Agora Verkehrswende

Transforming Transport to Ensure Tomorrow’s Mobility

12 Insights into the *Verkehrswende*

Impressum

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 (long 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.

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

Given the rapid changes to transport technologies, these 12 insights will no doubt need revising over time. Who three years ago could have expected electric 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.

Christian Hochfeld
Executive Director of Agora Verkehrswende on behalf of the entire Agora Verkehrswende team
Berlin, 28 March 2017

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Intro-
duction

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

Transportation shapes everyday life like almost nothing else. It allows people to commute to work, do errands, visit friends and family, and explore new cities and countries. It enables participation in social life, and also fulfils an essential economic function. Without it, people wouldn't be able to buy products from distant countries or sell their own abroad. And while globalisation has created problems, on the whole it has brought people closer together. Transportation has been an essential enabler in this process.

For all its benefits, transportation can have negative impacts on human health and quality of life. It creates noise, generates pollution, takes up space, and scars the landscape. Back in 1973, the German Advisory Council on the Environment said so much in its very first report, concluding that "transportation can do more harm than good" for the general public.[1]

This insight still applies today, both in Germany and other countries. 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 failed to contribute in absolute terms to reaching the German government's climate and clean-energy targets. Indeed, clean-energy policies have had little impact on the transport sector: final energy consumption is on the rise; CO_2 emissions have stagnated at high levels; dependency on oil is increasing; and new technologies have yet to take hold.

It is now apparent that emissions in the transport sector will decline little, if at all, over the coming years. This means that Germany is very likely to fall short of its national climate targets for 2020. And if the trend continues, Germany will be unable to honour its commitments under the 2015 Paris Agreement, which seeks to limit global warning to within 2 °C above pre-industrial levels.

1 See SRU (1973), p. 1.

The transport sector has yet to join the fight against climate change

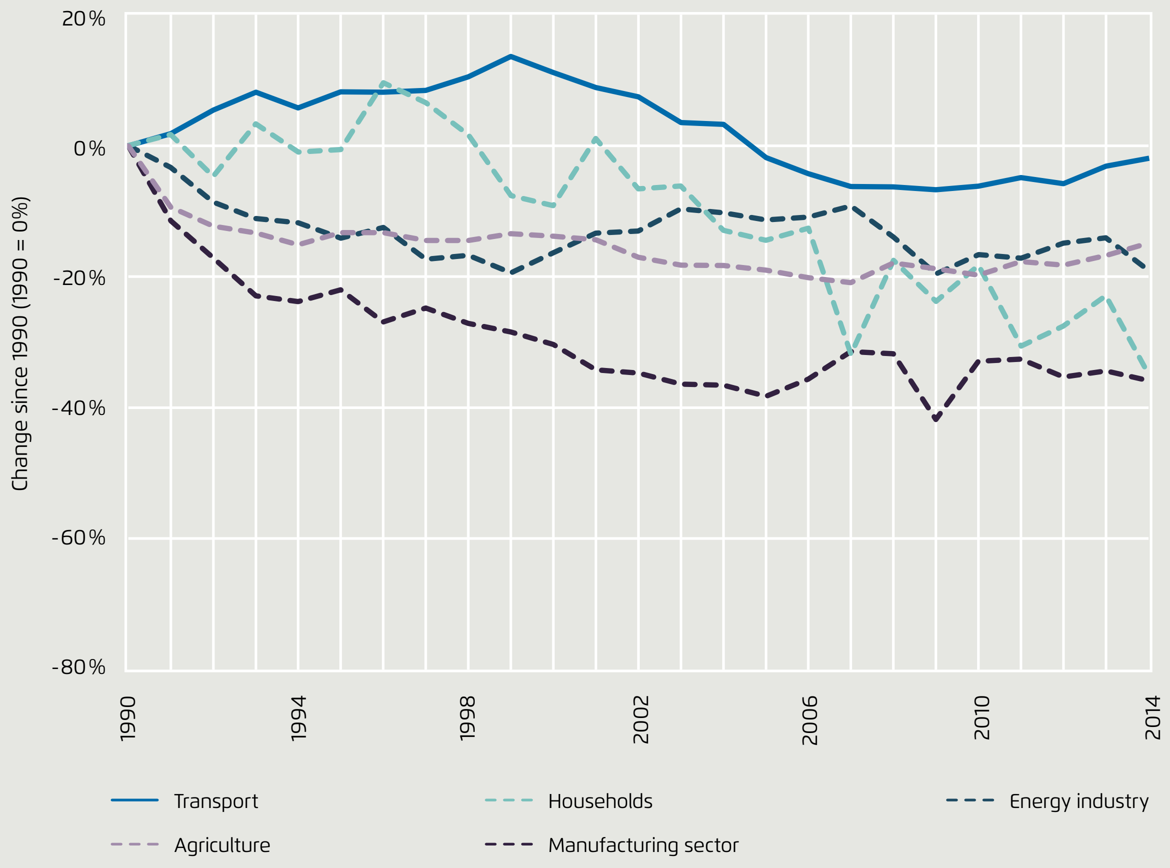
After the energy industry, the domestic transport sector is the largest emitter of greenhouse gases (GHG) in the German economy. Between 1990 and 2016, Germany's GHG emissions sank from around 1.251 billion metric tonnes of CO_2 to 906 million metric tonnes, or around 345 million metric tonnes. During this same time frame, emissions in the transport sector rose continuously save for a short period of decline after 2000. At 166 million metric tonnes, the current level of emissions in the transport sector is 3 million metric tonnes higher than in 1990. What is more, the share of national GHG emissions produced by the transport sector has risen from about 13% in 1990 to 18% in 2016 – an increase of roughly one-third.[2]

This rise is mostly attributable to cars and trucks, the chief means of transporting goods and passengers in Germany today.[3] Together, they are responsible for almost all CO_2 emissions and air pollutants generated from road transport.[4] The German Environment Agency (Umweltbundesamt, or UBA) estimates that in 2014 alone road transport caused 52.2 billion euros' worth of damage to the environment when also factoring in noise pollution and land use costs.[5]

All the while, the volume of traffic has continued to rise. Between 2005 and 2015, the number of passenger vehicles on the road increased by 8% and the number of trucks rose by some 14%.[6] The amount of air pollutants emitted into the atmosphere, while falling in absolute terms, is still harmful to human health,[7] and total CO_2 emissions have remained nearly constant despite the introduction of cleaner and more efficient motors. By contrast, private household emissions have declined

2 This data is based on UBA (2017a) and UBA (2017d).
3 See BMVI (2016a), p. 221 f. and p. 246 f.
4 See UBA, Emissionen des Straßenverkehrs in Tonnen 2014, Tremod, p. 63.
5 UBA (2016f), p. 36.
6 See BMVI (2016a), p. 218 f. and p. 244 f.
7 See UBA (2016e).

Relative change in greenhouse gas emissions since 1990 by category — Figure 0.1



Authors' figure based on UBA (2016c), p. 73

even as living space has increased.[8] The same goes for emissions from manufacturing, which have fallen despite a boost in production output (figure 0.1).

The statistics for energy consumption also paint a picture of a transport sector out of sync with national trends. In 2015, Germany's total energy use was around 6% less than in 1990. Improvements to industry and manufacturing during the decade after German unification were largely responsible for this drop, with households making up most of the difference in later years. By contrast, the transport sector today consumes 10% more energy than it did in 1990, 1% more than it did in 2005 and almost 2% more than it did in 2010. It is now responsible for roughly 30% of Germany's final energy consumption (figure 0.2). These numbers are at odds with federal government targets, which call for a 10% decrease of final energy consumption by 2020 and a 40% decrease by 2050 relative to 2005 levels.[9]

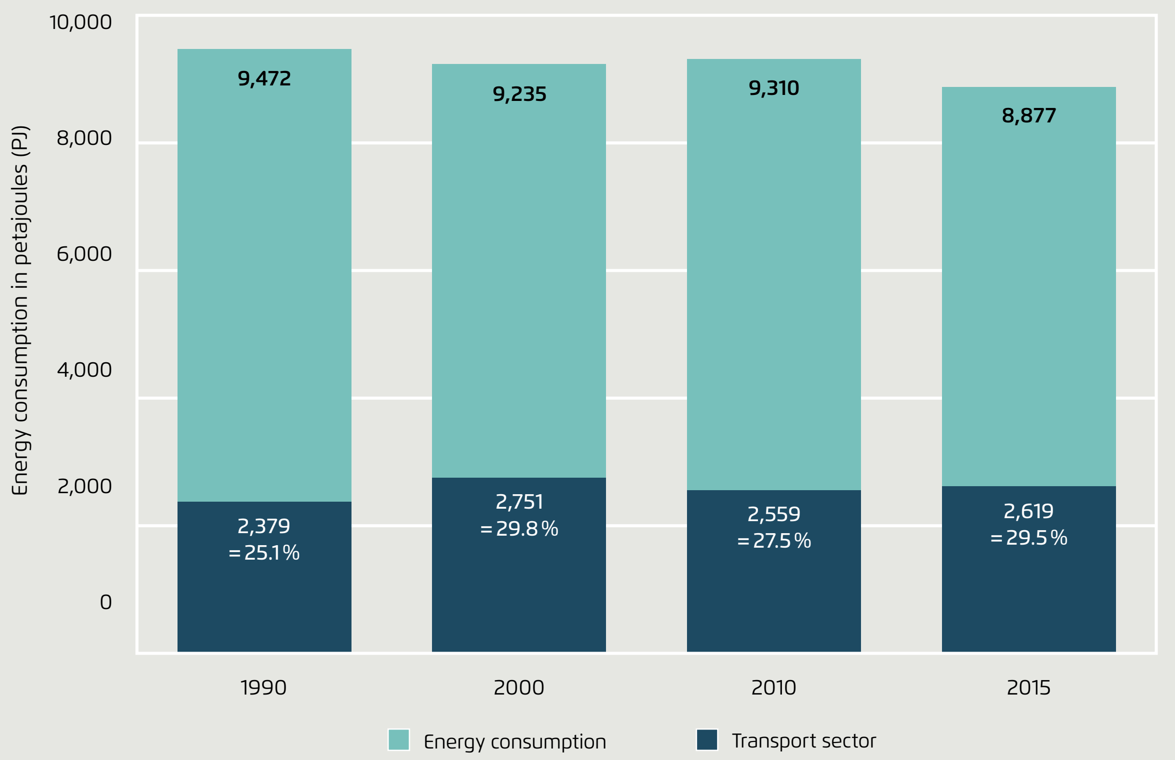
The transport sector is not only eating up more energy than any other segment of the economy[10]; it is by far

8 Between 2005 and 2014 direct and indirect emissions in the housing sector fell 6%. See Destatis (2016b), p. 569 and UBA (2016d).

9 See Bundesregierung (2010), p. 5.

10 See AGEB (2016a).

Annual energy consumption in Germany and share attributable to transport sector — Figure 0.2



Authors' figure based on AGEB (2016a)

Germany's largest oil consumer.[11] Indeed, oil enjoys a virtual monopoly in the transport sector, which draws 94% of the energy it consumes from oil-based fuels. Electricity contributes only negligibly to meeting energy demand for mobility, and for the past few years its level has dropped in both absolute and relative terms while increasing in every other economic sector.[12]

11 See BMWi (2016a).

12 See AGEB (2016a).

The Paris Agreement calls for the decarbonisation of transport by 2050

The continued high levels of energy consumption and CO_2 emissions in the transport sector have jeopardised German hopes of meeting the energy and climate policy targets set forth by the federal government's 2010 Energy Plan and elaborated in the 2050 Climate Action Plan. Reaching these targets will require a transformation of today's transport sector.

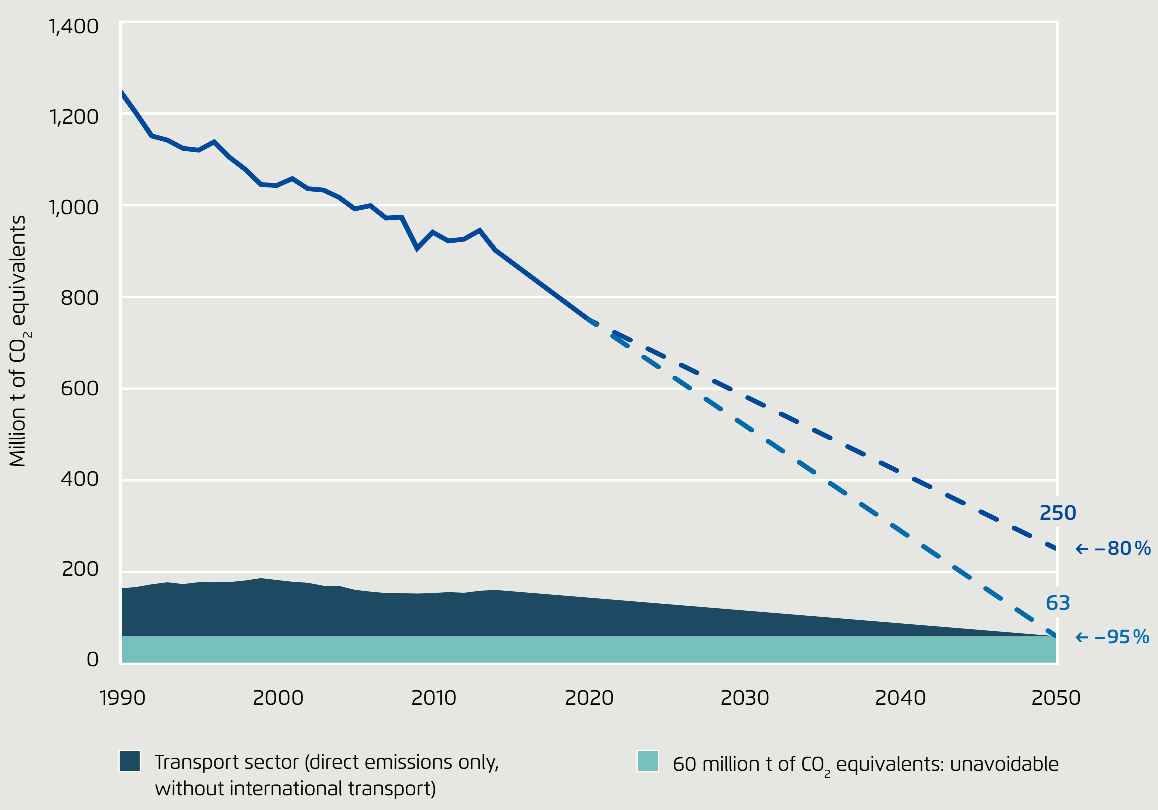
The 2010 Energy Plan – *Energiekonzept für eine umweltschonende, zuverlässige und bezahlbare Energieversorgung* is the official German title – aims for an 80 to 95% decrease in greenhouse gas emissions by 2050 over 1990 levels. This would mean reducing annual emissions to between 63 and 250 million metric tonnes of CO_2 (figure 0.3).[13] The 2050 Climate Action Plan, which became effective in November of 2016, speaks of the "complete elimination of greenhouse gases from the world economy" over the course of the century and calls on Germany to be "mostly greenhouse gas neutral by 2050."[14]

The 2050 Climate Action Plan represents the first time the German government has defined medium- and long-term targets for the reduction of GHG emissions in the transport sector. Specifically, they envision a 40 to 42% decrease by 2030 relative to 1990 levels. By 2050, the sector is to be "nearly independent of fossil fuels and hence greenhouse gas neutral."[15]

One year before the Climate Action Plan was enacted, the participants of the G7 summit in Elmau discussed the reorganisation of the transport sector away from carbon. Their closing statement spoke of the need for major cuts in global greenhouse emissions "accompanied by the decarbonisation of the global economy during this century."[16]

13 See Bundesregierung (2010), p. 4 and UBA (2016c). The reduction targets for greenhouse gas emissions and energy consumption only apply to fuels consumed in Germany. They do not take into account civil aviation and maritime transport. These exceptions also hold true for this report.
14 Bundesregierung (2016b), p. 6 and p. 9.
15 Bundesregierung (2016b), p. 26 and p. 48.
16 Bundesregierung (2015), p. 17.

Potential development pathways for German greenhouse gas emissions up to 2050 — Figure 0.3



Authors' figure based on UBA (2014), p. 38, UBA (2017a), Bundesregierung (2010), p. 4

This objective is in keeping with the Paris Agreement, which aims to hold "the increase in the global average temperature to well below 2°C above pre-industrial levels" and to bring net emissions of greenhouse gases to zero by the end of the century.[17] Already it is clear that these objectives will not be achievable without introducing negative emissions.[18] But they are expensive and hard to push through politically, as the dust-up over underground CO_2 storage has shown. The most sensible strategy is the reduction of emissions to an unavoidable minimum.[19] This includes the decarbonisation of the transport sector.

The budget approach developed by the German Advisory Council on Global Change (*Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderungen*, or WBGU) follows the same logic. It caps global CO_2 emissions between 2010 and 2050 at 750 billion metric tonnes so as to keep global warming below the 2 °C guardrail with a high degree of probability.[20] According to the WBGU, an equitable distribution of CO_2 allowances among the world's countries would leave Germany with an emissions budget of 9 billion metric tonnes of CO_2, or 220 million metric tonnes per year for the remainder of the period. But annual CO_2 emissions of the German transport sector already amount to some 160 million metric tonnes a year, almost three-fourths of Germany's annual allotment. There is no reason why the transport sector should have such special status relative to the industrial and housing sectors.

Despite these challenges, the drop in oil prices and other factors have led to an increase of energy consumption and emissions in the transport sector. Official projections forecast that emission reductions will continue to fall short of targets.[21] The discrepancy between objectives and reality reveal the enormous need for political action.

17 UNFCCC (2016a), p. 21 (Article 2 and Article 4). Since the United Nations Framework Convention on Climate Change entered into force in 1994, the environmental treaty has required developed countries to "take a leadership role" by reducing their greenhouse gas emissions more rapidly than developing countries. See UNFCCC (1992), Article 3.

18 Negative emissions are processes that remove greenhouse gases from the atmosphere. One method combines the increased use of bioenergy with the removal of CO_2 by means of carbon sinks. See O. Geden and S. Schäfer (2016).

19 Based on current technology, the industrial and agricultural sectors would still need to emit 60 million metric tonnes of CO_2. See UBA (2014), p. 38.

20 The assumed probability is 67%. See WBGU (2009), p. 27 ff. Since the publication of the WGBU study, around 30 billion tonnes of CO_2 have been emitted annually, which means that the remaining budget is lower today. It has become even smaller by the augmented climate targets of the Paris

21 According to federal government projections, emissions by 2030 will drop by only 18% relative to 2005 levels (Bundesregierung, 2016c, p. 300). Ifeu, INFRAS, LBST (2016) estimate that emissions will decline by around 40% by 2050 (p. 32 and p. 202).

Insight
01

Transforming transport requires decarbonisation and sustainable mobility.


Picture: mbbirdy / iStock

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.

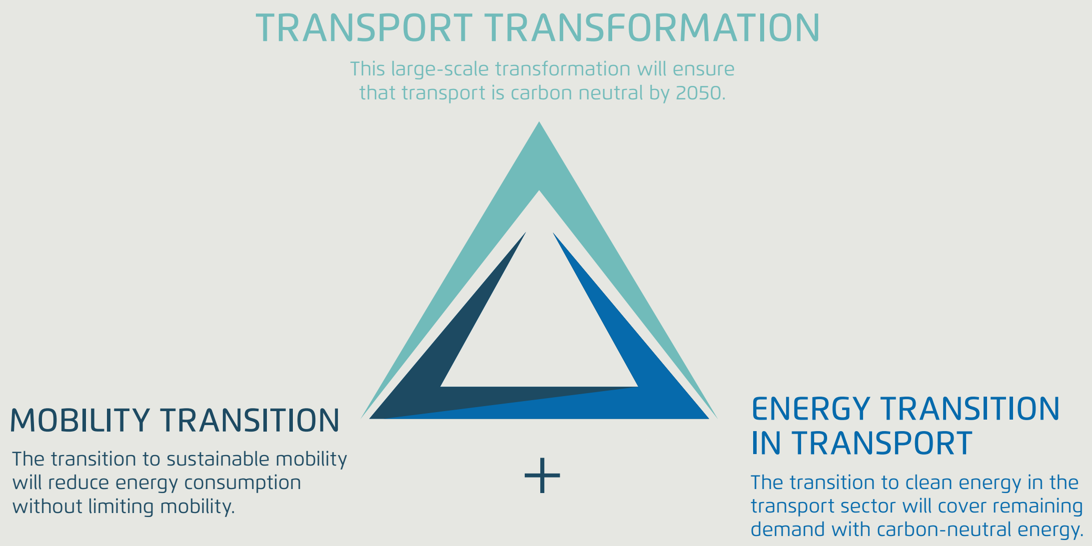
Although support for energy generation from renewable sources is generally high, public support still poses problems. Renewable power stations, wind turbines in particular, are not welcome everywhere,[22] and as their numbers grow, so too will resistance.[23] Hence, carbon-neutral energy must be used as efficiently as fossil fuels. Using renewables efficiently also keeps down its generation costs.

22 See *Tagesspiegel* (2016).
23 At the end of 2016, there were 28,217 wind turbines in Germany. These were responsible for 11.9% of Germany's gross electricity production. See BWE (2017) and AGEB (2016b).

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" (figure 1.1).

The first pillar, the mobility transition (known in German as the *Mobilitätswende*), is about changing how people get around. Its goal is efficiency – decreasing 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 hitherto unrealised potentials to reduce, reorganise and improve transport.

The geometry of the Transport Transformation | Figure 1.1



Authors' figure

The second pillar, the "energy transition in transport" (*Energiewende im Verkehr*) is primarily a technological challenge. Specifically, how can we meet the power demands of transport using efficient, carbon-neutral energy? Tackling this problem will require the right kinds of policies and political support.

The mobility transition allows the same mobility with fewer kilometres travelled

People want to be mobile because they cannot meet all their needs in one place. But mobility is not the same thing as transport, which is merely a means of overcoming distance. Mobility can be associated with long or short journeys; it can require much effort or little; it can take a high toll on the environment or a small one. The number of kilometres travelled is not the key measure of mobility.[24]

Over the past few decades, housing construction trends have increased the amount of traffic on the road.[25] At the same time, private vehicles have become the dominant means of transportation amid a greater emphasis on individuality.[26] The resulting traffic trends have proven hard to change, and many attempts to curb congestion and promote environmentally friendly transportation have been unsuccessful.

Changes are on the horizon, however. For the past ten years, there have been signs of a fundamental shift in people's attitudes towards cars. More and more, urban populations in North America, Europe and parts of Asia see driving as burdensome rather than pleasurable. People are looking for – and finding – alternatives to private vehicles.

Digitalisation and communication technologies have helped make this shift possible. (Insight 5 has more to say about them.) Emerging travel behaviour patterns require less transportation and rely on multiple,linked modes of travel. These new behaviour patterns often rely on innovative smartphone apps that allow users to switch seamlessly between modes of transport. The benefits are obvious. Substituting private vehicles for trains, for example, saves people from having to find a parking spot. And carsharing allows people to choose the vehicle they need on any given day, be it a cabriolet or a transporter. With new forms of behaviour now possible, people's habits will continue to change, and mobility's harmful environmental effects will diminish.

Transforming mobility is less about decreasing movement than changing its quality: planning routes more efficiently; combining environmentally friendly transportation options; reducing traffic. A new, multimodal mobility system like this will improve the way people and goods move around while helping to mitigate climate change.

Such a system requires the right regulatory framework. Fortunately, new technologies give policymakers the ability to align the transport sector with climate goals more effectively than ever before. They can promote new mobility services by deploying fiscal and regulatory instruments in various ways, e.g. to improve the management of public parking.

