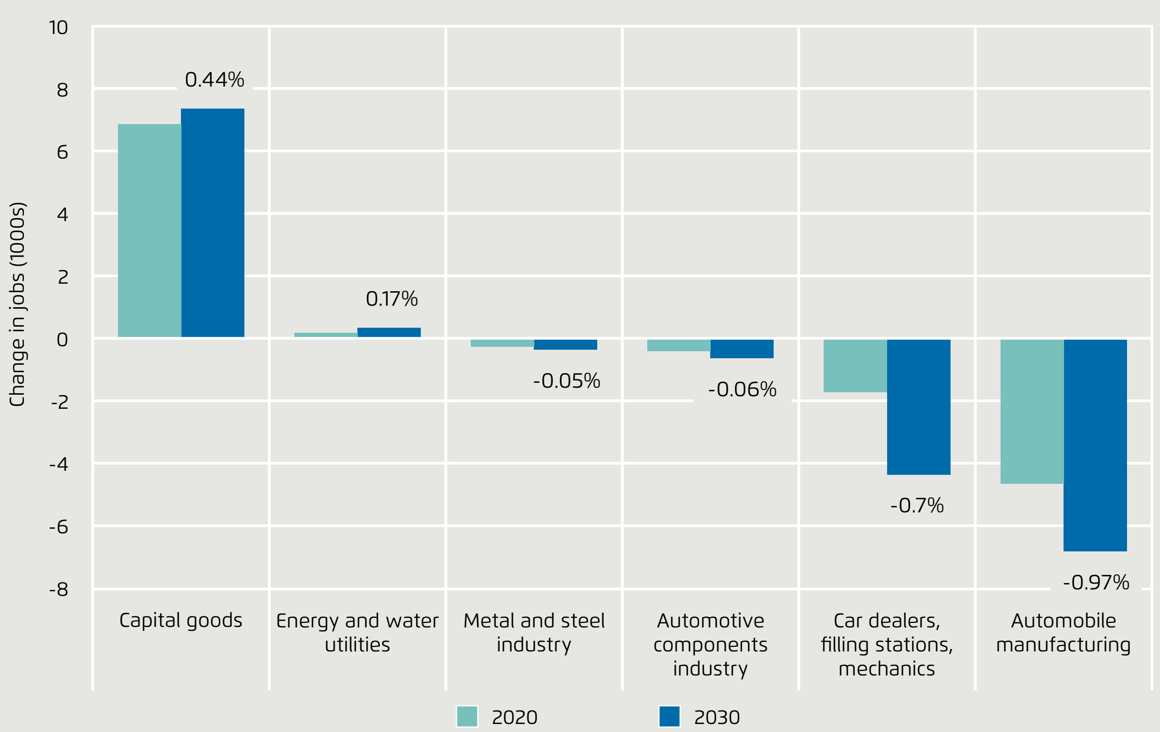
By contrast, self-driving vehicles could have a negative impact on employment levels. In particular, they have the potential to eliminate jobs in the freight, taxi and public transport industries. More than 83,000 people are employed as public transportation drivers in Germany.

The macroeconomic effects of the transport transformation will depend on a range of additional factors that are difficult to estimate at present. A particularly decisive role will be played by how the total cost of mobility develops over time; the effects to consumer spending and savings rates that arise from higher or lower individual transportation expenditures; and the effects resulting to supply chains and trade relationships from technological innovation and associated behavioural adaptation.

Considering the degree to which the automotive sector is intermeshed in capital markets, we can expect significant financial-market consequences to result from how the automotive sector meets the challenges of climate change. By the same token, the importance attached to climate change by financial market actors could have crucial impacts on the business strategies pursued by automotive manufacturers. Financial analysts typically draw conclusions by examining cyclical patterns in historical data. Accordingly, they fail to systematically account for the risks posed by climate change. And to the extent that their risk estimates fail to account for a warming planet, they are necessarily subject to a significant margin of error. In this way, scientists, policymakers and financial market regulators have a responsibility to communicate the risks of climate change to investors.

