CIRCULAR IMPACTS

Car Sharing in Germany

A Case Study on the Circular Economy

Funded by the European Union

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1 :: Abstract

This case-study paper examines future scenarios for car sharing in Germany, analysing drivers and impacts. Enabled by disruptive technological changes, car sharing is an example of a “product as a service” and becoming an increasingly viable alternative to the private ownership of cars. By intensifying the use of vehicles, car sharing has the potential to provide mobility using fewer physical and energy resources. However, other models of shared mobility, such as ridesharing enabled by autonomous vehicles, could actually have countervailing effects, drawing passengers away from public transit. Two future circular scenarios for 2030, Circular “Green” (car sharing) and Circular “Gray” (a broader concept of shared mobility) are developed and compared to a business-as-usual scenario. The paper highlights the impacts of the scenarios on motor-vehicle travel and production as well as greenhouse-gas emissions, also describing likely economic and policy implications. The case underlines the importance of analysing specific circular opportunities like car sharing in the context of a broader system of multi-modal transport.

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List of Abbreviations

ADAC	German automobile club (Allgemeine Deutsche Automobil-Club e.V.)
BAU	Business as usual (scenario)
BEV	Battery-electric vehicle
BMVI	Federal Ministry for Transport and Digital Infrastructure (Bundesministerium für Verkehr und digitale Infrastruktur)
CO_2e	CO_2 equivalent
EUR	Euros (currency)
GHG	Greenhouse gas
LOHAS	Lifestyles of Health and Sustainability
NMVOCs	Non-methane volatile organic compounds
PHEV	Plug-in hybrid-electric vehicle
Pkm	Passenger-kilometres
UBA	German Federal Environment Agency (Umweltbundesamt)
Vkm	Vehicle-kilometres

2 :: Executive Summary

Globally, more than one billion vehicles are currently in use and this number is expected to reach two billion units by 2030 (Sperling and Gordon, 2009). This growth brings with it challenges for both industrialised and emerging countries, including air pollution, urban congestion, surface sealing and additional resource consumption related to producing and operating these vehicles. In the EU, the number of passenger cars now exceeds 250 million and continues to grow (Eurostat, 2018).

Car sharing as a circular-economy transformation

Recent technological developments have increased the convenience of car sharing as an alternative form of providing mobility. Car sharing could potentially lower the number of passenger motor vehicles required to provide the same level of car-based mobility. However, many questions remain regarding the nature and magnitude of the future impacts of car sharing, especially given its expected convergence with ride sharing in the future (facilitated by the advent of autonomous vehicles). Given the enormous impacts of motor vehicles, and with the use of car sharing undoubtedly growing, it is of critical importance to clarify questions related to the expected future impact of these changes in car-based mobility.

In the circular-economy context, car sharing is an example of a product as a service, wherein consumers, rather than buying and owning a product, purchase the services a product provides (e.g. mobility in the case of car sharing). With Germany by far the largest car-sharing market in the EU, this CIRCULAR IMPACTS case study examines possible future impacts of car sharing in the country, starting with the reality today and comparing potential scenarios for the year 2030, each with different levels and effects of car sharing.

This case study does not provide a prediction of the future, which would be an impossible task given the remarkable innovations, disruption and uncertainties now taking place in the transport sector. Disruptive changes for the sector are in store, such as car sharing, ride sharing, autonomous vehicles, robo-taxis and electric vehicles.

However, this case study does shed light on the role that the circular economy could play in transport use and its effects, explains some of the trade-offs involved and identifies key driving factors that should be considered when making transport-related policy decisions. Though it investigates the case of Germany and specifies the year 2030, the underlying technological developments examined here are global in nature, meaning useful insights can be drawn from the case more generally.