To be sure, resolute political measures will be needed to tap the enormous potential of this transformation. Studies have estimated that a new mobility system can reduce energy consumption in Germany's transport sector by some 25% by 2050. With the decline already expected from efficiency measures,[27] the transport sector could see energy use fall more than half of what it was in 2005.[28] This outcome would significantly exceed the long-term targets defined in Germany's 2010 Energy Plan – and keep the volume of carbon-neutral energy needed for the transport sector to a minimum. Remember: saving energy means having to generate less of it.

Clean-energy transition, climate-neutral transport

Unlike the mobility transition, the energy transition in transport is for the most part a question of technology. But it, too, requires political support. Carbon-neutral transport requires carbon-neutral energy. And such

24 Becker, U. (2016), p. 17.

25 Research has shown that these trends are hard to reverse. See SRU (2005), p. 135.

26 See Knie, A. (2016), p. 43

27 See Ifeu, INFRAS, LBST (2016), p. 153 ff. and p. 189.

28 See Ifeu, INFRAS, LBST (2016), p. 189

energy, which in Germany comes mostly from sunlight and wind, is available only in limited quantities, and this will remain so for the foreseeable future. However, the Paris Agreement requires Germany and the other signatories to decarbonise their economies. This means for the time being that all sectors – industry, private households, the transport sector and so on – compete for the same limited quantity of carbon-free electricity. If they cannibalise themselves in the process, the net effect on emissions will be zero. A clean-energy transition in the transport sector thus requires an additional influx of carbon-neutral energy.

Electricity is the easiest way to inject more carbon-neutral energy into the economy, and it will play an important role in powering the vehicles of the future. There are two reasons why. First, there's still much room for Germany to increase electricity from solar and wind power, the country's most important sources of carbon-neutral energy. Second, electricity can serve as a direct power source for motor vehicles. Additionally that electricity can also be converted into zero-emissions fuels such as hydrogen. The problem with converting electricity, however, is that the process itself requires energy. The more conversion, the less solar and wind power available as final energy. And because the conversion process is technically demanding, it increases the cost of supplying energy. This means that the most efficient way to use electricity is in direct form.

To sum it up, the issues involved in transforming the transport sector are intertwined:

- The more efficient mobility becomes, the less renewable energy will be needed in the transport sector.
- The more renewables are converted into fuel, the more wind and solar energy is needed to achieve the same number of kilometres travelled.
- The more wind and solar power stations required for the transport sector, the greater the environmental impact of the energy transition in transport – and, possibly, the greater the public resistance.

Therefore, the best option for the energy transition in transport is to use electricity directly in the form of battery-powered cars and overhead lines for buses, trains and trucks. Though, in view of the many uncertainties involved with introducing these technologies, alternatives should not be ruled out today. Regulation must be informed by technological openness.

Elaborating a political framework for transport transformation by 2030

Of course, the primarily 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. It is important that policymakers identify short- and medium-term goals for meeting the obligations of international climate treaties, and define a clear path for getting there. Technological advances alone – electric vehicles, digital innovations, etc. – will not reduce CO_2 emissions.[29]

Experience tells us that transforming the traffic sector will require fundamental changes to the regulatory framework at the German and European levels. Future infrastructure investments must be targeted to reduce emissions, and the state 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.

In the mid-2016, the EU Commission set the agenda for low-emission mobility.[30] But many member states, including Germany, show few signs of the sought-after changes. For instance, Germany's 2030 Federal Transport Infrastructure Plan contributes virtually nothing to the reduction of emissions. (Insight 10 will have more to say about this.) Likewise, Germany's policies are plagued by inconsistencies: promoting the purchase of electric vehicles while cutting taxes on diesel and introducing a company-car tax that favours frequent trips and offers no incentives for the use of low-emission cars. This

29 See OECD, ITF (2017), p. 14.
30 See EU COM (2016a).

makes for more motor output – and more CO_2 emissions.[31] The lack of a general speed limit on the autobahn only adds to the problem.

The best studies available today argue for the electrification of the transport sector. This will require an integrated, electricity-based mobility system encompassing various modes of transport; the low-carbon generation of electricity, hydrogen and power-based fuels; and the identification of sustainable transport principles. By 2030, 20% of all road vehicles – 100 million cars alone – must be electricity-powered.[32] It is unlikely that the federal government's goal of putting six million electric cars on the road by 2030 will suffice to meet Germany's emission reduction targets in the transport sector.

The transport transformation is a long-term task that spans multiple areas of the economy. Such a task requires cohesive policies.[33] Policymakers at various levels of government, from the EU level to local municipalities, must coordinate their activities. If they neutralise or even hinder each other, the transformation won't be possible. The same goes for various sectoral policy areas; they too must be harmonised for it to work. 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 insofar as transforming the transport sector is not just about traffic and the environment. It's also about German industry, jobs, economic vitality and public health. Indicators such as the market share of electric vehicles show that some countries have already made great strides in restructuring their respective transportation systems for the sake of reducing air pollution, limiting dependency on oil imports and securing an advantage on future markets.[34] Germany has yet to be among the pioneers (figure 1.2).

31 See Destatis (2016c). According to the Federal Statistical Office, the increase of the average motor output of newly certified vehicles in 2015 compared with that of those in 2008.

32 See UNFCCC (2016b).

33 The federal government has stressed that the cohesiveness of policies promoting sustainable development must be improved. See Bundesregierung (2016a), p. 43.

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 changes. And without a transformation of the transport sector, Germany stands to lose its attractiveness as a site for industrial production.

Upon closer scrutiny, the transformation also represents a highly complex social challenge. For it demands that millions of people change routine behaviours and quit habits that have assumed a ritual-like character. This is a fundamental difference between the transport transformation and the energy transition. As a bipartisan policy since the Fukushima nuclear disaster, the German energy transition has mostly focused on changing electricity production, but it has not altered the product itself. Even as the share of solar and wind power grows, outlets still deliver electricity at 220 V and 50 hertz. By contrast, the transport transformation crucially depends on voluntary behavioural changes. Accordingly, the need for change must be communicated in a compelling way, and time must be given for the adoption of new habits. Judging from past experience, such processes tend to take decades, not years. This is also why immediate action is needed.

The transport transformation will succeed only with international cooperation

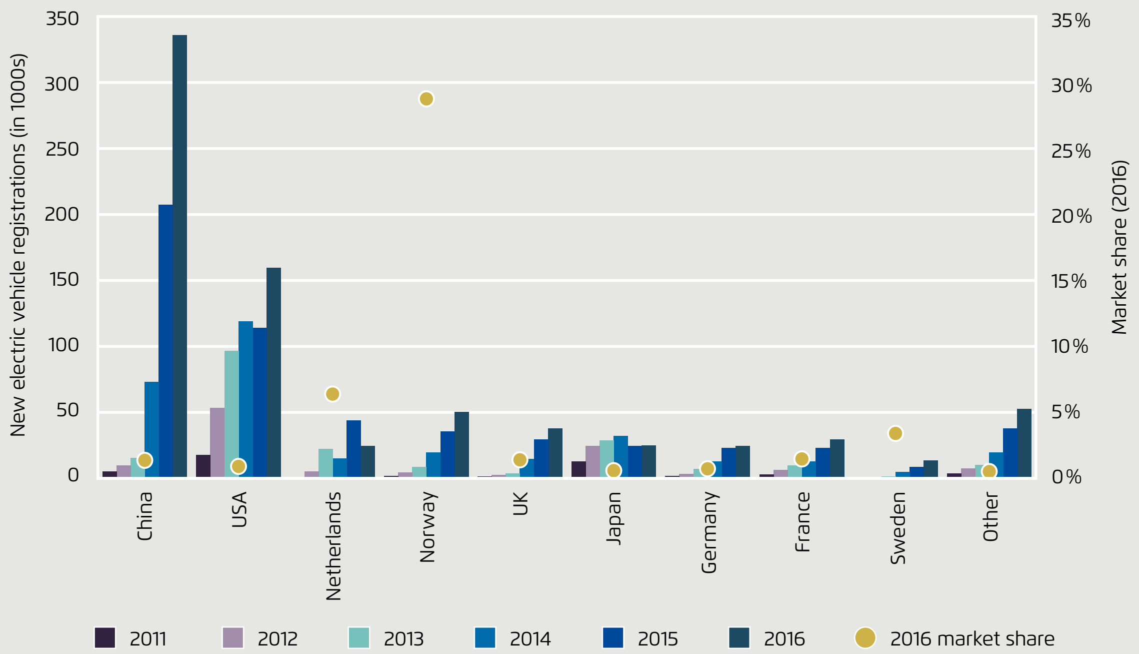
The transformation of the transport sector will require new cooperative impetus at the international level, especially in Europe. For one thing, transportation doesn't stop at Europe's borders, and for another, transport emissions are not regulated by the EU Emissions Trading Scheme. The EU's strategy for low-emission mobility creates a framework for future development and for specific vehicle, fuel and technology standards using a variety of directives, both planned and already in effect.[35]

34 See, for instance, IEA (2016a).

35 See EU COM (2016a).

Sale of electric vehicles* in various countries

Figure 1.2



IEA (2016a), p. 11; *Battery-driven vehicles and plug-in hybrids

The greater the EU's level of ambition, the fewer regulations must be passed at the national level for a successful transformation of the transport sector. Moreover, when countries attempt to go it alone, they tend to be met with resistance from national interest groups, and their policies are suspected of being incompatible with the EU domestic market – another reason to prioritise a coordinated Europe-wide approach.

Today, the transformation of the transport sector has grown beyond Europe's borders, with China and California leading the way. Their experiences can be valuable for current discussions in Europe. By the same token, progress in Germany in transforming the transport sector could trigger developments elsewhere. There is a precedent for assuming this: Without the German Renewable Energy Sources Act (EEG), for example, which encouraged technological advancements, wind and solar energy would be unaffordable for many poorer countries. China and California have triggered similar effects for battery costs, to the benefit of Germany and Europe. In the future, the transport transformation will also help poor countries introduce climate friendly transportation – and, in the process, promote international justice. That today's providers can also profit from the spread of new transport technologies to international markets is a welcome added effect.

International cooperation is needed for another reason. The digitalisation of the transport sector and electrify-based powertrain technologies will only be possible if imports of certain raw materials (lithium, cobalt) or of carbon-neutral electricity-based fuels increase on a massive scale. In principle, the market balances supply and demand. To avoid shortages or monopolies, international cooperation is urgently needed, especially during market ramp-ups of new transport technologies. Such cooperation creates the basis for the creation of extraction and processing capacities in manufacturing countries and ensures that demand peaks do not drive up prices, and thus slow the transformation. Either way, a strategy is needed for cooperation despite competition to ensure energy supply security and the availability of resources required for the transport transformation. The necessity of cooperation makes the transport transformation a key element in international security and peace efforts.

Insight 02

Efficiency is the guiding principle of the transport transformation.

Picture: LydiaGoolia / iStock

The transport transformation will bring major changes to people's everyday lives. A key aim of the transformation is to decarbonise the transport sector while using available resources – including human resources, energy, and money – as efficiently as possible. The transformation will pose technological challenges, but first and foremost it throws down the gauntlet to society. Its top priority – namely, efficiency – is likely to run up against the limits of public acceptance. And when it does, dogma must give way to compromise.[36]

The cheapest kilometre is a saved kilometre

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 (as Insight 3 explains in more detail). For fewer kilometres travelled means less motive power, and less motive power means less energy generated 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 help. Restructuring for efficiency will require time and the political resolve to pass legislation that is no longer focused on eliminating obstacles to vehicle traffic.[37]

Digitalisation serves efficiency

Digital technologies and new business models can achieve advances in efficiency even in the short term. They limit environmental damage less through reducing the need for transportation or through shortening routes than by changing people's behaviour.

Thanks to the digital networking non-motorised forms of transport, public transportation, and car- and ride-sharing services, individuals now have a compelling and practical alternative to private vehicle ownership. Driverless vehicles can also have a positive effect on the environment, provided they are used efficiently. (For more on this, see Insight 5.) With digital technologies, these means of transport can be better utilised and the traffic system made more intelligent. This will also result in efficiency gains and economic growth, as illustrated in figure 2.1.

36 Distribution effects or undesired consequences on system flexibility can, along with a lack of public acceptance, also restrict efficiency's priority.

37 See Difu (2011b), p. 5.

Efficiency gains and growth stimulus from intelligent networks (interlinked mobility by app) — Figure 2.1

Efficiency gains	€ billion	Growth stimulus	Mrd. Euro
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. (2012), p. 32

Economical vehicles in demand

The efficiency rule also applies to vehicles (Insight 6), 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."[38] 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. To be sure, the transport transformation, if it is to succeed, requires 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 size, their output, their weight and so forth.

In China, compact electric cars with limited speeds, so-called low speed electric vehicles LSEVs, have seen a boom, with more than 600,000 units sold in 2015. These cars are small, flexible, inexpensive – and largely unregulated. They are more energy efficient than comparable vehicles powered by combustion engines, but they are less efficient than public transportation and two-wheeled vehicles.[39] Whether they are suited for the German market is still uncertain.

Electric motorcycles are enjoying growing popularity as well. It is estimated that in 2015, there was more than a quarter-billion electric motorcycles on the road in China alone. In Germany, there are not nearly as many, with no more than 7,300 in use.[40] The number of electric bikes is on the rise, however. Considerably more pedelecs were sold in 2016 than in 2015 (though the year-over-year growth rate has slowed).

38 Article 2, para. 4 of the European Energy Efficiency Directive. See EU (2012). 39

39 39 See IEA (2016a), p. 23.

40 See KBA (2016), p. 8.

Efficient energy supply

Vehicles are tied to the energy that powers them. What is ultimately relevant for the climate is the level of CO_2 emissions from motorised transportation – and not, for example, where they occur in the transformation of energy into power. The entire process is important from *well to wheel*. Vehicle efficiency (*tank to wheel*) and fuel production (*well to tank*) are, by themselves, insufficient measures for judging climate relevance. What really matters is the efficiency of the system (as discussed in Insights 6 and 7).

Electric motors are fundamentally more efficient than combustion engines, and they do not emit CO_2 locally. But they are not CO_2 neutral if their electricity is generated using fossil fuels. The share of renewables in the German electricity mix is now around one-third, and thanks to the government's promotion of renewable electricity, it's growing. As the share of electricity from renewables increases, electric-powered transportation will become more efficient[41] and the amount of GHG emissions it creates will approach zero. Direct electricity use is the key for the transformation of the transport sector.

Should this option not be possible – whether due to technical reasons or due to lack of societal and political acceptance – 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. Yet combustion engines are only an option for the transport transformation if GHG emissions are otherwise on a path toward zero. Even with the most ambitious forms of vehicle optimisation,[42] drastic reductions in carbon emissions will only be possible through the use of carbon-neutral fuels generated from renewable electricity. But the production of electricity-based fuels itself requires a great deal of energy, making it significantly less efficient than direct electricity use (see Insight 7).

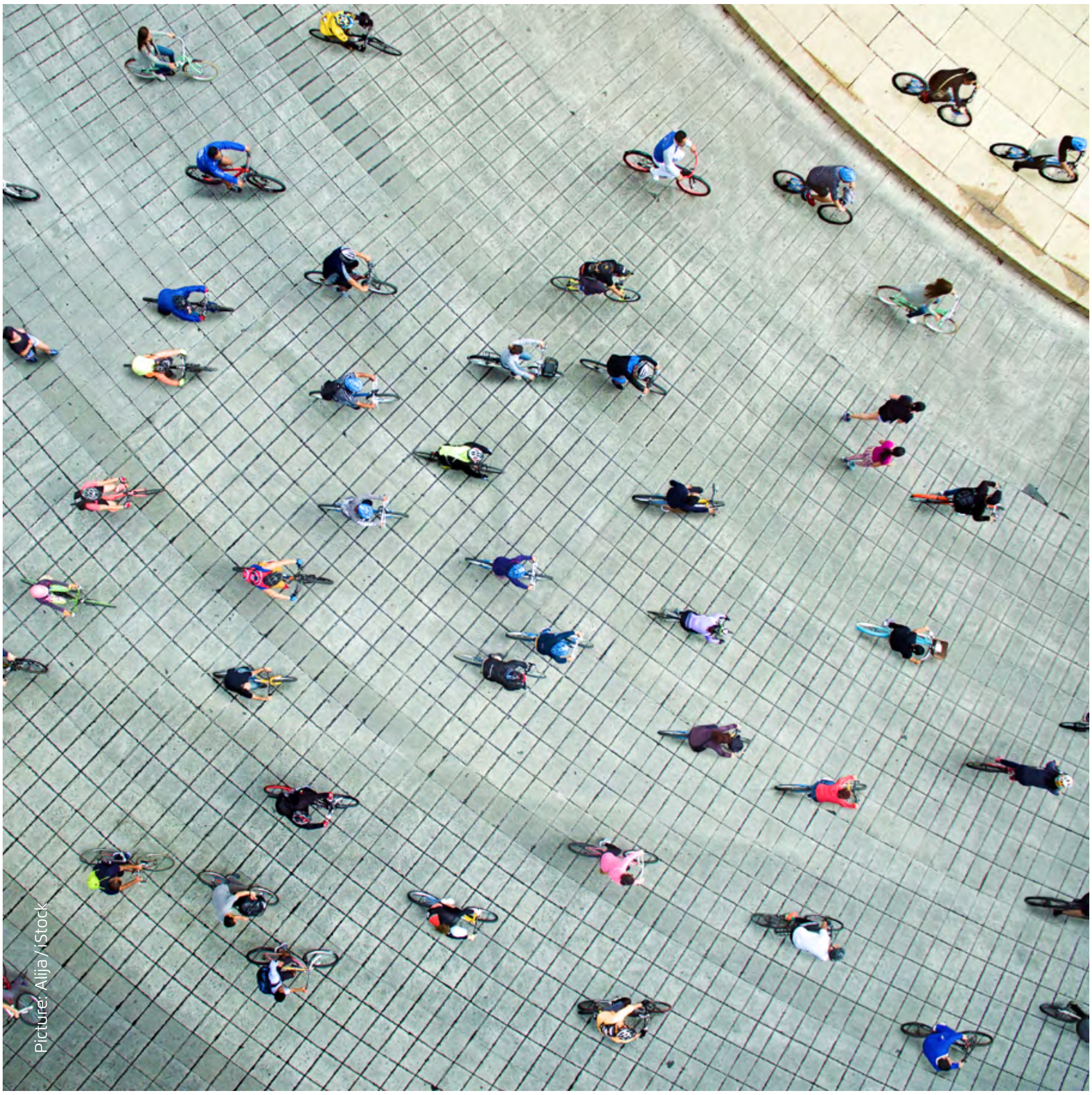
41 Renewable energies are not only CO_2 neutral; they have an efficiency level of 100%, while the maximum efficiency level of electricity generated from fossil fuels is just under 60%. See AGEB (2011).

42 The potentials for vehicle optimisation are far from being exhausted. See ICCT (2016a).

Carbon-neutral transportation 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.

Insight
03

In cities, the mobility transition has already begun.


Picture: Alija / iStock

For more than a decade now, private vehicle use in large German cities has been on the decline. At the same time, more people are getting around by bicycle, on foot, with public transport and through carsharing. Developments like these – fuelled in part by societal trends such as lower car ownership rates and fewer young adults with driver's licenses – have influenced the transport options that are in demand.[43]

Alongside traditional urban mobility options, whose mainstay continues to be public transport, new forms of individual transport are being driven by digitalisation, including collaborative services such as carsharing, ridesharing, and bikesharing. These services have brought with them new types of infrastructure: intermodal mobility hubs, bicycle parking, charging stations and the like. The growing spectrum of mobility services gives city dwellers a range of interlinked alternatives to private vehicle ownership without restricting their personal mobility. These trends will help expedite the meeting of climate targets in the transport sector, and should be accompanied by policies that encourage and solidify them.

The commercial transport of goods and services – the lifeblood of any city – poses more difficult challenges. The rapid rise of online sales has led to an explosion of local deliveries. The increase in traffic creates additional noise and air pollution, requires more land use and takes a heavy toll on infrastructure. Cities must devise policies to address these challenges, and, in some cases, will need innovative solutions.[44]

Attractive cities are not car friendly

The paradigm of the car-friendly city, a product of the early post-war era, made the automobile the focal point around which modern life turned; ecology and the needs of pedestrians and cyclists frequently came in second. This paradigm has since run its course. One reason is a change in values. For instance, 82% of Germans surveyed today want to live in cities and communities where owning a car isn't a necessity.[45] Today's guiding principles focus more on environmental and social concerns.

43 See Ahrens, G. (2013) and DLR, infas (2010).
44 See Difu (2014).
45 See BMUB, UBA (2015), p. 35.

The goal of creating liveable cities – attractive places to visit, live and work – has garnered increased attention as cities compete to attract businesses and skilled workers.[46]

A crucial catalyst for creating liveable cities is to enact modern urban development and traffic planning policies. A key aim in this regard is to minimise the distances to be travelled.[47] Denser housing combined with mixed-use urban development reduces traffic.[48] This allows people to make shorter trips, decreases delivery distances, reduces land consumption and leads to a range of new mobility services. When infrastructure formerly dominated by car traffic is repurposed for cyclists and pedestrians while roads and parking lots are converted into parks, people once again become the focal point.[49] What is more, such planning can lower the cost of maintaining urban infrastructure and operating public transport – thus easing the burdens on government and household budgets alike.[50]

From public and non-motorised transport to the mobility network

Reliable and convenient public transport remains the backbone of climate friendly urban development. It is indispensable for the quality of life in urban areas and for the functioning of cities and regions. It provides safe and affordable mobility options for everyone and ensures accessibility, even as it is significantly better for the environment than other motorised means of transport.[51]

The development of electric mobility stands to make public transport even more attractive. Electric buses are quieter than conventional buses and produce no local emissions. Accordingly, they can increase public acceptance for routes and stops in dense residential areas. Moreover, in comparison with diesel-powered bus fleets they can improve air quality, especially in

46 See Engel, B. (2015).
47 See Difu (2011b).
48 See Gehl, J. (2015), p. 87.
49 Ibid.
50 See FGSV (2013)
51 See Gies, J.; Deutsch, V.; Beckmann, K. J.; Gertz, C.; Holz-Rau, C.; and Huber, F. (2016).

inner cities with high concentrations of particulate matter and nitrogen dioxide.[52]

In the coming years, public transport will continue to change as new trends and developments emerge. Information technology is one example that is already changing how people get around. The mobility options it has generated – including shared-mobility services, intercity buses, etc. – are being integrated with traditional forms of ecomobility such as cycling and public transport. Smartphones and the Internet make this integration possible (Insight 5), offering people quick, on-the-fly access to various forms of transport.