Nevertheless, financial market actors are becoming more aware of the risks to their investments that emanate directly from climate change as well as from associated regulatory policies. To an increasing extent, investors have been taking an active role in the management of the companies in which they are invested in order to promote adaptation to climate change. As atmospheric carbon concentrations continue to rise, we can expect investors to devote even more attention to which companies have a dim future in a warming world. In coming years, for example, we can expect investors to increasingly withdraw from holding investments in oil, gas and coal companies. Divestment can also be expected in companies that do not extract or process fossil fuels but which are highly dependent on the fossil fuel industry. The automotive sector is particularly exposed to this risk. If individual manufacturers choose to cling to their existing business models, they will become increasingly vulnerable to changes in investment behaviour that is motivated by an awareness for climate change.

Employment effects of the energy transition in transport* — Figure 12



Ulrich, P.; Lehr, U.: Economic effects of E-mobility scenarios, Ecomod 2016, p. 9;

*Deviation from scenario with expedited adoption of electric vehicles (2030: 6.1 million electric vehicles in fleet) compared to base scenario (2030: 3.2 million electric vehicles)

Insight
12

The transport transformation will be driven by its benefits to society.

In recent decades a wide variety of efforts have been made to augment the benefits and mitigate the harms associated with transportation. However, it has not been possible to reduce the negative externalities of the transport sector to the degree hoped for by many. To name a few examples: More than half of Germany's population feels burdened or bothered by traffic noise; the concentrations of pollutants produced by vehicle emissions exceed legal requirements in many places; and the number of traffic accidents reached a new high in the history of Germany in 2015.

The transport sector deserves closer scrutiny, as it has failed to make a net contribution to the reduction of Germany's greenhouse gas emissions over the last quarter century. While there are many reasons for this, one particular problem is particularly relevant: Millions of people are responsible for producing emissions, which greatly diminishes the relative responsibility borne by the individual. In addition, at least in Germany, the consequences of global warming are difficult to recognise, or can only be imagined as part of a distant future. This undermines public support for policies to curb carbon emissions.

However, the transformation of the transport sector can create direct and near-term benefits for the individual. In our view, the directly experienced benefits of policies to promote carbon-neutral energy and sustainable mobility behaviour will become an important driver of the transformation. Clearly, the transport transformation offers greater benefits than just climate protection. Emissions-free vehicles improve air quality, thus reducing pollution impacts to human health. Electric vehicles are also considerably less noisy than automobiles with internal combustion engines. Less noise means less stress, and, by extension, lower long-term health risks such as cardiovascular disease. Fewer airborne toxins, less noise pollution and improved traffic safety would enhance quality of life in urban areas. Furthermore, by closely interlinking various transportation options, it will become easier for the individual to forego personal vehicle ownership, including the fixed costs such ownership entails.

The directly experienced benefits of transforming the transport sector will augment public support for the policy interventions designed to promote its advancement. Ultimately, the transformation of the transport sector should have direct benefits for a range of societal actors. Both the public and private sectors stand to benefit, as does the general public, who will experience how transportation is becoming safer, healthier and less stressful.

However, public support for the changes that are required cannot be imposed from above by law or dictate. We must recruit the active support of the entire populace with rational and enlightened dialogue.

The need for collective action is particularly pronounced in the area of sustainable transport, as change will be required in the daily routines of millions of people. The success of this effort will hinge on the active support of everyone, from political and business elites down to the common citizen. New organisational structures will need to be established at the local, national and international levels.

To be sure, the effort to remake the transport sector is a broad-based transformational process that will be ongoing for multiple decades. This process will necessitate robust and reliable regulatory conditions that are not called into question after each new election. Indeed, if policymakers display a flagging commitment to the overarching goal of transforming the transport sector and cannot commit to reliable subsidy conditions for business, this would critically undermine the ability of the private sector to make long-term investment decisions. Accordingly, it is imperative that policymakers present a clear roadmap and fully commit to undertaking the journey.

The government commission tasked with studying the future of nuclear energy in the wake of Fukushima recommended the creation of a National Energy Transition Forum. Such an organisation is still waiting to be established. Heeding this recommendation would provide a valuable boost to transport transformation.

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In partnership with key players in the field of politics, economics, science and civil society, Agora Verkehrswende aims to lay the necessary foundations for a comprehensive climate protection strategy for the German transport sector, with the ultimate goal of complete decarbonisation by 2050. For this purpose we elaborate the knowledge base of climate protection strategies and support their implementation.

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