Three 2030 scenarios: BAU, Circular “Green” and Circular “Gray”

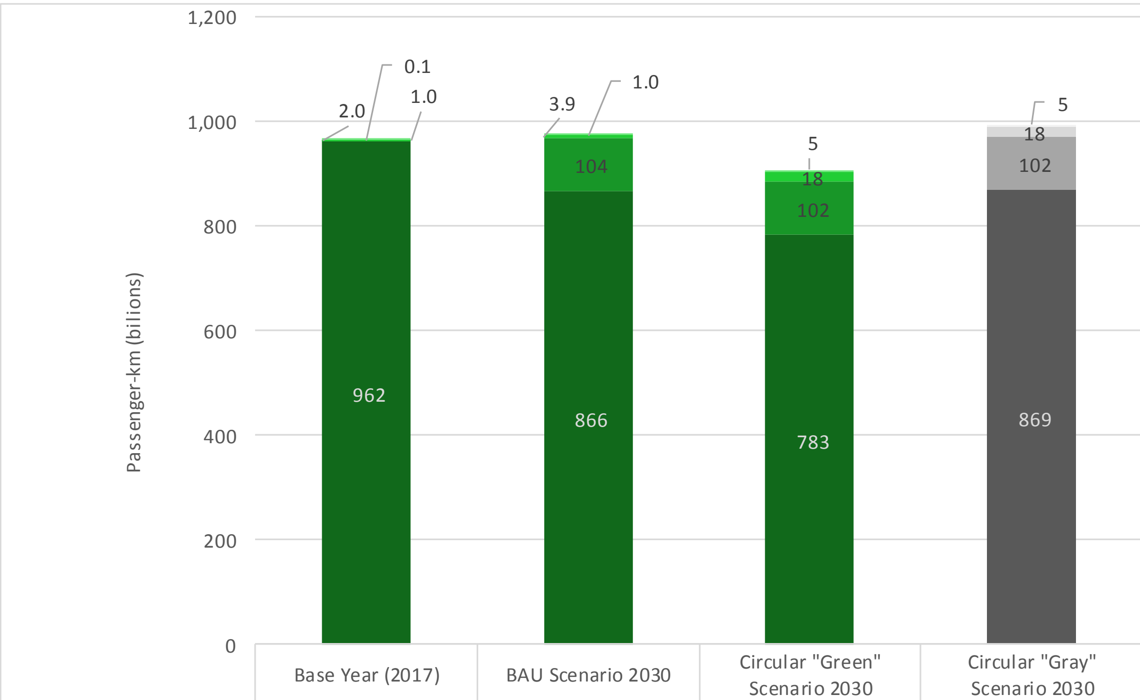
In this case study, three scenarios of car sharing development in Germany through 2030 are developed: a business-as-usual (BAU) scenario with lower levels of car sharing and two circular scenarios with significantly higher levels of car sharing. All 2030 scenarios are based on a set of underlying assumptions wherein the passenger-vehicle sector achieves greenhouse-gas emission reductions at levels in line with the German government’s climate commitments under the Paris agreement (Agora Verkehrswende, 2018). In addition, in all 2030 scenarios, the number of electric vehicles on German streets reaches 5 million by 2030. Achieving these ambitious assumptions is contingent on corresponding and effective policy interventions in Germany and the EU. With this common substrate to all the 2030 scenarios, the specific effect of car sharing can be better analysed.

Presently, car sharing makes up just one tenth of one percent (0.1%) of passenger-km delivered by motorised passenger vehicles in Germany. In the BAU 2030 scenario, car sharing rises to one half of one percent (0.5%) of all automotive passenger-kilometres by 2030 (a five-fold increase above today). In the Circular “Green” 2030 scenario, today’s mobility pattern is significantly disrupted, with car sharing growing to cover 2.5% of total automotive passenger-kilometres while reducing road traffic and CO_2 emissions. In contrast, though the Circular “Gray” scenario sees the same number of shared vehicles as the Circular “Green” scenario, this additional shared mobility fails to substitute private-vehicle traffic, actually fostering additional travel by motorised passenger vehicles along with the highest CO_2 emissions of the three 2030 scenarios. The Circular “Green” scenario is based on a continuation of present-day car-sharing effects in Germany, which studies show has the net effect of reducing users’ reliance on private passenger cars. The Circular “Gray” scenario, however, is consistent with the convergence of car sharing and ride sharing (driven by market adoption of autonomous vehicles), which can be expected to decrease prices for car-based mobility and entice away users of public transport services.