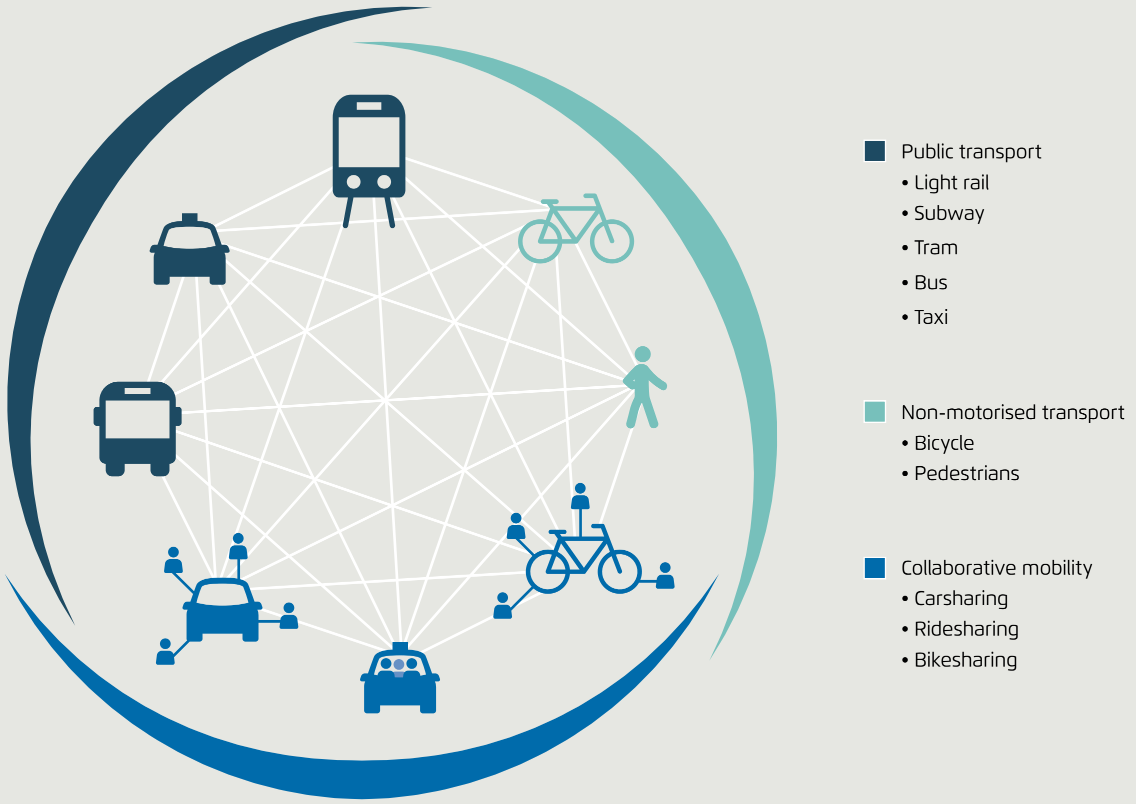
New and traditional means of transport will be combined to form comprehensive "mobility networks" (see figure 3.1). These networks blur the lines between public and private transport and enable users to determine an optimal combination of various mobility options without relying on vehicle ownership. This does not mean that cars should be banished from cities; on the contrary. They are an important component of the mobility mix. The growing numbers of carsharing and ridesharing options provide reliable transport while lowering private vehicle usage. The frequently voiced concern that collaborative services will cannibalise public transport is misplaced: carsharing users are loyal public transport customers, and vice versa. [53]

52 See Difu (2015).

53 See Topp, H. (2013).

The mobility network

Figure 3.1



Authors' figure

This transition in urban mobility will also affect how people travel from cities to other places. As more and more people use the new mobility networks for everyday commuting, the value of owning a private vehicle just for holidays and occasional jaunts to the countryside will decline, while rental cars and train services will seem more appealing. As a result, the way people travel longer routes will change for the better.

A key factor for ensuring the public acceptance for mobility networks like these is the nationwide expansion of mobility services. They must be made available not only to inhabitants of big cities but also to people who live in the outskirts and in small towns. Moreover, the mobility options must be reliable, easy to access and affordable for all. To achieve this, public transport systems require a stable framework, 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. At any rate, it is an urgent challenge that Germany's federal, state and local levels must address as soon as possible.[54]

Cities benefit from pedestrian and bicycle traffic

Walking and cycling are affordable, healthy and inclusive forms of transport. They do not emit greenhouse gases and pollutants, require less space and are relatively quiet.[55] Moreover, most cities with a large percentage of cyclists experience less traffic congestion.[56] As a result, walking and cycling are central factors in environmentally friendly transport and the quality of urban life.

As a mode of transport, bicycles have witnessed a sharp rise in popularity. The number of trips people are taking by bike is growing, as are the distances covered.[57] At the same time, people who rely on bicycles to get around tend to keep their destinations local.[58] This reduces distances travelled without restricting mobility.

54 See Gies, J.; Deutsch, V.; Beckmann, K.J.; Gertz, C.; Holz-Rau, C.; and Huber, F (2016).
55 See FGSV (2014).
56 See Tomtom Traffic Index (2016).
57 See BMVBS (2012).
58 See Difu (2011a).

For the success of the mobility transition, it is crucial that these positive developments continue, even in the face of possible public resistance. Cities must create safe and needs-oriented infrastructure systems for bicycles. When good bike paths are available, people will use them, and the number of cyclists will grow. Walking brings similar benefits to cycling, though only recently have urban planners turned their attention to pedestrians. Creating the right kind of infrastructure – uninterrupted networks of tree-lined paths, say – would encourage this trend. Together, walking and cycling can increase the share of non-motorised transport by over 50%. Even the freight transport sector can contribute, with electric and electric-assisted cargo bikes representing an as yet unexhausted potential.[59]

Fewer private cars means more public space

Urban space is limited and thus valuable. The way it is used determines whether a city is a liveable and desirable place to be. But competition for space among different groups of residents and travellers can lead to conflicts.

Motorised private transport claims the largest amount of public space. Measured by modal split, this type of transport occupies a disproportionate share of the urban environment, and plays a predominant role in how roads are designed and public space is used (figure 3.2). In terms of the common good, parked vehicles represent "the least necessary" utility and the one "most likely to be changed."[60]

In many cities, big and small, demand for parking exceeds capacity. This negatively affects the quality and attractiveness of cities (e.g. due to double parking, blocked bicycle lanes, etc). Moreover, parking spots tie up municipal funds that are not necessarily recoupable through parking fees.[61] However, municipalities have powerful instruments at their disposal to free up space and steer use. These instruments include parking space management and the promotion of carsharing.

Parking management plays a key role in planning integrated transport systems. Its policies shape traffic flow

59 See FGSV (2014).
60 DStGB. Quoted in AGFS (2012), p. 63.
61 See Bracher, T.; Lehmbrock, M. (2008).

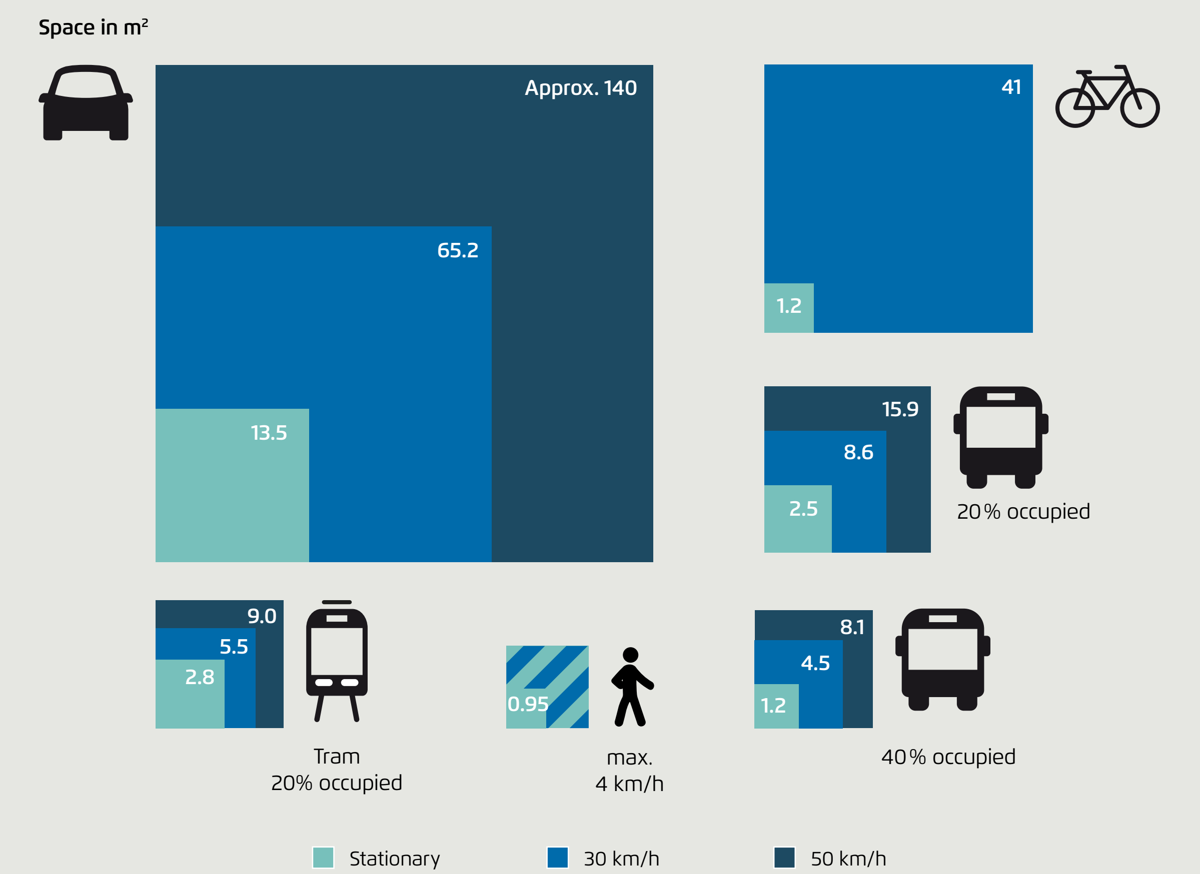
and land use and can, say, restrict available space, prioritise parking for deliveries and residents and reduce noise and air pollution.[62] Yet German municipalities possess limited leeway in setting parking policy. They can determine which parking zones are subject to fees, yet parking fines are set at the federal level. The same goes for the pricing of resident parking permits. In towns such as Zurich, Amsterdam and Edinburgh, municipal authorities have more room to maneuverer. Parking management in German cities would be more effective – better able, say, to reclaim urban space for public use – if they had more freedom to determine local policies. [63]

62 See Becker, U. (2016).
63 See DST (2016).

Another important instrument to free up space is the promotion of car- and ridesharing, a type of individual transport that serves the common good by lowering private car ownership and reducing the amount of space devoted to road transport. Empirical studies of various large cities have found that a single carshare vehicle can replace 8 to 20 private cars.[64] A comparison of the costs that a carsharing company must pay for a public parking space with the average cost of a residential parking permit reveals that private cars, which remain parked 23 hours a day on average, receive significantly higher levels of public subsidisation than shared vehicles. Carsharing companies pay between 25 and 85 euros a month for the use of a public parking space. Free-floating

64 See BCS (2016).

Space requirements of different types of transport at different speeds — Figure 3.2



Authors' figure based on Randelhoff, M. (2015)

operators pay even more. By contrast, the average two-year resident parking permit costs between 20 and 30 euros.[65] In order to promote carsharing, cities should also review existing fee structures, especially in areas where carsharing needs encouragement. To this end, Germany's states and municipalities should take advantage of recent national carsharing legislation, which makes it possible for local governments to designate parking spaces for carsharing vehicles.

Both these measures – parking management and carsharing – can help strike a balance between competing interests in the usage of urban space and move away from the typical focus today on specific modes of transport. As a result, they can increase cities' ability to compete internationally for residents, workers and businesses.

Freight transport, too, can be carbon neutral

The volume of urban freight transport has risen much more sharply in recent years than predicted, and it can be assumed that it will continue to grow in the future. In particular, exploding online sales have greatly increased the size of the courier, express and parcel (CEP) industry. In 2015, there were just under three billion CEP shipments in Germany, or 5.9% more than in the previous year. Between 2000 and 2015, the number of CEP shipments increased by 74%.[66] This rise has been accompanied by a growing volume of freight and passenger traffic.[67]

This growing volume of vehicles has not only slowed down traffic and made the roads less safe. It also has increased the amount of harmful pollutants released into the atmosphere (Insight 12). Most freight transport in Germany is performed by diesel vehicles, which are responsible for 80% of Germany's traffic-related nitrogen dioxide emissions. For several years now, levels of nitrogen dioxide at most outdoor monitoring sites in Germany have exceeded those defined by the EU air quality standards enacted in 2010.[68] As a result, in 2015 the EU opened an infringement procedure against Germany. If Germany doesn't take effective action soon –for example, by enacting driving bans for diesel vehicles – the EU will impose high fines. Moreover, environmental organisations have filed multiple suits against the German government over air pollution levels, putting additional pressure on policymakers.

The brief outline of freight transport sector underlines the urgent need for action at the municipal level. In its 2011 White Paper "Roadmap to a Single European Transport Area," the EU Commission recommended that countries "achieve essentially CO_2-free city logistics in major urban centres by 2030."[69] The solutions needed to meet this target have already been found.

The first solution comes in the form of sustainable approaches to city logistics. Typically, these approaches plan streamlined collection points for goods outside urban areas. Digitalisation is likely to improve such systems through shipper-independent bundling, which cuts down on the number of trips (Insight 5). There is also the option of distributing goods from the collection points using light trucks and depositing them at urban hubs. From there, electric-assisted cargo bikes can be used to deliver goods to customers. Pilot projects have shown that a multimodal distribution of goods is economically feasible.

The second solution is the use of light-duty electric vehicles for the transport of goods urban areas. The urban routes used by CEP providers are quite suited for this purpose, because in addition to being efficient and streamlined, most of them are also within the battery ranges of electric vehicles. Moreover, intelligent systems can be used to charge parked vehicles overnight at the depot.[70]

Using electric vehicles for inner-city deliveries benefits the community in many ways: it requires less space (especially if electric cargo bikes are used), reduces noise, and makes the streets safer. Smart, climate friendly urban logistics planning also helps shipping companies by decreasing the number of delivery runs, creating efficient distribution paths and saving costs.[71]

65 See the written report issued by BCS.
66 See BIEK (2016).
67 See Difu (2014).
68 See UBA (2017b).
69 EU KOM (2011), p. 144.
70 See TAB (2012).
71 See Difu (2014).

Nevertheless, municipal strategies for implementing approaches are still necessary. Such strategies, including diesel driving bans or truck guidance systems, can help cities in various ways to keep freight traffic out of sensitive areas.

Cities need more support

To usher in sustainable mobility, cities need to develop their own visions, define goals and take action. This requires a willingness to experiment and try out new, sometimes unconventional ideas.[72] Municipalities must steer bolder courses than they have in the past if they hope to bring about lasting change. Communities must ask themselves: in what kind of city do we want to live? And how can technological change serve the city and not the other way around?

The transformation of urban transport systems is mostly a task for municipal planning. Cities know the challenges and problems they face; in many cases, solutions are already available. What stands in the way of transformation is not so much lack of knowledge as implementation. How can policymakers and other public officials best work together in dealing with the transformation? How can cities systematically adopt the many complicated measures required for the transformation instead of merely carrying out individual pilot projects?

Comprehensive approaches, such as integrating urban development with traffic system planning, are crucial for achieving the desired effects of sustainable mobility and avoiding negative consequences. But the inclusion of planning beyond the city limits is important as well. Especially at a time when cities and local municipalities are under more and more pressure to cut costs while maintaining or even improving the quantity and quality of service, intercommunity cooperation has become vital.[73]

Such cooperation requires human resources, money and time. But it also needs alliances between government, administration, the private sector, the citizenry, academia and the media to ensure broad support for and public acceptance of policy aims. The conditions governing action vary from city to city. There is no one ideal strategy that applies everywhere.[74] This does not mean that decision-makers have to reinvent the wheel every time. There are many good approaches that can be transferred from one city to the next. But this requires experts, opinion leaders and ministries to gear information to the local authorities receiving it.

Municipalities may have authority over local planning, but they are often restricted in implementing it by existing traffic regulation and the Public Transport Act (Personenbeförderungsgesetzes, PBefG). Hence, they rely on the states, the federal government and the EU to push for the introduction of integrated concepts for urban development through coordinated programs (both in terms of policies and across ministries), knowledge sharing and hands-on projects. The municipalities need reliable funding of local transport (Insight 10) and a greater range to manuever.[75,76] Incentive systems that encourage local officials to try out new, sustainable forms of mobility and put them into practice is a smart way of helping municipalities innovate.

But what cities need most of all is legislative stability. Germany must pass so-called experimentation clauses that facilitate municipal action, especially when testing temporary or flexible policies (Insight 5). Germany's federal road traffic regulations (*Straßenverkehrsordnung*, StVO) and possibly the road traffic regulations of the German states must be amended to enable innovations without time-consuming repurposing of public policy. The measures and instruments used for implementation must be flexible, but they must also deliver an appropriate contribution to environmental protection, to climate change mitigation and to the common good.
The success of the transition to sustainable mobility will be decided not only by cities. New mobility services must have a stronger presence in the regions surrounding large cities in order to ensure as many people as possible can get where they are going.

72 See DST (2016).

73 See Beckmann, K. J. (2013).

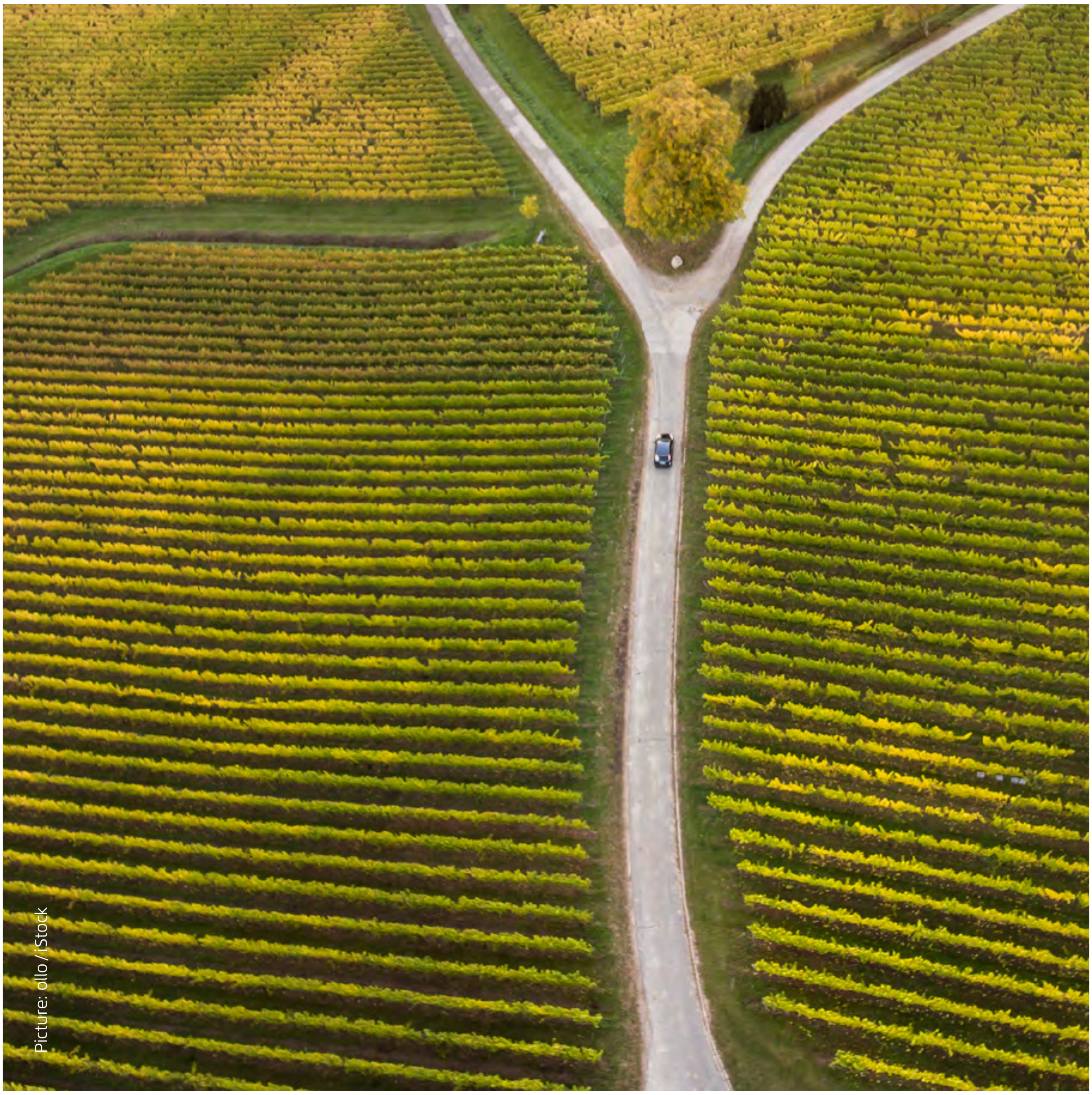
74 See Difu (2015).

75 One example for an expanded range of municipal action is setting the price of resident parking permits. As it stands now, federal guidelines prevent municipalities from aligning permit fees with, say, the economic value of inner-city areas.

76 See also DST (2016)

Insight
04

Rural areas also benefit from the mobility transition.


Picture: ollo / iStock

The choice of transport in inner cities is increasingly diverse. Yet, for the majority of rural residents, cars are the number one means of transport. For longer journeys and even for shorter trips, the car is the most preferred mode of transport for people outside urban areas. Cars are also the predominant form of transport among those going on outings and holiday trips, which make up a considerable share of the total kilometres driven in Germany each year. The immense challenge now is for policymakers to develop climate friendly alternatives to conventional cars. One solution would be to increase efficiency through technological improvements. Another would be to shift transport demand to more environmentally friendly modes.

The majority of Germans live in medium-sized cities and so-called *Speckgürtel* – suburban areas around large urban centres. The dream of owning a house in the country is shared by many. Jobs, however, are usually found in city centres or their outskirts. This has given rise to many roads linking cities with the surrounding countryside and to large volumes of commuter traffic. Together with more flexible working hours and living arrangements, this results in more people who are willing to travel ever greater distances to work and more cars on the road. The further settlements lie apart, the greater the distance each person must travel every day.[77] Subsidies such as commuter allowances and tax benefits for company cars – which increase the amount of harmful emissions released into the atmosphere – only worsen this problem.

Private cars remain important in rural areas

The number of kilometres driven daily is higher in the countryside than in cities. So is the availability of cars. In places with fewer than 50,000 residents, nearly 600 cars per 1,000 residents are registered, whereas in cities with over 500,000 residents, only 360 cars per 1,000 residents are registered.[78] Conversely, the availability and quality of public transport decreases as population density declines. Because cars are so readily available, public transport services cannot compete. Nonetheless, public transport remains a crucial public service for disabled people and those who don't own a car. While in the countryside, alternative transport services such as carpooling platforms and peer-to-peer sharing services are becoming increasingly easier to use as new technologies spread, it will be some time before economically viable business models arise due to scattered demand. Due in part to the provisions of the Public Transport Act (*Personen-Beförderungsgesetz*, or PBefG), a promising approach that has been largely overlooked uses cross-funding programmes between areas of high and low demand.

Today, mobility for residents in rural areas greatly depends on cars and this shows no sign of lessening. To ensure that car use meets climate change mitigation targets, the government must do more to promote electric vehicles. There are concerns about the limited range of battery electric vehicles, but these are easily disproven: electric vehicles can service 80 to 87% of all journeys made by rural and suburban residents.[79] Detailed studies of typical driver profiles show that battery life is sufficient for longer commuter routes as well.[80] 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.[81] Moreover, energy generation at home provides additional benefits. For example, roof solar power panels can produce energy that can be used for charging vehicles at home (Insight 9).

Electrification and cleaner mobility work in concert

Switching to electric vehicles in suburban areas is not the only way to mitigate climate change. There's considerable potential to shift from cars to alternative means of transport that not only are better for the environment but also reduce commuter traffic.[82] Remarkably, people take longer in cities to get to work than in rural areas. Shorter commutes are surprisingly more common in rural areas without large regional centres. On average, 30% of rural commuters need no more than ten minutes to get to work. What is more, 70% of work-

77 See Canzler, W. (2016)
78 Ibid.
79 TAB (2012)
80 Fraunhofer ISI (2014)
81 BMF (2016)
82 See Destatis (2014).

ers living outside urban centres travel by car to work, regardless of commuting times (figure 4.1).[83]

These findings offer starting points for new climate-friendly approaches to commuter traffic. Some 29% of commutes are shorter than five kilometres and 20% are between five and ten kilometres. 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 car – and also cheaper. Businesses have already made good progress in managing new transport solutions such as pedelecs.[84] For some time now, firms have offered company bicycle policies to encourage more workers to ride. If more people are to commute to work by bicycles or pedelecs on a regular basis, however, they will need pleasant, uninterrupted bike paths, express lanes and secure bike parking. Tourists, as well, would benefit from such improvements.[85]

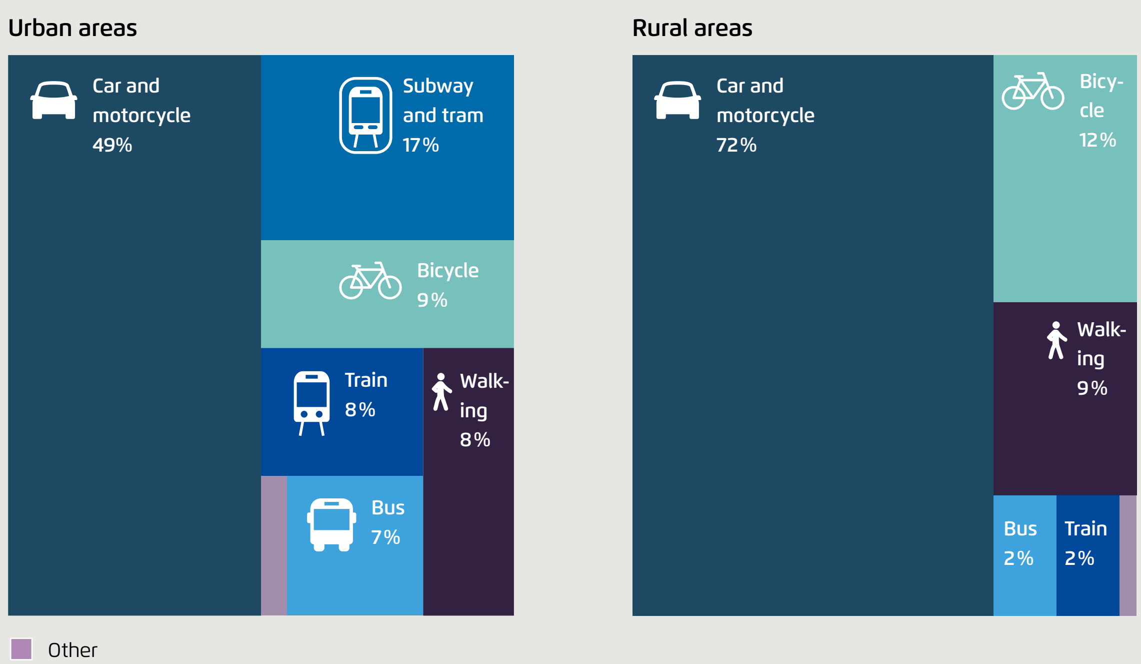
The infrastructure of regional public transport networks also plays a decisive role in commuter behaviour. In regions with good route coverage, commuters take public transit more often. If networks are well connected, people tend to use them more frequently.

Innovations in public transport bring alternative mobility options to rural areas

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 poorly organised, characterised by long waits

83 See Schüller, F.; Wingerter, C. (2016).
84 See Czowalla, L. (2016).
85 See Difu (2016).

Modes of transport used by urban and rural commuters — Figure 4.1



Authors' figure based on Zeit Online (2016) 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 of transport. At least 50% of all trips by the majority of residents regardless of age group are made by car.[86]

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 in rural areas. If this demographic trend continues, an important source of funding for rural public transit could dry up.

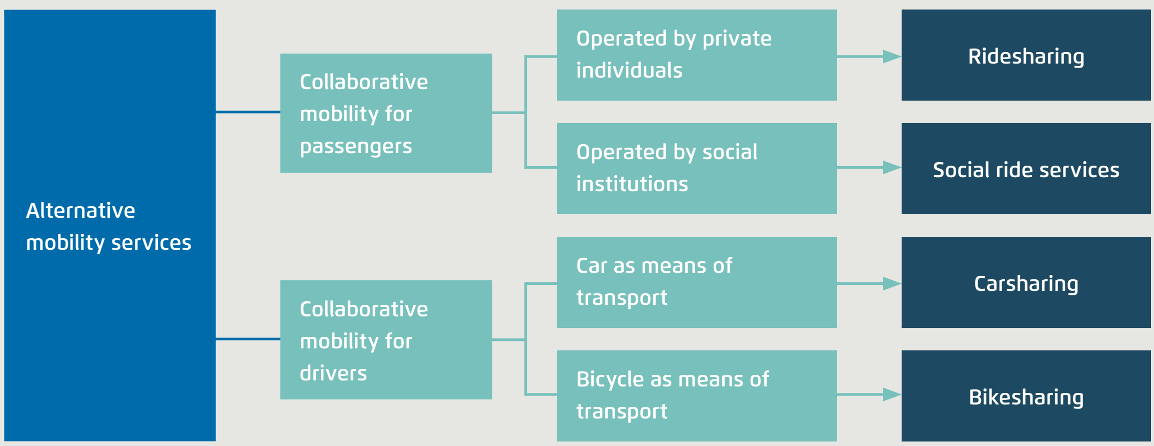
Given this current situation, it is time to rethink and redesign rural mobility (figure 4.2). Current demand for regular bus service can be met by using smaller vehicles instead of larger (but mostly empty) coaches. Such vehicles could be used flexibly on demand and deploy smart routing systems to improve 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 (see Insight 5). 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.

86 See VDV (2016).

Alternative mobility services for rural areas

Figure 4.2



Authors' figure based on BMVI (2016c), p. 29

Insight

05

Driverless vehicles are ideal for shared use.

Picture: svetikd / iStock

Digitalisation is rapidly changing the transport sector. Already today, it influences which modes of transport are used and combined, which routes are taken and which mobility services are on offer. For all that, the digital transformation of the transport sector is still in its infancy. Automation, connectivity, and a rising number of collaborative mobility services will set in motion far-reaching changes in how people get around. These trends offer not only the chance to bring about a safe, efficient and climate-friendly transport sector. They also provide an important foundation for innovative technologies and new business models (figure 5.1).[87]

A closer look at the possible effects of digitisation on the transport sector, however, shows that this process must be understood as an organisational task. It does not necessarily lead to positive effects; it is also associated with risks. Indeed, it could even jeopardise the transport transformation.

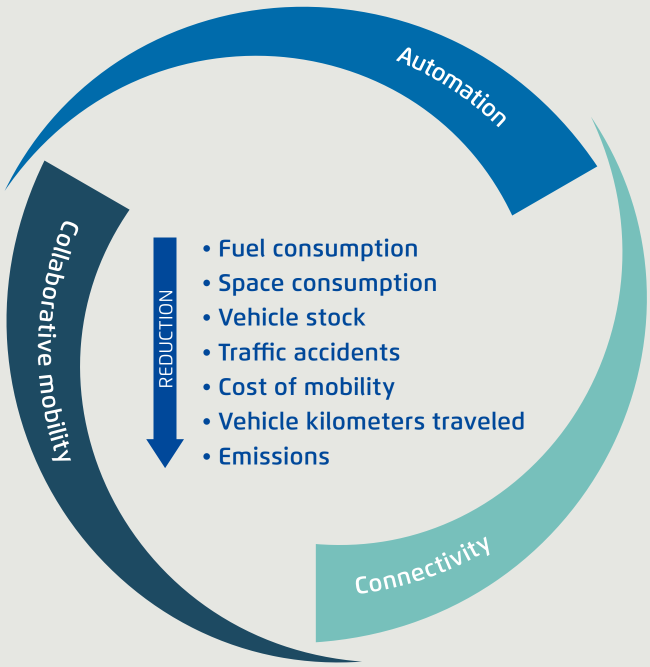
To be sure, digitalisation extends well beyond the transport sector. It has initiated a far-reaching, structural transformation that spans numerous domains. This transformation is impacting jobs in the industrial and service sectors (Insight 11) as well as data security and the resilience of technical systems, to name just a few effects. Clearly, such effects will play a role in determining public acceptance of digitalisation and its influence on the transport system.

Even a small number of driverless cars can increase traffic

Over the past few years, vehicle-automation technology has taken major strides (figure 5.2). With the first fully automated vehicles (level 5) vehicles slated to enter the

87 See Canzler, W.; Knie, A. (2016).

Digitalisation in transport – trends and potentials | Figure 5.1



Authors' figure

market in 2018, attention has mainly turned to safety, reliability, liability and ethics.[88] The German government has already taken note of these developments. Draft bills recently introduced by the German parliament to reform the Vienna Convention and Germany's road traffic laws spell out technical regulations for driverless vehicles and define the scope of driver responsibility.[89]

88 See Driverless Car Market Watch (2016). Tesla's driverless model will appear in 2018; Volkswagen's, in 2019; Daimler's, in 2020; Honda's, in 2020; Nissan's, in 2020; and BMW's, in 2021.

89 See BMVI (2015).

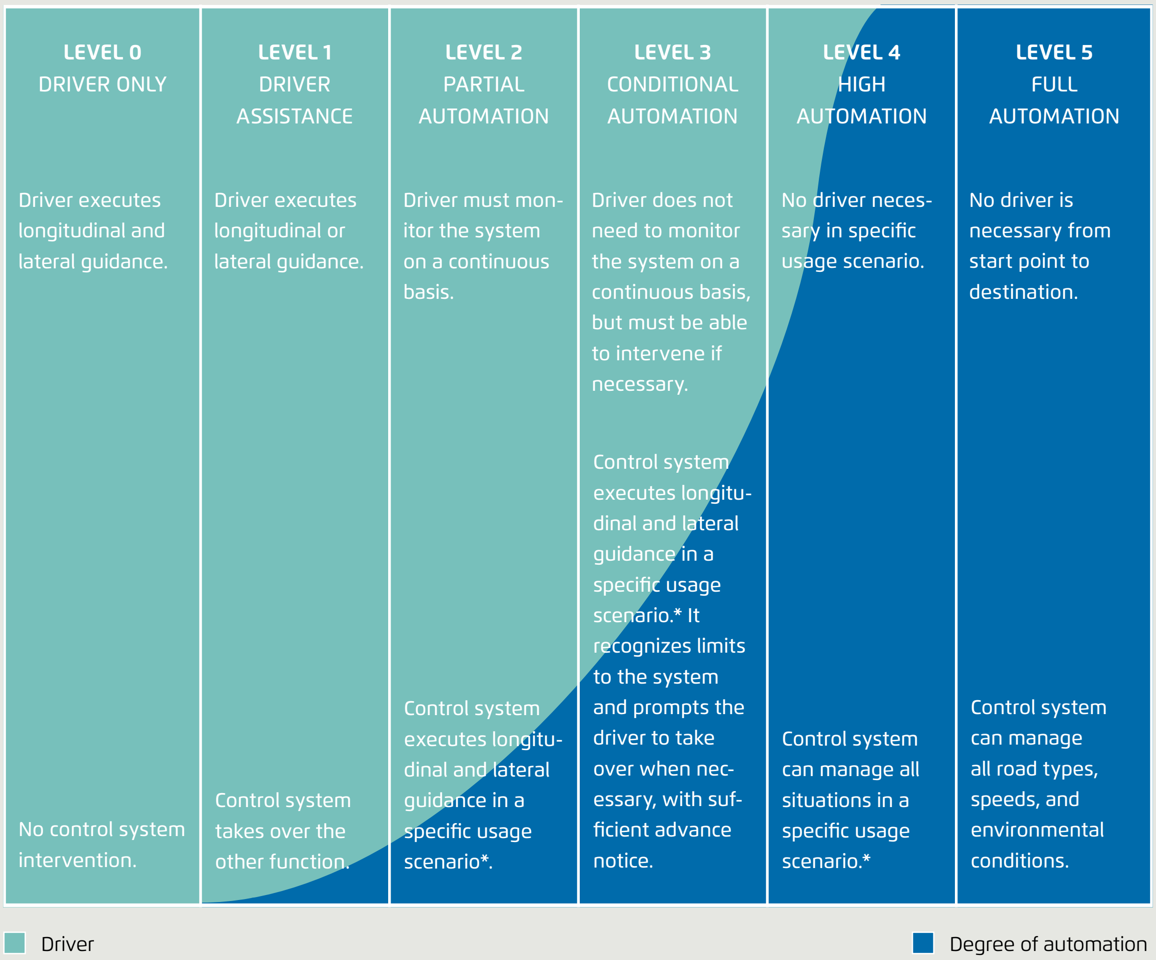
So far, there's been little discussion about how fully automated cars will affect vehicle use, mobility behaviour and, by extension, the environment. But these issues are decisive in whether driverless vehicles will help render the transport transformation a success – or not.

Thanks to automation, driverless cars are expected to operate more efficiently, travel closer to other cars, and make traffic more fluid.[90] While this could reduce fuel and energy consumption, other more disruptive effects

90 See BMVI (2015), p. 10.

Levels of vehicle automation

Figure 5.2



Authors' figure based on VDA (2015), p. 15; *Usage scenarios are based on road types, speed domains and environmental conditions are conceivable as well. A fleet of driverless vehicles, available on demand everywhere and at short notice, could lead to a fundamental reassessment of private vehicle ownership. Collaborative mobility services operated with fully automated vehicles could help shared vehicle use generate wider public support and gain growing importance. As a result, the integration of driverless vehicles into the mobility network is likely to blur the line between private and public transport (see Insight 3).

Preliminary studies of such scenarios in Lisbon, Pittsburgh, Singapore and other places have found that, were all road private and public vehicles fully automated, only 10 to 30% of the existing vehicle stock would be needed to cover current transport needs without restricting mobility – provided that automated vehicles are used collectively, either serially (carsharing) or in parallel (ridesharing).[91] A vehicle reduction of that magnitude would not only sink energy use in the transport sector; it would also give municipalities more room to determine land use and urban development (Insight 3). 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 the less densely populated areas (Insight 4).

The outcome of vehicle automation may not necessarily be positive, however. For instance, it might inadvertently generate more traffic. Owners could program their automated vehicles to circulate in cities without any passengers in order to avoid parking fees. Or people unburdened of driving might be more willing to commute longer distances as the time inside the vehicle can be used more 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 is likely to increase (figure 5.3). Even a drastic reduction of the vehicle stock of up to 90% could generate more traffic if, as previous scenarios have found, many people opt for shared driverless cars and small buses instead of high-capacity public transport.[92]

Hence, even in a future with fully automated vehicles, high-capacity rail- and road-based public transport will be needed to bundle demand and maximise efficiency. When combined with collaborative mobility services, driverless vehicles can provide an important, flexible supplement to fixed-route public transport, and can thus have a positive effect on vehicle demand and output. But strategies will still be needed to minimise the risk of rising distances travelled by private driverless vehicles. Such strategies might need to consider regulatory and fiscal policies, as well.

Despite uncertainty about the effects of automated driving, decision-makers and experts need to consider potential positive and negative effects early on. The general outlook is promising, though. 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 comfortable.

An interlinked transport system contributes to the mobility transition

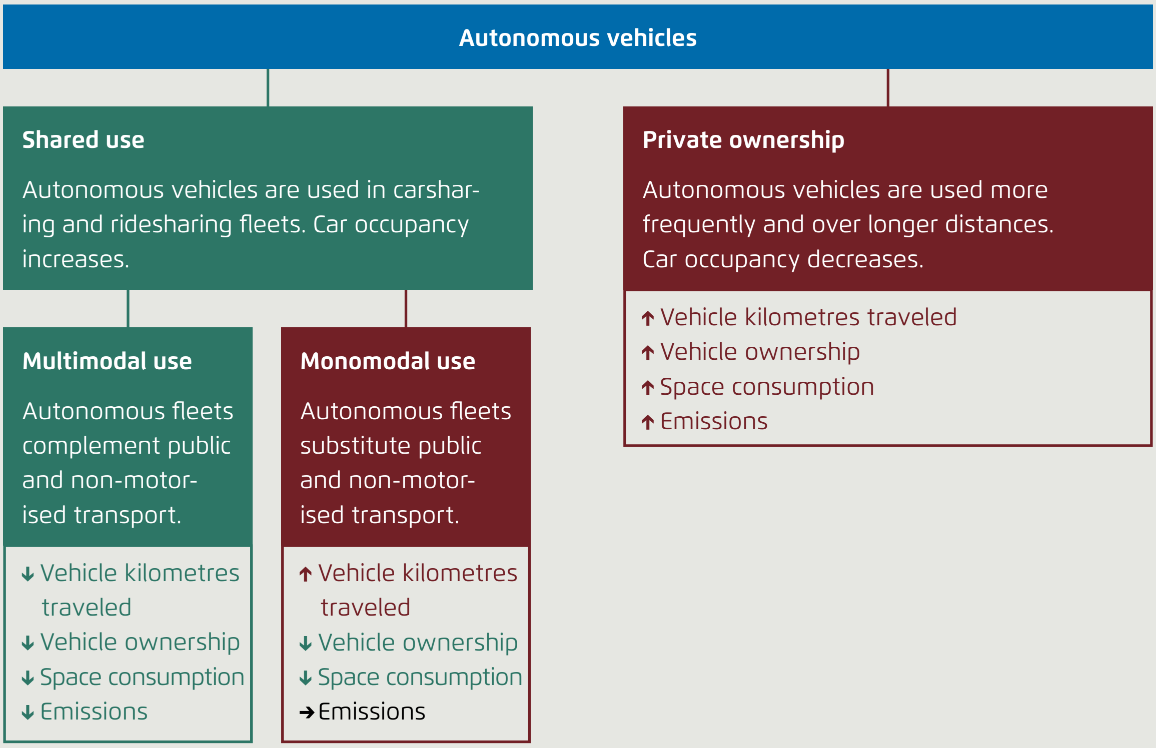
A transport system of the future must include road and rail transport with intelligent infrastructure and traffic control systems (for road signs, parking spaces, light signals and the like). Such a system will pave the way for vehicle automation and lay the groundwork for transport that is safer, more efficient and more climate friendly. Combined with big data applications, it can guide traffic proactively and seamlessly link multi- and intermodal trips. In this way, existing transport infrastructures can be used more efficiently.

Moreover, it can contribute to sustainable mobility behaviour and reduce traffic-related CO_2 emissions, and it can decrease the need for traffic infrastructure. An as yet undervalued benefit of a connected transport system is the added potential for shaping traffic policy.

91 See ITF (2016); Spieser, K. et al. (2014); and Zachariah, G; Kornhauser, M. (2013).

92 See ITF (2016).

Usage forms and possible effects of vehicle automation — Figure 5.3



Authors' figure based on Michael Glotz-Richter

Dynamically priced low emission zones and toll systems (Insight 10) 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.

In a connected system like this, however, every non-connected vehicle could be a source of interference. The question of how to organise a transitional phase containing both connected and non-connected traffic without loss of efficiency and safety remains an open one. But it urgently requires answering in view of the increasing automation of vehicles. Points of discussion include whether cyclists and pedestrians can and should be included in a connected transport system, whether separate infrastructures are needed for interlinked and fully automated modes of transport, and whether automated driving modes should only be allowed in special areas, such as rural roads or highways.

Automation is easier to implement with rail transport than with its road-based counterparts. Urban rail systems that use a single mode of transport offer more favourable conditions for connected and automated transport. Driverless trains can improve punctuality, timing and energy efficiency through, say, shorter safety gaps and more economical operation.

Smartphones are key for connected mobility

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. Moreover, they are increasingly important for the analysis of changes in mobility behaviour, and thus provide important information for multimodal, integrated transport planning.

Smartphones allow people to access a variety of mobility services – including station-based and free-floating carsharing vehicles – quickly and whenever they need them (figure 5.4). At the same time, smartphones are increasingly used to plan trips with single and multiple modes of transport.

With smartphone apps, users can enter preferences such as time, costs and CO_2 emission levels to calculate optimal routes and in many cases reserve and purchase tickets for inter- and multimodal journeys ahead of time. Smartphones make users part of a connected transport system that provides pertinent information about their mobility choices in real time. They make inter- and multimodal mobility simple, comfortable and economically transparent.

In cities, smartphones are already shaping the shift to intermodal and multimodal mobility – and it will continue to influence the organisation of mobility in the future. For smartphones to achieve their potential, it is crucial for start-ups to develop new, innovative mobility solutions. Yet traditional companies in the transport sector must also embrace digital technology. 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 with electronic ticketing.

It is important, however, that smartphone-centred mobility does not create a digital divide; comparable information, booking and payment systems must exist for people without smartphone as well. One example is the planned elimination of paper tickets and their replacement with eTickets by the end of 2018. With the new system, tickets can be purchased via smartphones or, if they are unavailable, with electronic chip cards.[93]

Many still underestimate the potential of smartphones for research and planning. Traditional methods of collecting data such as traffic censuses, questionnaires and travel diaries can barely keep up with the increasing variety of mobility services on offer. The use of mobile devices enables detailed analysis of mobility behaviour while reducing the effort people must make to share data. Mobile devices can significantly improve the detail, scope and reliability of data used in long-term studies and traffic simulations. The need for establishing digital methods of data collection in transport research and planning is plain. The potential of smartphones is not restricted to individual benefits.