Case-study results: future car sharing in Germany

Effects on passenger-km. Figure 1 shows the case-study results for the annual passenger-km travelled in Germany by motor vehicles in 2030, breaking them down by use application (private car or car sharing) as well as energy source (fossil fuel or electric). Including the base year of 2017 allows a comparison to the present-day situation. In the Circular “Green” scenario, the total passenger-km of motorised passenger vehicles are reduced by 7% compared to the BAU scenario, whereas the Circular “Gray” scenario drives an increase of 2% in passenger-km.

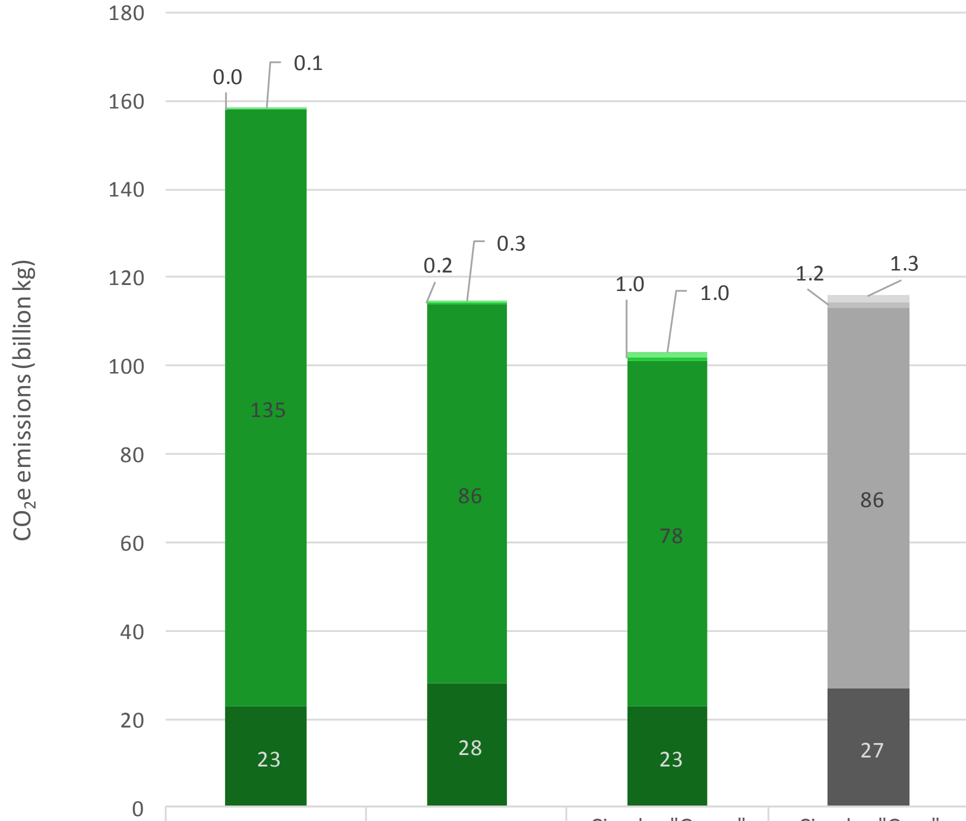
Figure 1. Annual passenger-km in Germany (motorised passenger vehicles)



	Base Year (2017)	BAU Scenario 2030	Circular "Green" Scenario 2030	Circular "Gray" Scenario 2030
Car sharing (electric)	0.1	1.0	5	5
Car sharing (fossil-fuel)	1.0	3.9	18	18
Private electric cars	2.0	104	102	102
Private fossil-fuel cars	962	866	783	869

Effects on greenhouse-gas emissions. Significant reductions in greenhouse-gas emissions are evident in all the 2030 scenarios vis-à-vis present-day emissions (see Figure 2). The most important factor behind the significant drop in 2030 emissions from present-day levels is the authors' underlying assumption of an ambitious rise in the average energy-efficiency of vehicles of all fuel types combined with a shift to electric vehicles. By contrast, the additional contribution of car sharing is modest. The BAU scenario delivers CO_2e emissions reduction of 28% by 2030 compared to 2017. In the Circular "Green" scenario, the additional car sharing reduces the total emissions a further 10% beyond those achieved in the BAU 2030 scenario. By contrast, the Circular "Gray" scenario sees no climate benefits compared to the BAU scenario, with emissions actually increasing by 1%.