For instance, Germany's national cycling plan for 2020 (Radverkehrsplan 2020) has shown that smartphone-based data collection provides a valuable contribution to demand-oriented planning of transport hubs and junctures for intermodal mobility.[94]

Connected mobility and data privacy do not conflict

Each day, smartphones and modern cars collect enormous amounts of transport data – from apps for route planning, from the use of new mobility services or from navigation devices in private cars. As transport systems have been more automated and connected, questions of availability, ownership, use and privacy of this 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 and use of collected data and allowed to decide whether to share it. A "privacy by default" design can guarantee users the control of own personal data and for the most part avoid privacy disputes.[95] To avoid the restriction of data usage, personal data can be processed by being anonymised or pseudonymised.[96] In this way, large amounts of information

93 See Mobilität21 (2016).

94 See Nationaler Radverkehrsplan 2020 (2016).

95 See von Schönfeld, M. (2015).

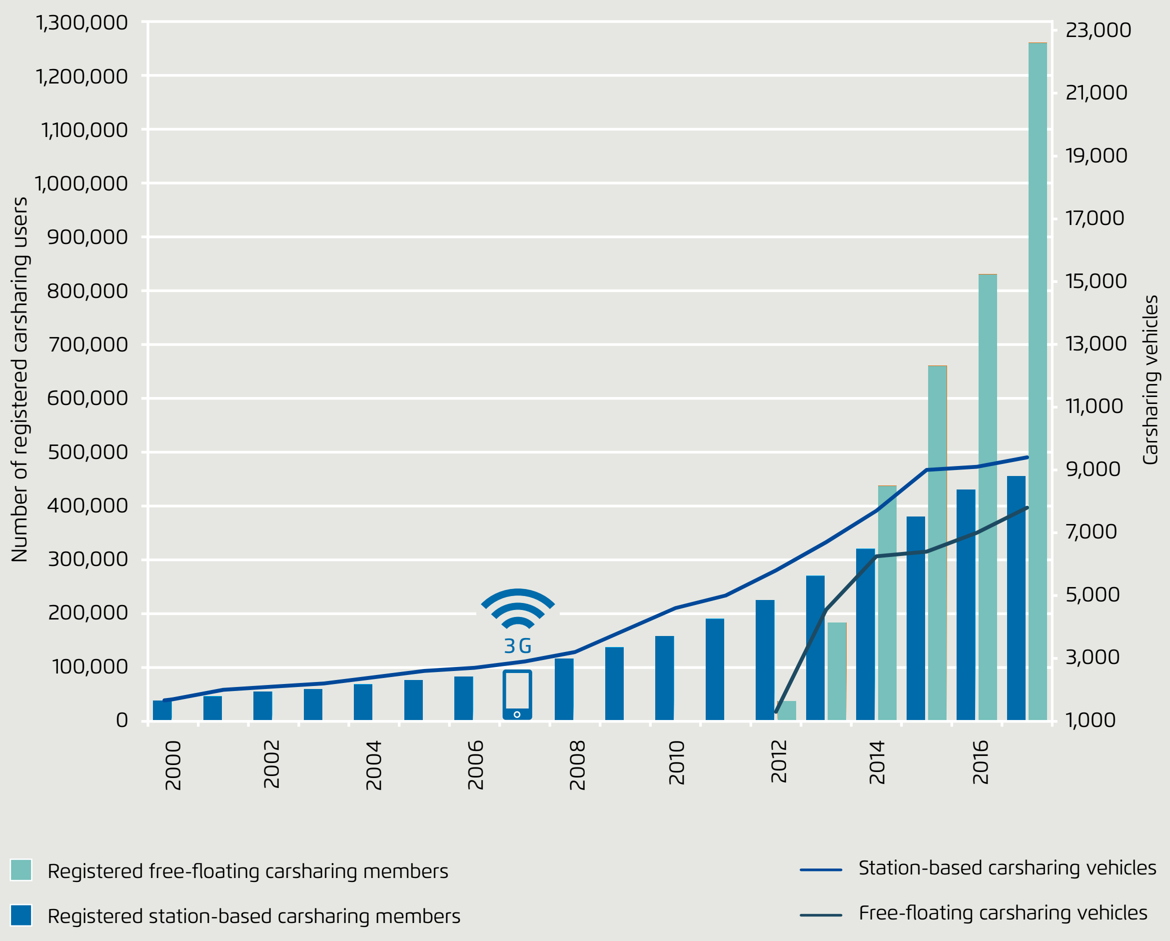
96 The Federal Data Protection Act (Bundesdatenschutzgesetz, BDSG) defines anonymisation as "means the modification of personal data so that the information concerning personal or material circumstances can no longer or only with a disproportionate amount of time, expense and labour be attributed to an identified or identifiable individual" (Sec. 3, para. 6). It defines pseudonymisation (also called aliaising) as "replacing a person's name and other identifying characteristics with a label, in order to preclude identification of

can be recorded for, say, big-data applications, without violating the principle of data minimisation enshrined in Germany's data privacy laws[97]

Another requirement alongside data privacy is the nationwide availability of public mobility and infrastructure data. Providing source maps, timetables, price information, real-time weather data and accident alerts creates a level playing field and promotes new, innovative mobility services. The availability of public information 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%, and generate economic savings of around 28 billion euros.[98] To unlock the potential of transport data applications, national open data regulation can govern the disclosure of data in a uniform standard and safeguard its availability on an online portal.[99]

the data subject or to render such identification substantially difficult" (Sec. 3, para. 6a).
97 See von Schönfeld, M. (2015).
98 See EU COM (2015).
99 In Germany, the Mobilitäts Daten Marktplatz (MDM) has already started doing this. See MDM-Portal (2016).

Growth in station-based and free-floating carsharing in Germany — Figure 5.4



Authors' figure based on BCS (2017)

Field testing paves the way for innovation

Though the digital revolution has arrived in the transport sector, little reliable empirical data exists on the climate effects of new mobility services. Indeed, more experience is needed with real-life operation to prepare technology for series production and to investigate the effects of innovative mobility services on mobility patterns and travel behaviour.

Germany has already begun to try out new approaches in the transport sector. These include an incentive program to encourage the use of electric vehicles (*Schaufenster Elektromobilität*)[100] and digital testing areas for automated and connected mobility.[101] But much of this testing is focused strongly or almost exclusively on technology. Only in a few cases has the integration of innovative mobility services with the transport system been the focal point. But experimentation in this area could generate valuableinformation about the potential of digitalisation. Among other things, policymakers should discuss the promotion of new mobility services such as ridesharing by loosening or temporally repealing the Public Transport Act. This will encourage ridesharing and allow information about its public support and influence on travel behaviour to be collected for designing innovative regulation (such as widening the scope of the experimentation clause of Art. 2, para. 7 of German Public Transport Act).[102]

To better promote experimental approaches like these in Germany, politicians must understand that they play a vital role in pioneering transport sector innovations. Following examples abroad, they must discuss how best to create more room for experimentation.[103] For instance, field testing could be carried out for fiscal policy instruments such as the introduction of low emission zones and new parking management strategies and for the promotion of cooperation between, say, traditional transport sector companies and new mobility services.

In any case, it's important to coordinate planning authorities at the regional and municipal levels, accompanied by transparent, systematic study of experiences in the field. This ensures that insights gained can be applied elsewhere – for example, to uncover shortcomings in common approaches to transport management. At the same time, field testing can deliver reliable knowledge about the validity of traffic models and strategies for decarbonising the transport sector.

100 See Schaufenster Elektromobilität (2015).
101 See BMVI (2016b).
102 A passage from that clause reads: "For trying out new types or means of transport in the field, the approval authority can, when requested in special cases, approve exemptions from provisions in this act or enacted on the basis of this act for the duration of up to four years, provided that it does not conflict with public transport interests."
103 One example is the loosening of taxi legislation in the Swiss canton of Geneva to allow the testing of ridesharing services in real-life operation. See *Tages-Anzeiger für Stadt und Kanton Zürich (2016).*

Insight
06

Electrification is key to an energy transition in transport.

Picture: suze/photocase.de

Despite more efficient traffic planning and new mobility habits, motorised vehicles will continue to produce significant traffic volume in the coming years. 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.[104] 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 German Climate Action Plan 2050 calls for the decarbonisation of the transport section and for Germany to be a leading marker and provider of electric vehicles. Moreover, it aims to reduce the cost and increase system reliability for hydrogren.[105] But the legal framework for reaching these aims needs more work. The experience gained with renewables has shown that new markets arise provided investors believe the framework is reliable. Creating this framework is a task for lawmakers.

104 See OECD, ITF (2017).
105 See Bundesregierung (2016d).

Battery electric vehicles are the standard for efficiency and low-cost operation

The electrification of road transport is a general term covering various types of vehicles:

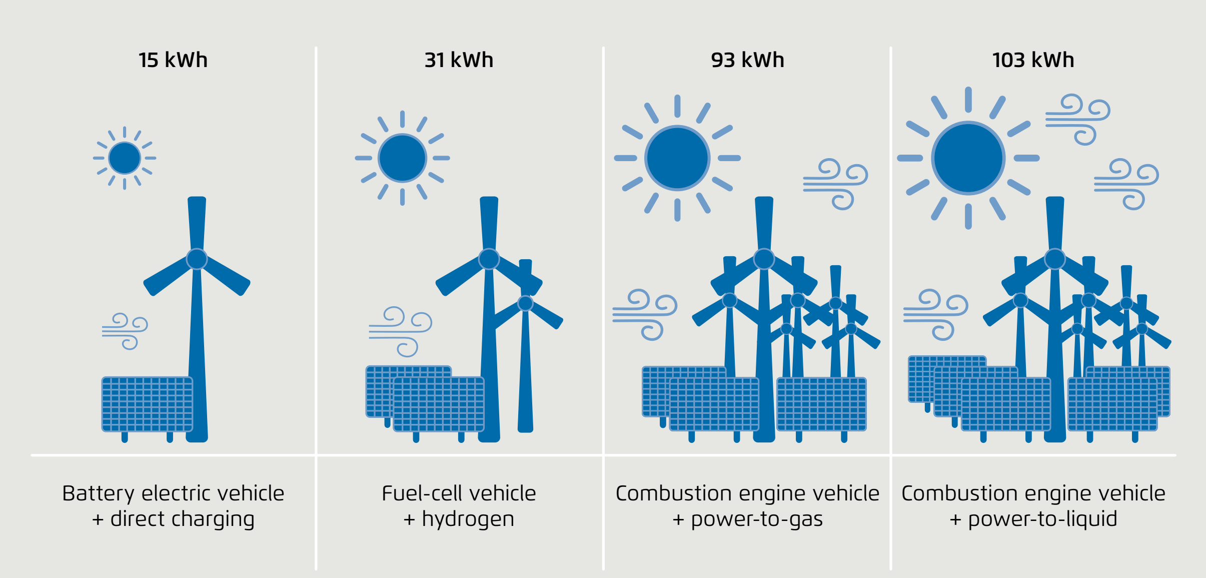
- Battery Electric Vehicles – BEV,
- Range Extended Electric Vehicles – REEV,
- Plug-in Hybrid Electric Vehicles – PHEV,
- Fuel Cell Electric Vehicles – FCEV.[106]

Each type of electric vehicle is more efficient than a combustion engine and is of central importance for the clean-energy transformation of the transport sector.

106 According to sec. 2 of Germany's 2015 Electric Mobility Act (Elektromobilitätsgesetzt, EmoG), an electric powered vehicle is "an entirely battery electric vehicle, a chargeable hybrid electric or a fuel cell vehicle."

Amount of renewable energy required for various powertrain and fuel combinations (per 100 km)

Figure 6.1



Authors' calculations and figure based on DLR, Ifeu, LBST, DFZ (2015), p. 15

Provided electricity is generated from renewables, the electrification of road transportation will play a vital role in the decarbonisation of land-based transport. Without it, this project will be almost impossible to realise.

Of the above technologies, battery electric vehicles (BEV) are particularly advantageous because they use renewable electricity directly without transforming it into other forms, thus avoiding conversion loses.[107]

This efficiency advantage in the entire process chain means that battery electric vehicles require the least amount of renewable electricity of all other decarbonisation options over a 100-kilometer trip. (See figure 6.1; for more on fuels, see Insight 7.) The second most efficient type is fuel cell electric vehicles (FCEV) running on hydrogen generated from renewables. Much less efficient are cars with combustion engines that run on renewable gas or renewable liquid fuel.

The direct electricity use in battery electric vehicles for road transport is not only the most efficient energy option. On the basis of the current state of knowledge, it is also economically the most affordable form of decarbonisation. Relative to all other combinations of powertrains and fuels, battery electric vehicles cause the least amount of additional costs compared with a reference scenario without decarbonisation (figure 6.2).[108] The cost balance takes into account all costs from today until 2050 for energy supply, petrol stations, charging station infrastructure and vehicle acquisition.[109] Battery electric vehicles are the standard on which other powertrain and fuel combinations must be measured.[110]

Electrification can be a means of decarbonisation not only for passenger cars but also for light utility vehicles. Short trips in cities and back to-base trips[111] are particularly suitable for commercial transport and fleets. Smaller trucks can use the same energy supply and powertrain concepts as passenger vehicles.[112] Even for larger truck models, pure electric engines are a possibility. Electric buses are already being used, especially in urban areas. In Germany, there are pilot projects with hybrid busses, plug-in hybrid buses and an increasing number of electric busses. Some of these can be charged without cable.[113] Reducing noise and air pollution is an important motivation for the electrification of road transport, especially buses and light utility vehicles in urban areas (Insight3).

Economic optimisation is important for assessing future technology options, but it is not always adequate for the successful use of new technologies. Factors such as public acceptance of alternative powertrain systems and how well they can be integrated into the energy system should not be neglected. It is very possible that, in addition to battery electric cars, other alternatives such as fuel cell electric vehicles will play an important role. And it is likely that a mix of different vehicles with alternative powertrain systems will be used. The exact composition of this mix mostly depends on the development of prices and ranges.

107 The hydrogen for fuel cell vehicles must be produced from wind and solar energy, not from fossil-based fuels and natural gas, if it is to contribute to decarbonisation. For more on fuels, see Insight 7.

108 In the reference scenario used by this study, conventional fuels (petrol, diesel, kerosene, crude oil) will continue to be the main energy sources for the transport sector in 2050. See Öko-Institut, KIT, INFRAS (2016).

109 See Öko-Institut, KIT, INFRAS (2016). Figure 6.2 shows only local road traffic. In the cited study, the term "local road traffic" refers to motorised individual transport with passenger cars, motorcycles, light utility vehicles and trucks up to 18 metric tonnes. The study produces similar findings for long distance road transport. For more on freight transport, see Insight 8.

110 Given the dynamic nature of this field, these cost prognoses are subject to change, in which case a new assessment will be needed.

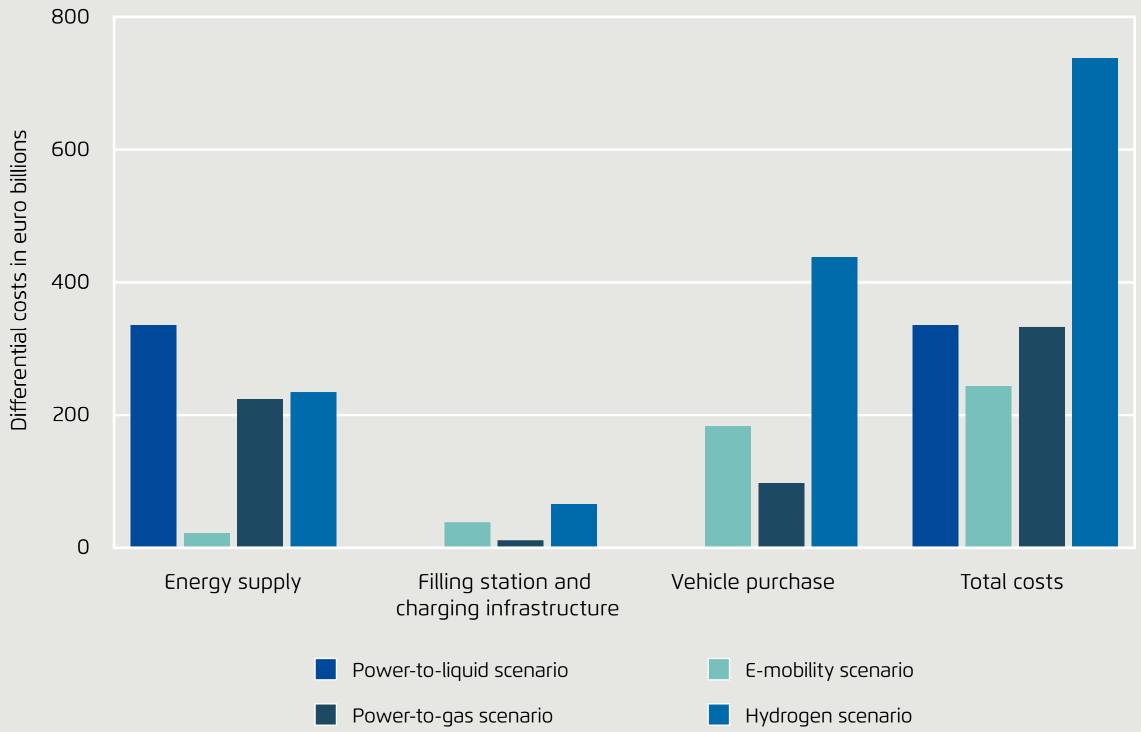
111 These are trips in which vehicles return to a charging station after reaching their destination. See *Schaufenster* Elektromobilität (2015).

112 See INFRAS, Quantis (2015); Ifeu, INFRAS, LBST (2016).

113 See NOW (2016).

Road traffic (without long-distance freight traffic): Differential costs in comparison to reference scenario for 2010 to 2050 period (positive: higher costs)

Figure 6.2



Authors' figure based on Öko-Institut, KIT, INFRAS (2016), p. 74

Lower prices and greater ranges make electric vehicles more attractive

High purchase costs, concern about range and a lack of charging opportunities are the main obstacles today keeping people from buying electric cars. For the success of fuel cell electric vehicles, the initial outlay is also a decisive impediment, as is the fuelling station infrastructure, which is a long way from covering the nation. But these factors will change noticeably in the coming years as the climate target benchmark years of 2030 and 2050 get closer.

In the past decade, battery price projections have undergone a downward correction. Between 2008 and 2015, the forecasts for plug-in hybrid batteries dropped by 73%.[114] Costs for electric vehicles and fuel cell electric vehicles are projected to drop considerably as well.[115] For instance, costs for battery packs in 2015 were projected at 250 €/kWh. Between 2020 and 2025, they are expected to drop to 100 €/kWh. Prices for electric cars in the next few years are predicted to fall faster than predicted in previous studies.[116]

Amid rising costs for internal combustion engine cars (a result of higher emissions standards) and falling battery prices a question has arisen: when will electric cars achieve cost parity with internal-combustion engine vehicles? Some use scenarios project that electric car prices will be able to compete with traditionally powered vehicles somewhere between 2023 and 2030.[117]

114 See IEA (2016a).

115 See ICCT (2016b); Öko-Institut (2014); ICCT (2016c).

116 See ICCT (2016d).

117 See NPE (2016); ICCT (2016b); ICCT (2016d).

Car manufacturers in Germany and elsewhere have taken note and announced ambitious electric vehicle sales targets for 2020–2025.

Increasing battery capacity has extended ranges per charge.[118] Several major car manufacturers have stated that by 2020 their vehicles will have ranges exceeding 400 kilometres. If these can be reached in real-life use, concerns about limited range will no longer be an impediment to prospective buyers, especially because the range of fuel cell vehicles will also not be much higher.

There is more uncertainty about how costs for fuel cell vehicles will develop, though. Here too, prices are expected to fall as more units are sold.[119] Current forecasts for the 2030–2050 market penetration of fuel cell vehicles vary enormously.[120] The industry leaders that make up the Hydrogen Council believe that, measured by the total cost of ownership (TCO), fuel cell vehicles have the potential to achieve cost parity with medium- und large-sized passenger cars by 2025.[121]

Despite the promising technological developments in road transport electrification, it is not yet clear whether they can take hold quickly enough to provide the needed contribution to the decarbonisation of the transport sector. Crucial for this is not least the development of an appropriate legal framework. Germany's current aim of putting six million electric vehicles on the road by 2030 will probably not suffice to reach the ambitious reduction targets of 40 to 42% relative to 1990 levels set down in the 2050 Climate Action Plan. Hence, 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, such as the tried and trusted approach of adopting emissions standards. At the same time, regulation must be geared towards 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. Many have proposed accompanying this strategy with zero-emission vehicle mandates like the ones used in California or mentioned in China's latest draft policy. Should EU regulation not be enough for Germany to reach its climate targets in the transport sector, further national measures will be needed. One strategy that could be considered is a reform of the motor vehicle tax.

Access to quick and reliable charging is essential

Two of the impediments for more widespread public acceptance of electric vehicles are the lack of charging stations and long charging times. It's not enough that most owners can charge their vehicles at home. Sufficient quantities of publically accessible charging stations must be available as well, especially in cities. Furthermore, the charging infrastructure must be aligned with users' needs and grow in accordance with the market penetration of electric vehicles. Three factors make investment in charging infrastructure difficult, however. First, charging technology is rapidly changing, as the issue of inductive charging shows. The same goes for the communication infrastructure of electric vehicles. Finally, the charging infrastructure must be designed in a way that benefits the power system. Together, these factors pose complicated challenges for the private sector and for policymakers.

The establishment of a suitable nation-wide network of publically accessible charging stations is the stated goal of the German federal government[122]. The current plan provides for 36,000 standard charging stations and 7,000 rapid charging stations by 2020. The federal government has earmarked 300 million euros to encourage the construction of 10,000 standard charging points and 5,000 rapid-charge stations by 2020.[123] The program is also designed to create an appropriate infrastructure for hydrogen and fuel-cell technology, with the aim of

118 See ICCT (2016c).

119 See ICCT (2016b); Öko-Institut (2014); McKinsey (2010).

120 See TAB (2012). Cf. ICCT (2016b)

121 Hydrogen Council (2017), p. 9: "When FCEVs reach at-scale commercialization, we are confident that cost parity (from a TCO perspective) can be reached by 2025 for medium to large passenger cars."

122 See LSV (2016). The Ladesäulenverordnung, Germany's charging regulation enacted on 9 March 2016, defines charging points "as a suitable device designed to charge a one electric vehicle at a time" (Sec. 2, no. 9). By contrast, a charging station can have multiple charging points.

123 See BMVI (2016e).

establishing 400 hydrogen stations by the middle of the next decade. Public funds through 2026 have also been set aside for this purpose.[124]

In the long term, however, charging infrastructure should not rely on public funding alone. Rather, expansion must be supported by a mixture of private investment and seed funding from the state. The private sector is on the verge of an investment wave in charging stations for electric vehicles.[125] Companies in the automobile, gas and oil industries are planning to build the first 100 hydrogen stations by 2018 or 2019.[126]

What remains unclear which business models will be affordable yet profitable, especially for quick charging stations. The priority for lawmakers now should be to provide reliable conditions for investment.

Electrification requires a strategic approach

The growing number of efficient cars and vehicles with alternative powertrains will decrease Germany's dependency on foreign oil. However, the acquisition of resources for battery manufacturing can produce dependencies on other imports and cause new environmental problems. Moreover, this can lead to resource competition if, for example, resources for decarbonisation are required by different sectors at the same or if other applications have higher demands. Developments here need to be carefully observed in order to avoid or minimise (physical or economic) supply shortages. Discussions of the environmental effects of electric vehicles – such as the manufacture and disposal of batteries – should keep in mind that the long-term problems caused by combustion engines are no less challenging when it comes to climate change, the environment and raw materials.

What is undisputable, however, is that a quick expansion of the market share of electric vehicles will raise questions about how to meet the demand for resources and cope with shortages. As the number of units sold increase, so will the demand for battery cells, most of which are now produced in Asia.[127] This will bring additional import dependencies, whether directly through the import of batteries or indirectly through the demand for raw materials used to manufacture the battery cells. The German National Platform for Electric Mobility (*Nationaler Plattform Elektromobilität*, or NPE) projects that shortages in natural graphite and cobalt could occur.[128] The availability of these and other resources such as lithium 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. The electrification of road transport requires new, comprehensive and proactive strategies that protect the environment while also securing resources.

124 See Bundesregierung (2016d).
125 In November of 2016, Daimler, BMW, Ford, Porsche and Audi announced a planned joint venture for a Europe-wide network of rapid charging stations. See BMW Group et al. (2016). Tesla now operates its own rapid-charging network in Europe and has now built 56 supercharger stations in Germany. See FAZ (2016).
126 See H2 mobility (undated).
127 See NPE (2016).
128 See NPE (2016); Ifeu (2016).

Insight
07

Carbon-neutral fuels can supplement wind and solar energy.

Picture: TeerawatWinyarat / iStock

The shift to alternative powertrains for cars, light utility vehicles, buses and freight transport vehicles is an important contribution to the decarbonisation of the transport sector, but it's not enough. For instance, experts believe that ships and airplanes will continue to require liquid or gas fuels for the foreseeable future.

Fuels for the energy transition in transport must be carbon-neutral. 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.[129]

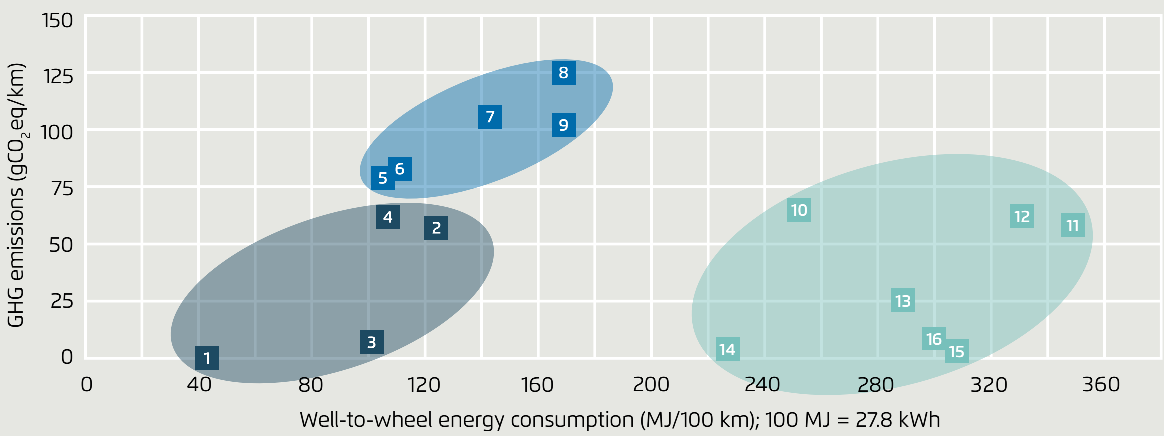
The climate and energy policies for the fuels of the future must take into account GHG emissions and well-to-wheel energy consumption for fuels. Due to their high levels of GHG emissions, traditional liquid fossil fuels must phased out if the transport sector is to be decarbonised (figure 7.1).

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.

Figure 7.1 shows that electricity from renewables is cleanest and most efficient in battery electric vehicles (BEV) and fuel cell electric vehicles (FCEV). A number of electricity-based fuels also perform quite well when it comes to emissions. Yet like biofuels, they consume more energy and are less efficient than electricity used

129 See INFRAS, Quantis (2015).

GHG emissions relative to energy consumption in 2020 (well-to-wheel) Figure 7.1



Electric vehicles
1 Electricity in BEV (wind)
2 Electricity in BEV (EU mix)
3 Hydrogen in FCEV (wind)
4 Hydrogen in FCEV (reforming of natural gas)

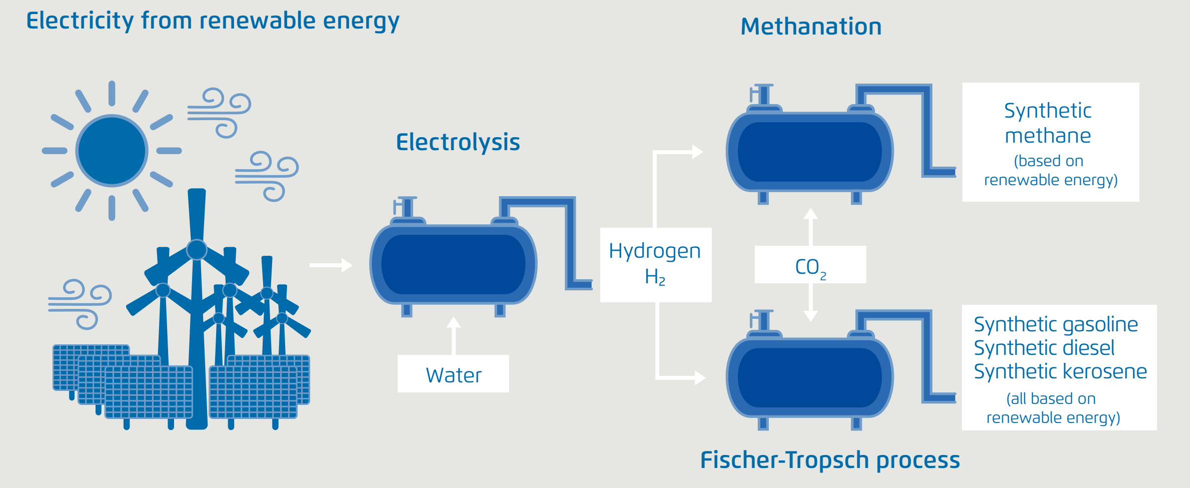
Fossil fuels
5 Hybrid diesel (petroleum)
6 Hybrid gasoline (petroleum)
7 Diesel (petroleum)
8 Gasoline (petroleum)
9 Natural gas (CNG)

Biofuels and synthetic fuels
10 Biodiesel (rapeseed)
11 Ethanol (sugar beet, used in E10 blends)
12 Biomethane (maize)
13 Biomethane (municipal waste)
14 Syndiesel (B2L, waste wood)
15 Syndiesel (P2L, renewable electricity)
16 Synmethane (P2G, renewable electricity)

Figure based on JRC, EUCAR, CONCAWE (2014b)

Production process for hydrogen, P2G methane and P2G fuels from sun and wind

Figure 7.2



Authors' figure

in electric batteries and fuel cells. Furthermore, the GHG emissions depicted in figure 7.1 might be far greater on account of indirect land use change (ILUC).[130]

Carbon-neutral fuels can supplement electricity but they are no substitute

Converting electricity into fuel requires several steps. First, electricity is used to produce hydrogen from water. Hydrogen can be used directly in fuel cell vehicles or it can be converted into methane gas via P2G (power-to-gas) technology or into liquid fuels using a P2L (power-to-liquid) procedure. The resulting fuels are carbon-neutral only if the electricity used for their generation comes from renewables (figure 7.2).

130 The effects of land use change are not included in the calculations of JRC, EUCAR, CONCAWE (2014b). The reasons are discussed in more detail in JRC, EUCAR, CONCAWE (2014a), p. 10: "We do think these effects [of Land Use Change] are likely to have a significant impact on results, but the current state of knowledge does not allow us to estimate them with confidence."

Presently, the conversion of renewable electricity into fuels is being tested at several pilot facilities but has yet to be commercialised. A large-scale generation of sustainable electricity-based fuels requires more renewable power than is currently available. Experts are now studying whether, when and how P2G/P2L plants can become economically viable and climate friendly.

Electricity-based fuels have one significant disadvantage relative to direct electricity for battery electric vehicles: high conversion losses. The losses from hydrogen production are lower than P2G and P2L as only one conversion step is necessary.

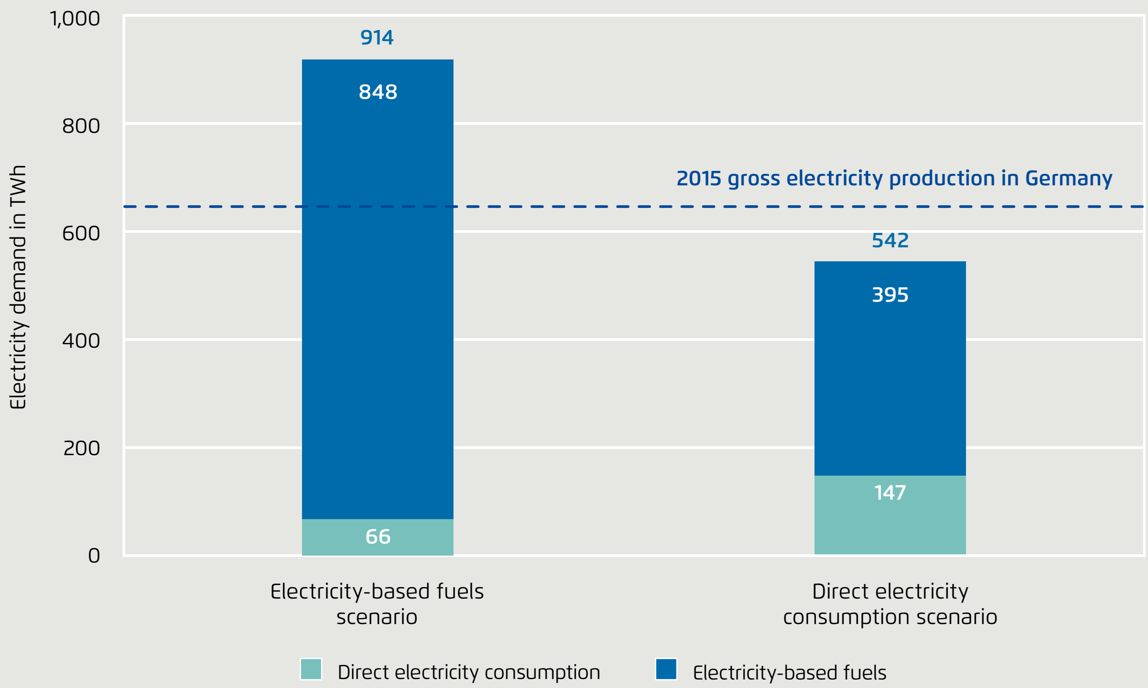
If the transport sector were decarbonised for the most part using electricity-based fuels, electricity demand for transport could amount to 914 terawatt hours (TWh) by 2050 (figure 7.3). This is more electricity than Germany's gross electricity generation in 2016.[131]

A decarbonisation strategy that relied mostly on direct electricity would require less energy. Such a strategy

131 This conversion is based on data from the Öko-Institut (2016). In 2016, gross electricity production in Germany amounted to around 648.2 TWh. See AGEB (2016b).

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

Figure 7.3



Authors' calculations and figure based on Öko-Institut (2016), p. 20 and AGEB (2016b)

would push technological efficiency, and encourage the use of electric vehicles and the construction of overheard contact lines for trucks (Insight 8). But even in this scenario, electricity demand would be very high – 542 TWh – because airplanes and ships would still rely on electricity-based fuels.[132]

Two consequences can be drawn from these scenarios. First, the use of carbon-neutral fuels should be reserved only for modes of transport that are unable to use electricity directly.

This applies first and foremost to air traffic, which for the foreseeable will have no alternative power save carbon-neutral drop-in fuels. The same goes for ships. And like airplanes, they must be made carbon-neutral within a few decades. The second consequence is that carbon-neutral fuels, while providing a necessary supplement to direct electricity use for individual modes of transport, are not a practical option for every segment.

132 This conversion is based on data from the Öko-Institut (2016).

Sustainability standards ensure the integrity of electricity-based fuels

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. This, coupled with concerns about production costs, is a sure sign that electricity-based fuels will also have to be imported.

In the face of this near certainty, Germany must push for carbon-neutral renewable electricity both in and outside its borders. In this connection, sustainability criteria must be defined requiring solar sites to have sufficient quantities of water for hydrogen generation. Such criteria should also define other basic conditions for the sustainable production of these fuels. These criteria should be drafted and internationally ratified as soon as possible.

As of today, little is known about the world's sustainable potential for these fuels. This, and the fact that its commercial production is still being tested, further underline the importance of using them only where no alternatives are available.

The example of 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 energies in final energy consumption of the transport sector in 2015 was just over 5%, with biofuels making up the largest share.[133] If they are to contribute to the complete carbonisation 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 limit potential benefits.

For instance, food-based biofuels take up valuable arable land that could otherwise be used for food production. As demand for biofuels grows, there'll be more pressure on communities to cultivate areas not being used for agriculture, giving rise to indirect land-use change (ILUC). Converting untouched areas or natural preserves into agricultural land is likely to release greenhouse gases and destroy the habitats of many plants and animals.[134]

The world's potential for sustainable biomass, therefore, is limited. Fuels from sustainably produced biomass in Germany will not be enough to replace growing amounts of diesel and petrol. The same goes for the rest of the world. A noticeable increase of the share of biofuels in the global fuel supply above today's level of 3% would lead to massive increase in agricultural land.[135] In addition to indirect land-use changes, this would create more conflicts between the energy and food production industries.

133 See BMWi (2016b).

134 See BMVBS (2013).

135 See IEA (2016b).

From the vantage point of mitigating climate change, then, biofuels from cultivated biomass offer neither the quantity nor the quality of energy needed from a viable alternative to fossil fuels.

Biofuels from waste and residual products are different from biofuels from cultivate biomass in that they do not compete with agricultural land for human food and livestock feed.

But the quantities of these biofuels in Germany are limited – too little, at any rate, to make a difference in the transport sector. The same goes for other countries. Globally, second-generation biofuels from agriculture and forestry waste products can only provide a maximum of between 13 and 19 exajoules (EJ). By contrast, the global final energy consumption of the traffic sector is estimated to range between 100 and 170 EJ by 2050.[136]

If biofuels are to contribute to decarbonisation, Germany and Europe must pass legislation that ensures a large reduction of greenhouse gases, adherence to sustainability criteria and the elimination of ILUC. It is doubtful whether the new EU directive currently under discussion to promote renewable energy use (Renewable Energy Directive, RED II) will provide adequate incentives to achieve the needed level of fuel decarbonisation while meeting sustainability requirements.

Whether biofuels, carbon-neutral fuels or hydrogen, none of these potential propulsion energies is without its problems. For each one, questions about infrastructure, technology promotion, import dependencies, volume potential and economic costs must be answered. These issues must also 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.

Government policies will shape the phase-out of oil and natural gas

In the long run, fossil fuels need to be replaced by electricity and climate-neutral fuels. But achieving this will require a more coherent regulatory framework.

136 See INFRAS, Quantis (2015), p. 16.

Take energy taxation policies. As they have developed historically, they have come to serve mixed objectives. In fact, fuel taxes are not primarily geared towards the decarbonisation of the transport sector.

They primarily serve other aims – e.g. fiscal policy or competition policy. But these aims can conflict with one another. For instance, the energy tax is an important source of state revenue. Nevertheless, competition policy aims to ensure that the German haulage industry is not disadvantaged relative to its European competitors. This has led to tax cuts for diesel fuel, depriving the state of almost 8 billion euros of annual revenue.[137]

Tax on diesel is 18.41 euro cents 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. A uniform taxation of diesel and petrol based on its energy and CO_2 levels would be a first step towards the complete replacement of fossil fuels with climate-neutral electricity.

137 See UBA (2016b).

Insight
08

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


Picture: Bim /iStock

The freight transport sector is growing, and with it, CO_2 emissions. In 2004, the total weight of goods shipped in Germany amounted to 4 billion metric tonnes. Within 10 years, it had risen to 4.5 billion metric tonnes.[138] Between 1990 and 2014, freight traffic increased by around 350 billion ton-kilometres to 653 billion ton-kilometres.

During the same period, freight CO_2 emissions rose from 37 million tonnes to 59 million tonnes, around a third of the CO_2 emitted from the transport sector (see figure 8.1).

138 See Hütter, A. (2016).

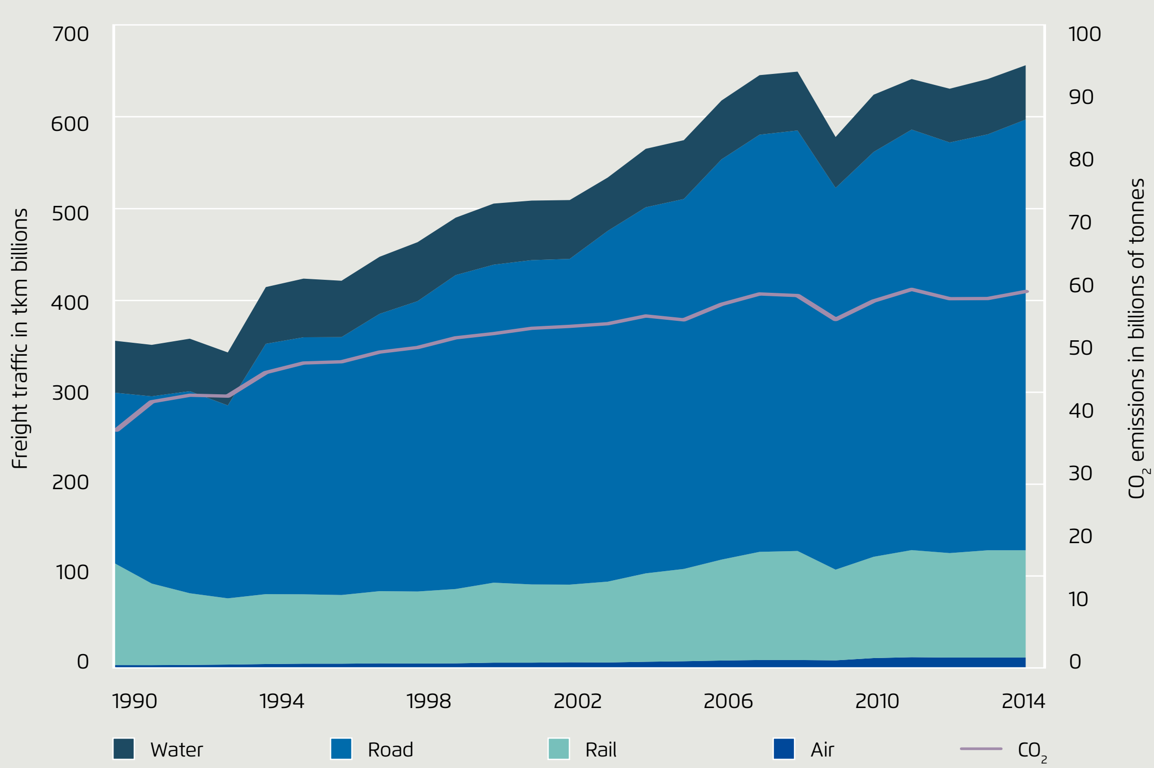
Germany's Federal Ministry of Transport has forecast that by 2030 freight traffic will have grown 38% over 2010 levels.[139] In view of this growth, the decarbonisation of freight traffic can be achieved only if final energy demand drops significantly and fossil fuels are replaced by wind and solar power and by renewables-based fuels (see Insights 6 and 7).

Standing in the way of this objective is the uneven distribution of road and rail freight. Trucks make up 71% of freight traffic; trains, only 18% (figure 8.1).[140]

139 See BMVI (2014), p. 8.

140 These figures are from the German Environment Agency (UBA), Emissionen des Straßenverkehrs in Tonnen 2014, Tremod 5.63. The share of ship transport is 9%; air freight amounts to only 2%.

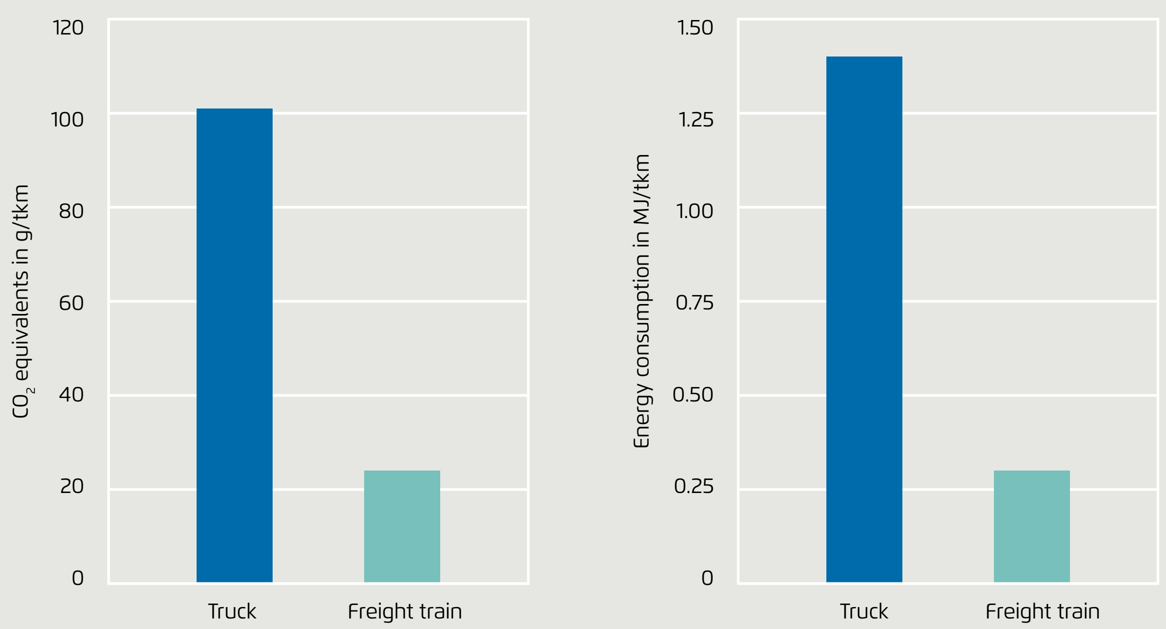
German freight traffic and CO_2 emissions, 1990 to 2014 — Figure 8.1



Authors' figure based on UBA data, Tremod, p. 63

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

Figure 8.2



Authors' figure based on UBA (2016g)

But one tonne-kilometre by freight train requires only around 20% of the energy of one tonne-kilometre by truck, and causes only around 25% of its harmful climate emissions (figure 8.2).

Hence, even with the imminent shift to ever greater shares of renewable electricity for road transport, the existing rail system is more efficient than trucks. Another reason to bolster rail traffic is that there's not enough available land for expanding the highway system so that it can handle more freight traffic. Both these factors speak for significantly increasing the share of rail freight transport.

Nevertheless, current forecasts expect that trucks will continue to haul most of Germany's freight well into the future. For this reason, it is important that trucks be outfitted with carbon-neutral powertrains and fuels. Moreover, a system for powering long-haul freight trucks must be introduced at the European level.

Competitive rail freight maximises railway's potential.

For a while now, politicians have been calling for a shift of freight traffic from roads to rails. Germany's 2002 national sustainability strategy aimed to increase rail freight by 25% by 2015. Germany fell well short of this objective, however, and made no mention of new targets in its 2016 sustainability strategy. The EU Commission will also fail to reach its current goal of using trains and ships to reduce 30% of road freight traffic for distances greater than 300 kilometres if the conditions for rail freight transport do not improve.[141] Advances are needed in rail logistics, infrastructure, financing and noise abatement. Moreover, while rail freight is more efficient than road transport, it must use its energy more economically.

141 EU-KOM (2011), p. 9.

There are various ways to transport goods by rail:

- Unit trains (i.e. trains in which all cars carry the same good)
- wagonload freight and
- less than wagonload freight.

Traditionally, the benefits of rail are maximised when large loads are transported over long distances. For example, unit trains are often used for large volume commodity shipments (e.g. wood pellets or recycled materials). Today, high-value production and consumer goods are being transported in increasingly smaller payloads, as unit trains are only responsible for a portion of the shipping in this segment (e.g. in seaport hinterland transport).

Unit trains play an important role in what is known as combined transport (CT). Containers or other swap bodies are brought by truck to CT terminals where they are loaded onto trains. When the trains arrive at their destination CT terminal, their loads are placed on trucks and driven to the recipient. These terminals are crucial for the integration of road and rail traffic.

Due to the dominance of just-in-time production processes, many companies today are no longer able to full an entire train with goods. The demand for transport of single wagons serves combined transport and individual cars and wagonload freight, in which cars and wagon groups are put together at railroad yards. This bundling is economically necessary but still too expensive and slow compared with road transport. Automation and digitalisation can decrease costs, increase efficiency and make rail traffic a more appealing option.

One problem is that many companies that produce goods suited to rail transport no longer possess their own sidings connecting the factory with the railway system. Abandoned industrial tracks should be checked to see if a reactivation is possible and beneficial. By contrast, companies without their own sidings that ship less than wagonloads must rely on logistics centres. These centres enable intermodal transport chains based on flexible combinations of wagonload freight and less than wagonload freight. Intermodal logistics centres like these can also function as hub-and-spoke networks. They enable the smart bundling of and reassembly of trains at hubs, channelling trains along radials, or spokes, that extend from the hubs. Shipments do not necessarily take the shortest path from point A to point B, but this system ensures that trains are efficiently loaded, which saves costs.

If rail freight becomes more appealing, the pressures to expand rail capacity will increase. In 2014, rail freight totalled 117 billion tonne-kilometres. The climate change scenario of Germany's Environment Agency projects that rail freight could rise to 280 billion tonne-kilometres by 2050, while the business-as-usual scenario forecasts only 186 billion tonne-kilometres.[142] Accordingly, the growth potential of rail is large, provided existing capacities are better used by expanding the rail system and avoiding hub bottlenecks. The top priority must be to enlarge the main corridors that lead from the ports along the German North Sea and in Antwerp, Rotterdam and Amsterdam.

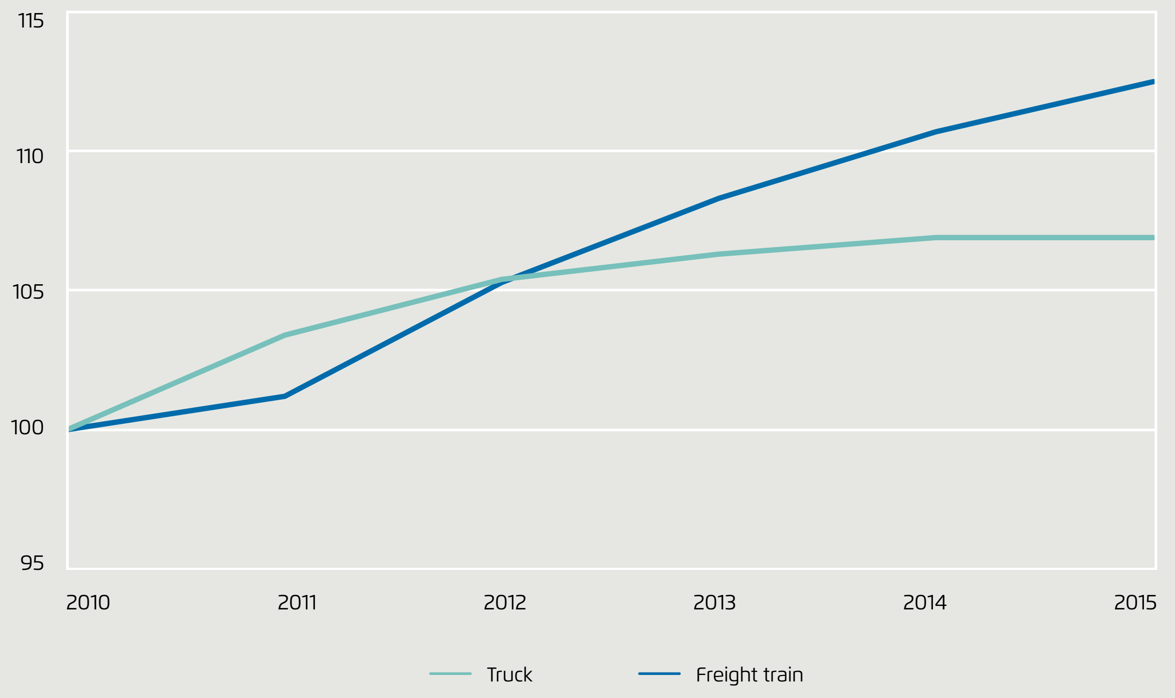
One reason why more freight traffic hasn't shifted from roads to rails, despite decades-long calls for action, is the uneven cost burden. This is particularly visible in the differences in fees levied on rail lines and trucks and in the state taxes on electricity and diesel. The price indices in Figure 8.3 show the discrepancies caused by unequal fees on rail and road freight traffic.

The central levers that could close the cost gaps are (1) levying tolls on all trucks and streets based on the external costs of CO_2[143] and (2) lowering track fees for trains.Moreover, the government must do more to monitor and sanction widespread price dumping in the road freight sector – another factor that tilts competition against rail freight.

Although railways are better for the environment than road transport, they must be made better still. This is especially true because their environmental advantage vanishes once carbon-neutral trucks hit the roads in significant numbers. Railway lines yet to be electrified should be made so as soon as possible. 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. If diesel locomotives continue to be used, new

142 See Ifeu, INFRAS, LBST (2016).
143 See INFRAS, Fraunhofer ISI (2016).

Producer price index for road and rail freight (2010 = 100) Figure 8.3



Authors' figure based on Destatis (2017), p. 21 and p. 63

standards must be introduced to reduce harmful pollutants. Moreover, the public acceptance of freight lines can be improved significantly if trains are equipped with modern braking systems that make rail traffic much quieter.

But 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).[144] 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.

European policies show the way to the carbon-neutral truck

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, other means will be necessary to make heavy long-haul trucks[145] run more efficiently, including better powertrains, better aerodynamics, less rolling friction, lighter construction, speed limits and optimised auxiliary consumers. The potential for improving efficiency is considerable.

Semi-trailer trucks with a total permissible weight of 40 tonnes (standard for long-haul trucks) have a savings potential of 25 to 40%.[146] Such savings are primarily achievable with binding CO_2 fleet targets, such as those the EU introduced for passenger cars and light utility

144 See Ifeu, INFRAS, LBST (2016), p. 25.

145 Here, the term truck includes semi-trailers.

146 See Ifeu, TU Graz (2015), p. 22; and Mock, P. (2016), p. 15.

vehicles in 2009. The EU Commission is currently preparing draft regulation for trucks and other heavy-duty vehicles. In the future, additional efficiency gains might be obtained through platooning – the coupling of multiple semiautonomous trucks on highways, and well-coordinated drafting.

In 2017, Germany permitted extra-long trucks known as gigaliners on certain types of roads. These trucks, which may have a maximum length of 18.75 metres, have been criticised for distorting competition between rails and roads in favour of the latter.[147] Germany does not plan on lifting the total allowable weight from 40 tonnes (or 44 tonnes in combined traffic) to the 60 tonnes permitted in the Netherlands and Denmark and the 64 tonnes permitted in Sweden, though it's doubtful that this restriction will remain for long. Moreover, the 1.3-meter increase in permissible semi-trailer length will lead to the gradual replacement of existing semi-trailers.[148] But these extra-long trucks will not fit the wagons used in Europe for combined traffic. In the face of evidence that the combined traffic sector is weakening, reforms to oversize truck regulations are urgently needed.

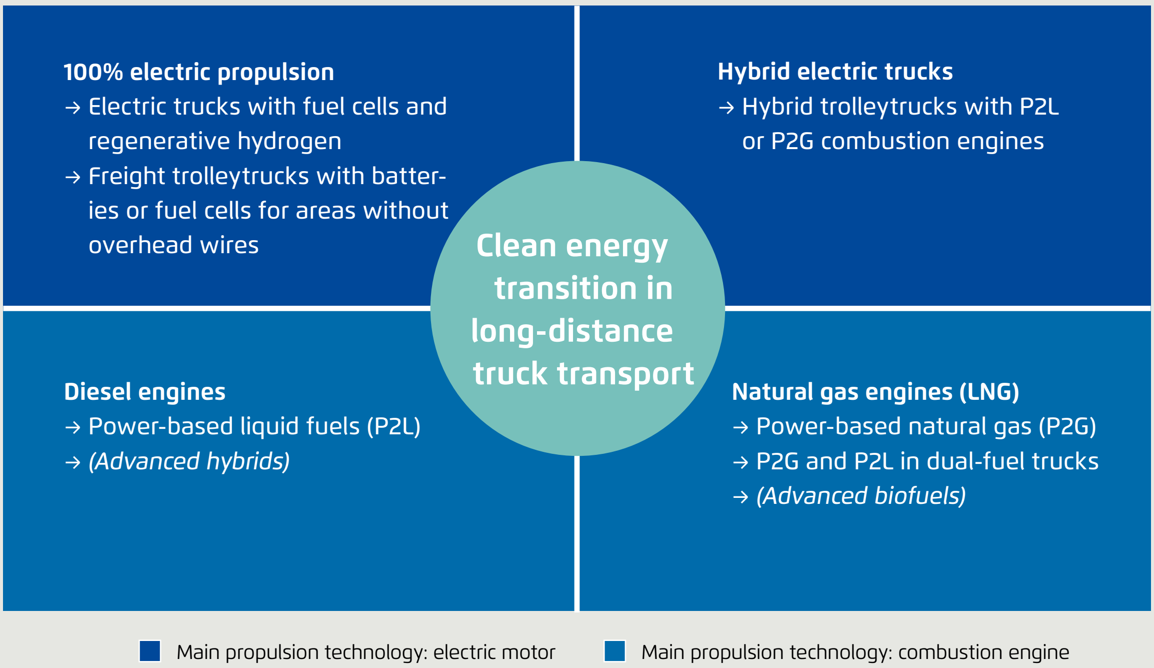
Due to its nature, long-haul truck transport frequently crosses national borders. Accordingly, carbon-neutral approaches to motive power must be coordinated at the European level, so that each country has the necessary infrastructure (such as an overhead contact system). If this doesn't happen, logistics companies won't decide to retrofit their diesel trucks or switch to new freight systems. And vehicle manufacturers won't decide to introduce new, low-carbon models. There are various electricity-based powertrain concepts for long-haul road freight in the post-fossil age (figure 8.4). Advanced biofuels are subject to the restrictions as described under Insight 7.

147 See Sonntag, H.; Liedtke, G. (2015).

148 See BASt (2016).

Possible propulsion technologies and energy sources for carbon-neutral long-distance truck transport

Figure 8.4



Authors' figure

As with passenger cars, the most efficient and economical option for decarbonisation is the direct use of electricity from sun and wind. But based on foreseeable technological developments, batteries in 2050 will still fall short of typical ranges in the long-distance freight traffic, where semi-trailers and trucks weighing up to 40 tonnes make trips of 1,000 kilometres and more.[149] The most affordable option to avoid range restrictions combines overhead contact lines with carbon-neutral P2L diesel and/or batteries for sections of road outside the overhead system[150]. Besides technology, 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. On the one hand, LNG trucks are already available today and a LNG station network is currently in preparation. Moreover, LNG trucks produce less (albeit marginally) GHG emissions than diesel trucks,[151] and the production of synthetic liquid methane is somewhat more efficient than P2L. On the other hand, national gas is a fossil fuel and, as such, can at most serve as a bridge technology (Insight 6). If the LNG technology is expanded, the resulting path dependencies will make it more difficult to switch to CO_2-free trucks. Furthermore, investments in LNG vehicles and fuelling stations will lower the chances of implementing overhead contact lines or fuel-cell systems.

But it should be noted that discussions about electricity-based fuels such as liquefied P2G methane have mostly taken place in Germany. At any rate, the example of LNG shows that the German federal government and the EU Commission must develop a coordinated propulsion system at the European level. At the same time, governments must focus on bringing out about a significant increase in vehicle efficiency.

149 See INFRAS, Quantis (2015).

150 See Öko-Institut, KIT, INFRAS (2016).

151 See Ifeu, TU Graz (2015). The carbon intensity of LNG varies greatly depending on supply paths and upstream chains.

Insight
09

Power supply and transport benefit from sector coupling.


Picture: Timmitom / photocase.de

Electricity from wind and solar power is projected to become the main energy source for future transport (see Insights 6 and 7). But national CO_2 emissions will decrease only if additional amounts of renewable energy are generated. Accordingly, it is crucial for the clean-energy transition to keep pace with the transformation of the transport sector.

Though the share of wind and solar power in Germany's electricity generation is rapidly growing, they are unpredictable, weather-dependent sources of energy. Hence, it's all the more important to coordinate flexible levels of supply and demand. Electric cars can be part of that solution when equipped with smart or bidirectional charging capacities. The transport and energy sectors stand to benefit greatly through this type of collaboration, known as sector coupling.

Additional wind and solar power will drive the energy transition in the transport sector

In 2015, Germany generated 651 terawatt hours (TWh) of electricity,[152] of which its transport sector consumed a mere 12 TWh.[153] Current scenarios predict that by 2050 electricity demand in the transport sector will increase to around 900 TWh hours (see Insight 7). This increase is in part due to the greater demand for transport services. Predictions differ greatly on how direct and indirect demand will rise after 2030 due to increasing use of electricity-based synthetic fuels.[154] Given that the sustainable annual total potential of renewable energy is a 1,000 TWh, it appears likely that Germany will become reliant on imports of electricity and/or electricity-based fuels.[155]

The German government aims to reduce total electricity consumption 25% by 2050 relative to the 460 TWh used in 2008. During the same period, the government aims to increase the share of renewable energy to 80% of total power generation. If these goals are met, renewable energy sources will generate around 370 TWh annually. But the reduction in total energy use is unrealistic given the additional demand projected for the transport sector. By the same token, the renewable energy targets are incompatible with the goal of decarbonising the economy, including the transport sector. The expansion of renewable energy needs a significant boost if the 2050 climate targets are to be met.

Electromobility offers flexibility to the power sector

The coupling of the transport and energy sectors can ensure that demand for electricity in the transport sector corresponds with the supply of renewable electricity. However, such coupling might also destabilise the power system, if, say, many electric vehicles are being charged at once or demand for electricity in other sectors is high, and only small amounts of electricity are being generated.[156] If smart power management systems are used, however, such that charging takes place only when there's supply, additional flexibility benefits will accrue to the power system.

Sector coupling can also include bidirectional charging – feeding energy back into the grid from an electric vehicle's battery. This new technology 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 (figure 9.1). To bridge the gap between supply and demand, both producers and consumers need to become more flexible. Smart charging and bidirectional charging are two ways to achieve this.

As it stands, however, no viable business models exist that use electric cars for this purpose.[157] It is also unclear how vehicle batteries will handle bidirectional charging in the long run. Be that as it may, smart charging is the only practicable option for electric vehicles running on renewable energy.

152 See AGEB (2016a).
153 In 2015, renewable electricity made up 30% or 196 TWh of gross electricity generation in Germany. See AGEB (2016b).
154 The highest projected total electricity use for the transport sector amounts to 2,000 TWh. See LBST (2016).
155 See DLR, Ifeu, LBST, DBFZ (2015).
156 See Schill, W.-P. et al. (2015).
157 See Volkswagen AG; Lichtblick SE; SMA Technology AG; Fraunhofer IWES (2016).

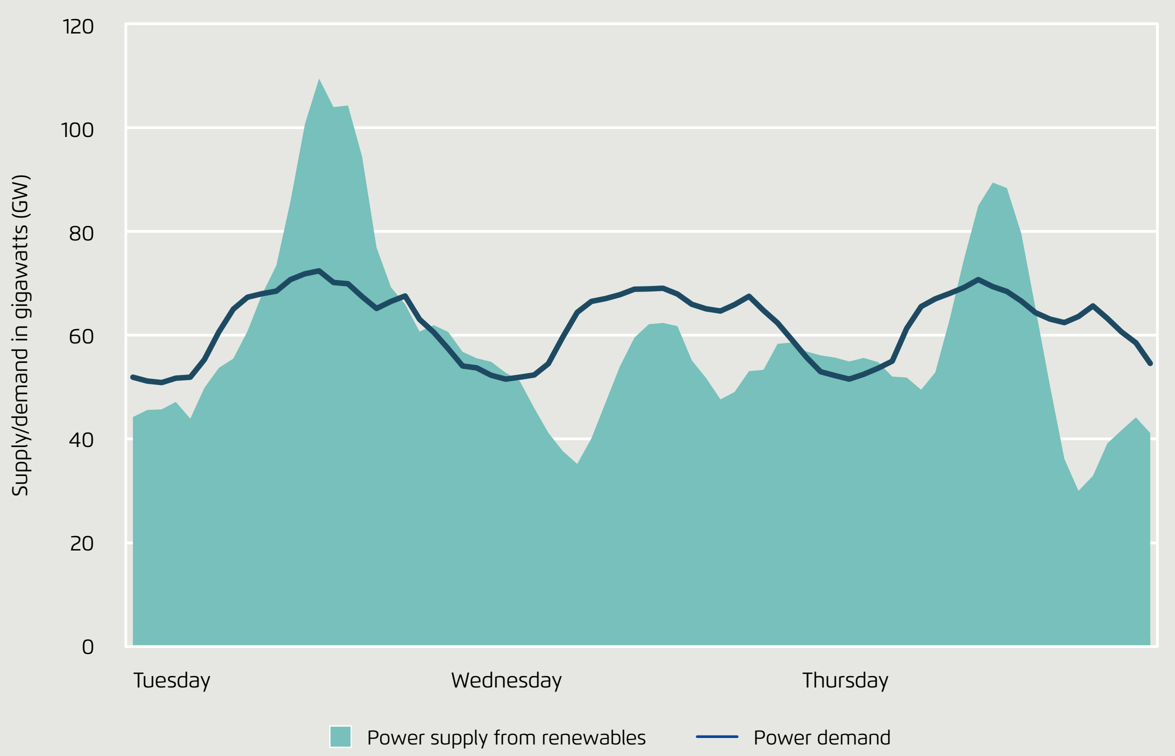
Policies need to be found to make smart and bidirectional charging possible. In particular, it is important that planners make sure that the charging infrastructure they create possesses this technology (see Insights 6 and 10). Power grid operators and electricity producers could use tariffs to create incentives for smart and bidirectional charging. Doing so will require appropriate regulation in addition to technological capabilities. Yet it is also important to expand power distribution grids while keeping future requirements for quick charging stations in mind.[158]

Though intelligent cost-based charging can supplement photovoltaic installations when demand for renewables is high, it can also lead to increased demand at night for cheap electricity from lignite-fired power plants, which are heavy emitters of CO_2. To ensure that generation keeps up with transport sector demand, capacities for renewable energy electricity generation in Germany must be increased at a much faster rate than they are today.

Home battery units charged by roof-top PV installations are another option for overnight charging and for decreased 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.) Moreover, households with their own solar units save on state-imposed costs in the electricity price. Such decentralised generation represents an appealing alternative for many people and can be understood as a means of speeding up the energy transition in transport.

158 See EU COM (2016b).

Scenario for power demand and generation in 2030 — Figure 9.1



Authors' calculations and estimates performed by Agora Energiewende

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. So far, repurposed batteries have found profitable use only in the industrial sector, where they are linked together to form larger units that provide extra stability for the grid. Currently, however, there are no economic policies or regulations governing the use of second-life batteries in households. One reason is because repurposed batteries have to meet the same safety standards as new ones, and it is doubtful that providers will vouch for the safety of the batteries given that they don't come with information about temperatures and charging cycles from their first life. Another reason is that the production of more efficient and cheaper batteries will presumably lower the cost benefits that might have been gained from using second-life batteries.

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. But this option has its difficulties. Electrolysers – facilities that generate hydrogen via electrolysis – are most efficient and cost effective when run at full capacity, considering their high investment costs.

Their occasional use for load management doesn't make economic sense.[159] 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. P2G technology has a similar function to that of a safety buffer.[160] With existing technology, however, the total efficiency of hydrogen production, storage and reconversion amounts to no more than 40%.[161] One final 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.

159 See UBA (2016a).
160 See BMWi (2016d).
161 See EFZN (2013).

Insight
10

Rethinking the development and financing of transport infrastructure.


Picture: urbancow / iStock

The transportation 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. In this connection, there are two main challenges: (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.

Smart infrastructure planning can encourage emissions reductions

In 2016, the revised version of the Federal Transport Infrastructure Plan (*Bundesverkehrswegeplan*), the federal government's most important planning document for transport infrastructure, was adopted.[162] This planning document sets forth 270 billion euros worth of investments up to 2030. While the Federal Transport Infrastructure Plan identifies the reduction of harmful emissions and greenhouse gases as an overarching priority, it allows that planned investment projects will only lead to annual CO_2 reductions of 0.4 million tonnes.[163] In this way, the 2030 Federal Transport Infrastructure Plan does not adhere to the goals of the 2050 Climate Action Plan (Klimaschutzplan), which was also adopted in 2016. The 2050 Climate Action Plan foresees CO_2 emissions reductions of the transport sector of 40 to 42% over 1990 levels by 2030. As the sector currently emits some 160 million tonnes of CO_2 annually, this means that emissions reductions of 4.7 million tonnes per year are required.

Against this backdrop, there is a need to review the Federal Transport Infrastructure Plan and the associated supplementary acts with the aim of identifying whether adjustments can be made so that planning is in accordance with emission reduction goals. We believe that the adjustments should follow a yet to be developed 2030 Transport Transformation Policy (*Verkehrswendekonzept 2030*). This policy should stipulate the measures required to usher in the transport transformation (see Insight 1). As a comprehensive planning document, the 2030 Transport Transformation Policy should take economic, ecological and social factors into consideration in a balanced way while pursuing the goal of optimising the overall transport system.[164] In order to ensure public support, the development of the 2030 Transport Transformation Policy should accommodate the participation of the citizenry while also seeking to transfer decision making responsibility to the local level.[165] By treating local authorities as more than just agents executing orders from above, active participation from below can be promoted while also undercutting tendencies for the development of infrastructure projects of excessively large size.[166]

The planning of transport infrastructure should be informed by the principle of "rail before road". Indeed, for the mobility revolution and the clean-energy transition in transport to succeed, it will be essential to set priorities and targets in the financing and planning of infrastructure in order to achieve the greatest possible shift from road to rail transport. Yet it will not be enough to simply invest less in roads and more in railway capacities. There must be enhanced human resources dedicated to the planning and engineering of new rail infrastructure. Furthermore, it would be beneficial to allocate funding for rail network expansion for periods longer than five years, which is the normal budget time frame at present. In order to achieve emission reduction targets in the transport sector, the carrying capacity of existing infrastructure should be additionally enhanced though digitalisation, automation and improved signals technology.

Rail network expansion should be oriented to improving European core network corridors. A particular focus should be placed on the elimination of bottlenecks in "seaport hinterland areas" and at particularly busy rail hubs, such as Cologne. Adding new capacity to busy hubs will be essential for reducing chronic delays in the transportation of people and goods.

162 BMVI (2016d).
163 BMVI (2016d), p. 24 ff.
164 Bracher, T. et al. (2014).
165 Roland Berger (2013).
166 Bodewig-Kommission (2013).

An additional important goal should be to create sufficient opportunities for trains to overtake one another, as different travel speeds are customary when transporting people and goods. The improvement of rail networks to accommodate freight trains, which in Europe are typically 740 meters long, would be relatively inexpensive, but has not been assigned a high priority in infrastructure planning to date.

While rail transport has inherent environmental advantages, as a mode of transport it is being confronted by increasingly stringent environmental standards. The electrification of rail lines is a key challenge at present. Some 59% of rail lines are electrified, but this percentage is too low. If the installation of overhead wires would be economically inefficient due to irregular use, carbon-neutral train operations should be achieved with batteries and/or fuel cell technology. Furthermore, the noise created by rail transport must be reduced not only to encourage public support for rail network expansion, but also for human health reasons (see Insight 8).

When planning road infrastructure, alternatives to new construction or expansion should be considered to a greater extent; in some cases, it would even make sense to eliminate certain roads. 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. It should be possible to avoid certain infrastructure expansion measures by improving the integration of local and regional actors. For example, when taking the economic, ecological and social requirements of transport infrastructure into account, one might find that a modified travel route through a city is preferable to directing traffic around that city. To name a further example, the rehabilitation of old rail bridges can be preferable to the construction of new road bridges.[167]

The infrastructure of the future is more than concrete and steel

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 technical standards are adhered to. In this regard, regulators will need to adopt common standards for cables and plugs (and, potentially, for cable-free inductive charging) while also ensuring an open market for competition. In addition, transparent billing methods for charging stations services must be guaranteed. "Mobility cards" that enable customers to flexibly use different modes of transport to arrive at their destinations should incorporate the possibility of using charging stations operated by different providers.

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. Within the scope 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. It could potentially be more beneficial to select a single fuel solution for subsidies in order to minimise economic costs while generating synergies (see Insight 8).

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 would help to enable semi-automated transport solutions, which could become fully automated at a later date (see Insight 5). IT technology offers incredible latent potential for the transport sector. 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 poten-

167 BUND (2017).

tial offered by advanced IT systems can only be fully exploited if existing transportation infrastructure such as traffic lights, traffic signs and public parking spots become more intelligent and are embedded in larger networks. In this way, the digitalisation of traditional transportation infrastructure will play an important role for networking vehicles and increasing their efficiency.

Policymakers have a responsibility for enabling non-discriminatory access to electric-vehicle charging points and alternative-fuel filling stations. If existing business models prove to be inappropriate for ensuring that necessary infrastructure is installed and operated, then the government must take action to ensure that financing conditions and regulatory rules are reliable and adequately designed to encourage a successful transformation of the transport sector.

New ways of financing navigate the transport transformation

Today, public investment in transport infrastructure is financed with proceeds from energy taxes. Generating revenues of some 40 billion euros annually, energy taxes represent the German government's most important consumption tax.[168] Of this amount, the federal government spends some 10 billion euros annually on transport infrastructure.[169] The revenues not used for transportation spending flow into the general budget. These tax revenues are set to shrink with each passing year as the energy transition in transport continues and fossil fuel consumption declines.

Figure 10.1 shows end consumer prices for each 100 km driven when relying on various vehicles and energy types. It also details the share of these costs collected as taxes. Taxes on electricity are lower in absolute and relative terms than taxes on diesel and gasoline. One cause is the low level of taxes on electricity (2.05 cents per kWh); another is the higher efficiency of electric motors in comparison to combustion engines. The other electricity price components mandated by the government – including the EEG levy and grid usage fees – are paid by end consumers, but do not flow into the federal government's budget.

Electricity taxes generated revenues of 6.6 billion euros in 2014.[170] Assuming electricity tax rates remain the same, the additional revenues produced by the electrification of the transport sector would not be sufficient to compensate for the decline in tax revenues from lower diesel and gasoline consumption. Accordingly, adequate funding for infrastructure projects is not assured over the long term, and new solutions for infrastructure financing need to be explored.

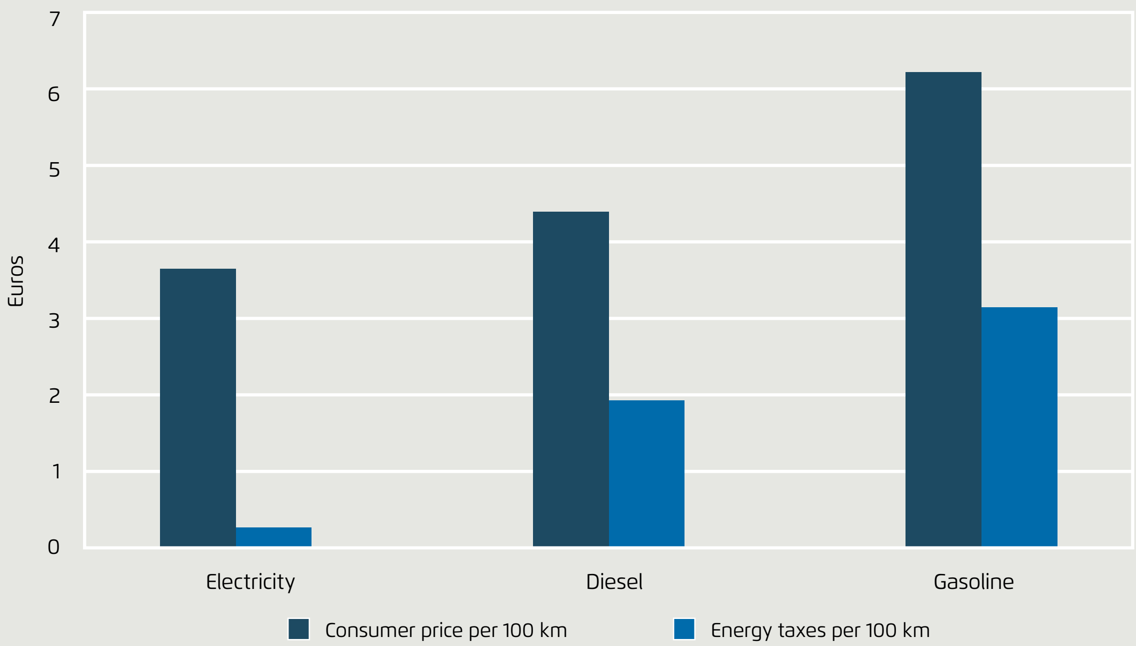
There are various arguments in favour of increasing the use-based financing of transport infrastructure as an alternative to the existing tax-based system. Recommendations along these lines have been issued by two commissions that were formed by the transport ministries of the German states: namely, the Daehre and Bodewig Commissions.[171]

In addition to ensuring funding for transport infrastructure, user-based financing would allow ecological factors to be taken into consideration. With the introduction of a toll-road system, it would be possible to allocate the internal and external costs of transportation to the economic actors who are responsible for creating them (in line with the "polluter pays principle"). German autobahns already have a toll system for trucks weighing over 7.5 tonnes. In 2018 the system will be expanded to all federal highways (*Bundestraßen*). In accordance with the "Eurovignette" Directive, EU member states must establish toll systems for heavy freight vehicles. While the first version of the Directive adopted in 1999 only dictated the implementation tolls for the use of certain roads, the amended 2011 version foresees surcharges for externalities such as air pollution.

German policymakers are currently working to develop an "infrastructure fee" for personal vehicle use. Unfortunately, this fee will not set incentives for more ecological behaviour, as fee levels will not vary based on the number of kilometres driven. To support the transition to sustainable transport, we advocate the adoption of a toll that would be collected based on kilometres driven. Furthermore, we believe toll levels should be designed to reflect the externalities and infrastructure usage costs associated with each specific vehicle. The toll should

168 BMF (2015).
169 Wieland, B. (2016).
170 BMF (2015).
171 Daehre-Kommission (2012); Bodewig-Kommission (2013).

Consumer prices and energy taxes per 100 km automobile fuel source — Figure 10.1



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

be variable in time and space in order to promote more efficient traffic flows. Finally, the toll system should be designed in a cost-effective way and should also provide for reliable data security.[172]

There is a need for financing not only for transport infrastructure in a narrow sense, but also for electricity infrastructure. Indeed, the expansion of the power system must be expedited as an essential step in the transport transformation (see Insight 9). The expansion of electricity infrastructure has been financed to date with the 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.

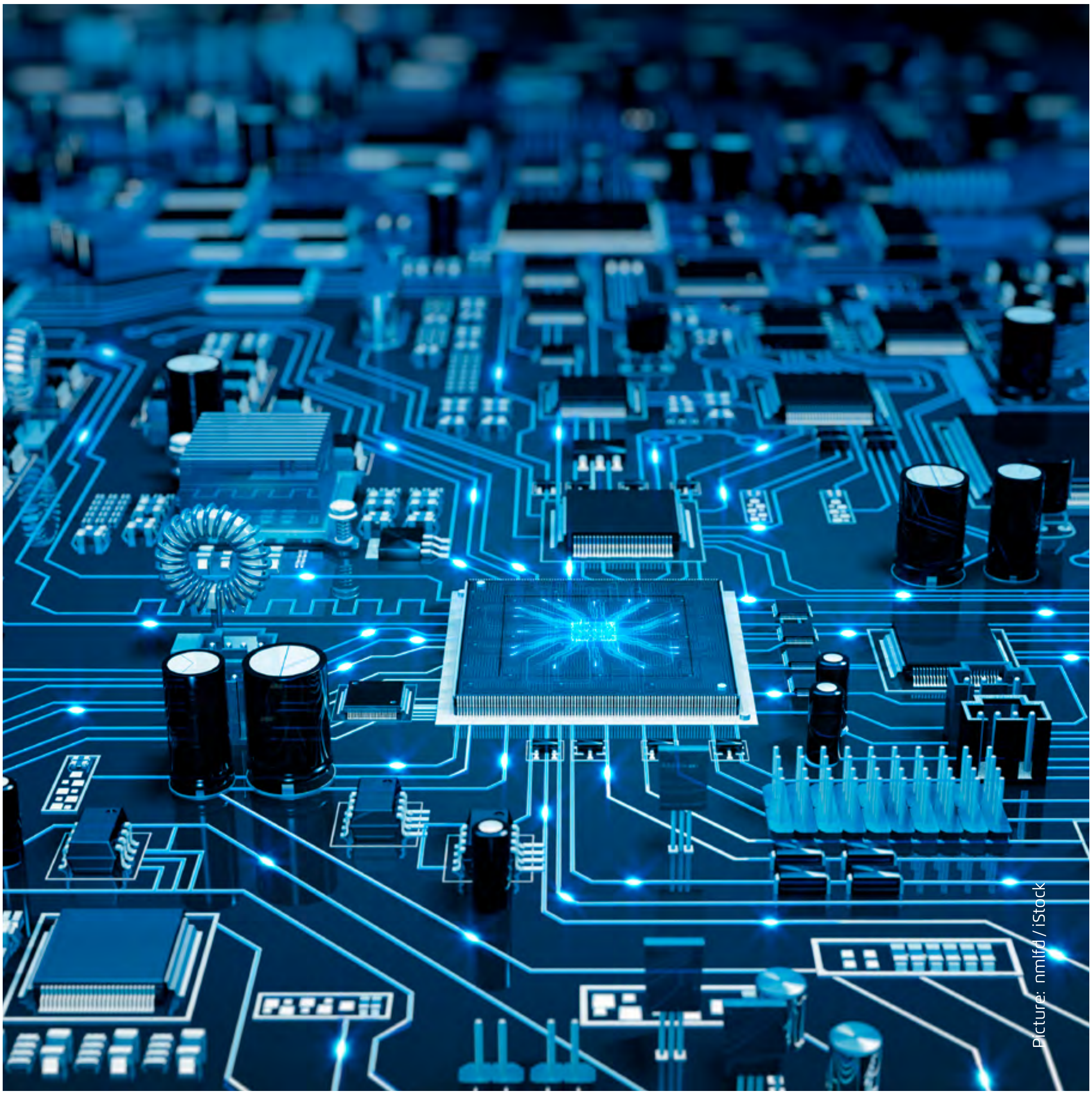
Additional research and debate are needed to clarify whether current burden-sharing arrangements for power-system financing should remain unchanged, or whether the overall system of taxes and levies for the transport and power sectors needs to be reformed.[173]

172 FÖS (2016).

173 BMWi (2016c).

Insight
11

The transport transformation can strengthen German industry.


Picture: nmlfd / iStock

Since the invention of the automobile by Carl Benz in 1881, the automotive industry has produced millions of vehicles. And while numerous advances in vehicle engineering have been witnessed over the past century, one core principle has remained unchanged: reliance on the internal combustion engine as principal part of the power train. However, new innovations in electric vehicle technology, combined with the exigencies of climate change, have suggested that the reign of the internal combustion engine could be coming to an end. Indeed, the automobile industry seems to entering an era of substantial transformation, if not a full-fledged technological revolution.

The future belongs to carbon-neutral vehicles and mobility services

The recent wave of innovation in the area of electric vehicles has been driven in no small part by the goal of slowing down human-induced global warming and decarbonising the energy and transport sectors.
Yet other factors are at work: 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 not only visible in Germany, but worldwide, and they are triggering significant macroeconomic effects.

The mobility transition and the energy transition in transport have the potential to improve quality of life while also reducing the risks of climate change. However, changes in the transport sector may necessitate painful adjustments on the part of individual groups or society as a whole.

Specifically, concerns have been voiced about the dangers posed to Germany's export-oriented automotive industry. Regardless of the regulatory decisions made by German and/or European policymakers, the success of the German automotive sector will depend crucially on its ability to adjust to changing market requirements - both domestically and internationally. There can be little doubt that decarbonisation and digitalisation will exert significant impacts on the number of jobs, structure of employment, and value creation chains in the automotive sector. Our success in managing undesired or negative societal impacts – while they are difficult to quantify at present – will be augmented if political and business leaders take an active hand in shaping the transformation process, rather than being driven in a reactive sense by it. Business leaders in the automotive industry are increasingly aware of this fact.

The private sector should be responsible for determining the powertrain and efficiency technologies they wish to develop and implement so that emission reduction goals can be met. However, 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. Technical hurdles, increasing international competition and ever more stringent regulatory policies mean automobile manufacturers are confronted by a complex nexus of challenges.[174]

Creating jobs with industrial policy that guides structural change

The German automobile sector's success in defending and expanding their 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. Structural change is already well underway; actions being taken today will determine in part whether Europe remains a major location for the production of automobiles in the future.[175]

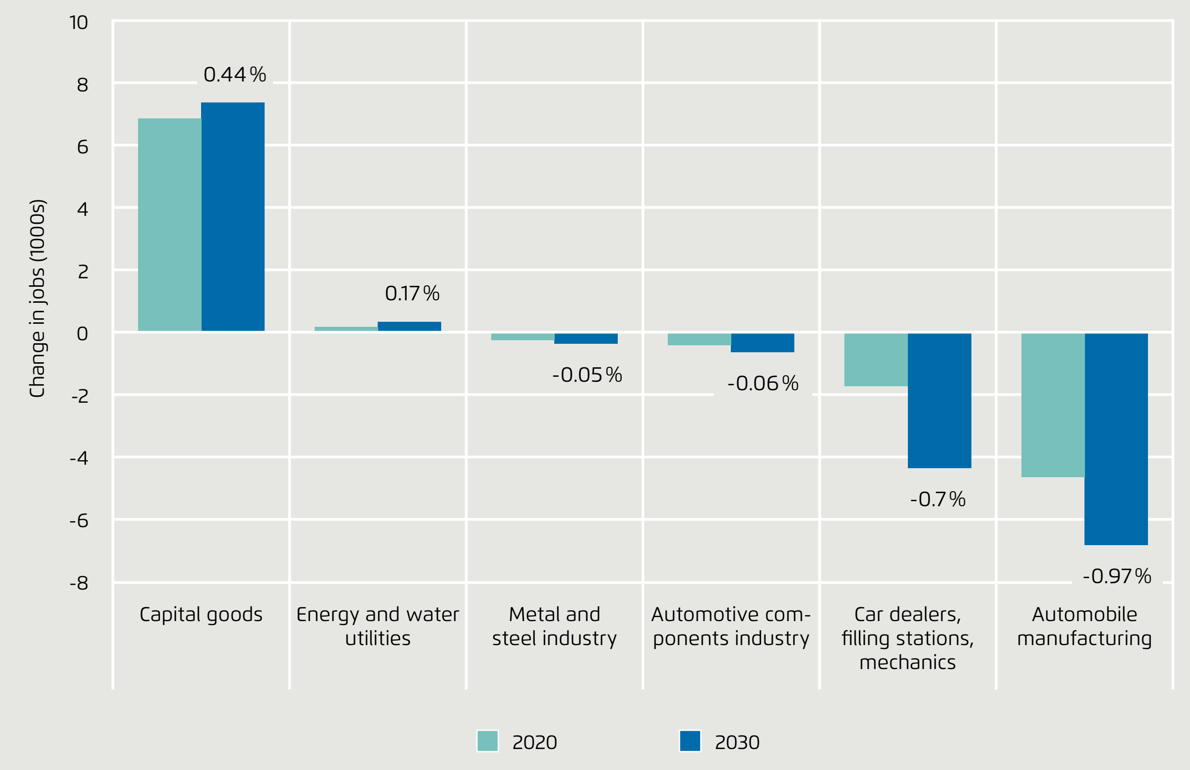
Proactive efforts to steer structural change can help to secure employment in the automotive sector. Business and political leaders have been devoting particular attention to the manufacturing of powertrain technology, which currently employs some 250,000 workers domestically. The speed at which new powertrain technologies replace the internal combustion engine will be a critical determinant of the future of these jobs.

At present, it is difficult to predict the specific technologies that will become ascendant, or the pace at which

174 PwC (2016), p. 3.

175 See IG Metall (2016), p. 6 and Wissmann, M. (2017), p. 7.

Employment effects of the energy transition in transport* Figure 11.1



Ulrich, P.; Lehr, U. (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)

change will occur.[176] However, it is clear that the production of electric powertrains is less labour intensive than the production of combustion engines and traditional gearboxes. Existing studies come to the conclusion that the macroeconomic employment effects associated with the rise of electric vehicles will remain limited in the period up to 2030 (see fig. 11.1). However, these studies presuppose that battery-power electric vehicles will not achieve rapid growth in market share prior to 2030.

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, as can be seen first and foremost in China. In China, experts only see strong growth prospects for vehicles with alternative powertrain technologies and for vehicle components that are "highly relevant for alternative vehicles".[177] 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-powered vehicles.[178] However, it is not reasonable to assume that supplying energy to the transport sector

176 ELAB (2012); TAB (2012); Öko-Institut (2016) sowie Ulrich, P.; Lehr, U. (2016).

177 TAB (2012), 194.

178 FitchRatings (2016).

will require fewer jobs in the future than it does today. New jobs will be created for the expansion and maintenance of power infrastructure and/or the production of electricity-based fuels. However, cost factors and public-acceptance issues suggest that alternative fuel production will primarily occur in other countries.

Economics 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.[179] 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 transportation industries. More than 83,000 people are employed as public transportation drivers in Germany.[180]

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. Experience tells us that public support for government policy is often mediated by how such policy impacts jobs. As a result, improving our understanding of how the transport transformation will impact the labour market is of key concern. Enhancing our understanding of this issue is crucial for assessing various strategies for guiding structural change, not least to ensure there is sufficient support for such intervention among political leaders and the citizenry at large. In this connection, it is important to communicate that the transport transformation cannot be held responsible for employment effects that are the unavoidable result of automation and the digitalisation of production (viz. Industry 4.0).

179 McKinsey & Company (2016), p. 4.

180 VDV (2016), S. 30.

Financial markets are recognising the importance of sustainable transport

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.

The nexus between climate change and the transport sector poses a range of potential risks to the stability of financial markets. For example, the geophysical consequences of a warming planet or ambitious environmental policies to combat climate change could lead to significant losses in automotive sector investments. And while the transport sector does not appear to pose an acute risk for the stability of financial markets at present, risks of this type cannot be discounted.[181] The risk of a *black swan* event – that is, an event with a uniquely powerful impact whose probability was underestimated based on Gaussian risk calculations – is not sufficiently accounted for by traditional financial risk models.

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. Such efforts to raise awareness represent an important tool for promoting the success of the transition to sustainable transport.

The perceived risks to traditional business models will grow as climate change risks become more visible. Financial market actors are increasingly 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

181 BMF (2016a), p. 12 ff. and BlackRock (2016).

to climate change. Alternatively, they have been divesting from endangered subsectors in order to avoid holding stranded assets. 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.[182] 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.

Disinvestment from such companies will lead to their declining market capitalisation and undermine their ability to finance their activities. While climate considerations are not yet a significant driving force in capital markets, there are numerous indications that investors are becoming increasingly sensitive to the financial risks of climate change. In a recent publication, BlackRock, the world's largest investment fund, stressed that it views "climate aware investing … as a necessity".[183] Other institutional investors with some 30 trillion US dollars under management have been pressuring the automotive industry to take proactive measures to ensure climate change does not exceed 2 degrees Celsius. In this connection, they have been working *with* rather than *against* policymakers and civil society groups.[184]

In public discourse concerning the transition to clean energy and sustainable transport, financial markets have been largely ignored. However, capital markets actors have the potential to become an extremely important driver of the transition to sustainable mobility. We should therefore keep our eyes on the financial sector, and encourage the active support of financial market actors in this process.

182 BMF (2016a), p. 16 and UBA (2016b), p. 47.
183 BlackRock (2016), p. 9.
184 IIGCC (2016), p. 3.

Insight
12

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


Picture: sabthai / iStock

In recent decades a wide variety of efforts have been made to augment the benefits and mitigate the harms associated with transportation. Roads and railways have been built; emissions limits have been adopted; and vehicle safety standards have been improved. However, it has not been possible to reduce the negative externalities of the transport sector to the degree hoped for by many. For example, more than half of Germany's population feels burdened or bothered by traffic noise.[185] The particulate concentrations produced by vehicle emissions exceed legal requirements in many places. Roads and railways represent a growing burden for the animal and plant world, as they fragment and destroy natural habitats. Furthermore, the number of traffic accidents reached a new high in the history of Germany in 2015.[186]

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 complex 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, transport transformation 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 patterns will become an important driver of the transport transformation.

The transport transformation offers greater benefits than 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. As low-income segments of the population are disproportionally exposed to the negative effects of vehicle traffic, reducing noise pollution and toxic emissions also makes a contribution to environmental justice.

The health benefits of physical exercise – including walking or riding a bicycle – are well established. Wide and well-connected foot and bicycle paths promote local mobility while also making alternatives to personal vehicle use more appealing. Furthermore, lower speed limits in urban areas can promote road safety while encouraging a built environment that is more people friendly.

The transition to sustainable mobility promises to improve air quality and reduce noise pollution while also promoting more physical exercise. In this way, it doesn't just promote the health of the individual, but also helps to slow the rise in health care spending, including individual health care premiums. According to a study conducted by the American Lung Association in ten US states, the widespread adoption of electric vehicles in 2030 would save 13 billion US dollars in terms of avoided health care expenditures and lost productivity.[187] Similar studies should be conducted for Germany, as they would lend fresh momentum to discussion concerning the health benefits of environmental policy.

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. Car sharing services promise to reduce the amount of urban space required for parking vehicles, including the traffic associated with searching for parking spots. This would boost the attractiveness of urban areas while also improving quality of life for residents.

Moreover, in and outside of urban areas, less vehicle traffic would reduce the human impacts to flora and fauna. Ensuring the health of the natural environment is not a wedge issue: some 94% of German say that spending time in nature is part of a good life.[188]

185 UBA (2017c).
186 Destatis (2016d).
187 Holmes-Gen, B.; Barrett, W. (2016).
188 BMUB, BfN (2016), p. 62.

Last but not least, sustainable mobility has economic benefits. Reducing the use of fossil fuels would protect the German economy from the damaging effects of another period of rising oil prices. Embracing sustainable transport would also encourage the economic competitiveness of German industry. By contrast, resisting the inexorable trends toward sustainable transport would be associated with competitive disadvantages. In this way, sustainable transport could also help to protect job.

Discussion promotes public support

Logic dictates that the directly experienced benefits of transforming the transport sector will augment public support for the policy interventions designed to promote its advancement. Ultimately, the transition of the transport sector should have direct benefits for a range of societal actors:

- Sustainable transport should help to stabilise health care expenditures while also shoring up public faith in the ability of the government to take positive action that promotes the health and security of the populace.
- Sustainable transport promises to improve quality of life in our cities and towns while also expanding the planning decisions that are made at the local level.¬
- The private sector will increasingly recognise that the active steering of structural change offers greater opportunities than a doomed effort to preserve the status quo.
- Last but not least, individuals will directly experience how transportation is becoming safer, healthier and less stressful.

However, policies do not automatically garner broad public support by virtue of being beneficial. Various historical examples make this clear, including initial resistance to seat-belt laws in Germany. While the majority of drivers recognised in the 1970s that ¬seat belts are a valuable safety device, a deep aversion to buckling up persisted for many years. Psychologists working for the German Transportation Ministry even determined that opponents of seat-belt laws displayed a "willingness to engage in violent conflict".[189] Today, no one thinks twice about buckling up, as seat belts have dramatically reduced traffic accident fatality rates and awareness for this fact is firmly anchored in the public's mind.

However, historical experience with seat belts hints at the challenges that may arise in achieving public acceptance for the transport transformation. 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.

Collective action is paramount

In the wake of the 2011 Fukushima disaster, a commission charged with examining the future of nuclear energy in Germany emphasised that the energy transition "can only succeed with collective action at all levels of government, business and civil society".[190] 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. For clearly, 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 and government support 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 on the future of nuclear energy recommended the creation of a National Forum on Energy Transition. Such an organisation is still waiting to be established. Heeding this recommendation would provide a valuable boost to transport transformation.

189 SPON (2010).

190 Ethik-Kommission (2011), p. 11.

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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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