Figure 2. CO_2e emissions from motorised passenger vehicles in Germany

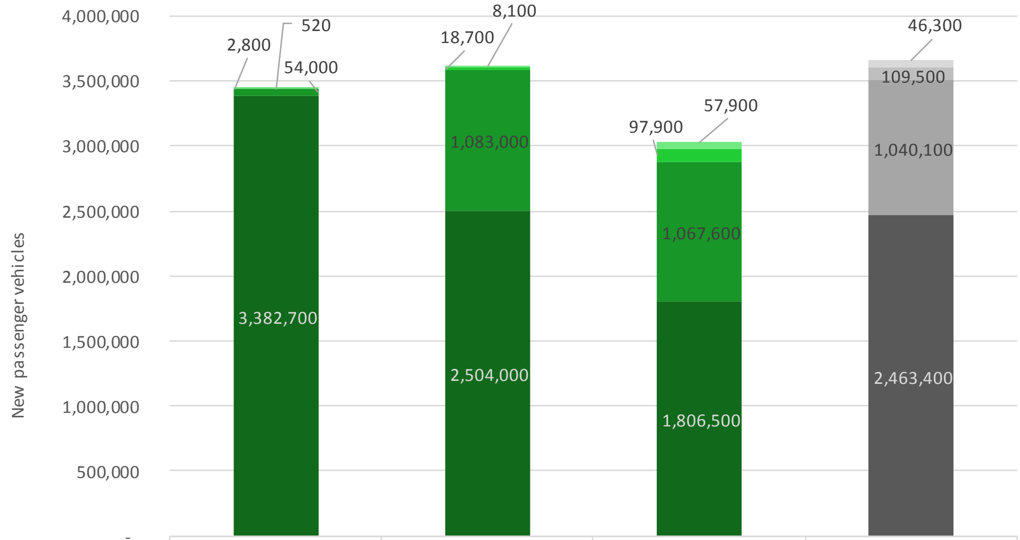


	Base Year (2017)	BAU Scenario 2030	Circular "Green" Scenario 2030	Circular "Gray" Scenario 2030
Car sharing cars (use)	0.1	0.3	1.0	1.3
Car sharing cars (production)	0.0	0.2	1.0	1.2
Private cars (use)	135	86	78	86
Private cars (production)	23	28	23	27

Note: the decrease in CO_2e emissions for the 2030 scenarios results primarily from ambitious gains in vehicle-fleet efficiency (at levels in line with Germany achieving its climate targets).

Effects on vehicle production. The most dramatic differences amongst the scenarios relates to the production of new vehicles. Currently, the average lifespan of a car-sharing vehicle in that application is three years. After this period of time, car-sharing vehicles are typically sold in the used-car market and become private vehicles. Due to decreased demand for vehicles overall in the Circular "Green" scenario, car production for the German market falls 16%, while 5% of new-car production is for the car-sharing market. In contrast, car production actually increases slightly (by 1%) in the Circular "Gray" Scenario.

Figure 3. New passenger vehicles in Germany



	Base Year (2017)	BAU Scenario 2030	Circular "Green" Scenario 2030	Circular "Gray" Scenario 2030
Car-sharing cars (electric)	520	8,100	57,900	46,300
Car-sharing cars (fossil-fuel)	2,800	18,700	97,900	109,500
Private cars (electric)	54,000	1,083,000	1,067,600	1,040,100
Private cars (fossil-fuel)	3,382,700	2,504,000	1,806,500	2,463,400

Conclusions

This circular-economy case study on car sharing examines an area of dynamic and large-scale change driven by rapidly evolving technologies. Key insights from the study include:

Car sharing will likely blur into ride sharing in the coming decades - Car sharing is likely to merge with ride sharing from both a usage and business-model perspective as autonomous vehicles enter the market. Car manufacturers are already positioning themselves for a major revolution in urban mobility.

Future impacts depend on the policy framework - Car sharing could be headed for a significant scaling up. However, the degree to which shared mobility attracts users from private vehicles or from public transit will determine car sharing's urban, environmental and resource impacts. Policies such as congestion pricing, parking fees, fuel taxes and other measures can address the implicit subsidies that encourage private-vehicle use. Particular policy attention is needed on ways to address the negative effects of increased ride sharing and the market adoption of autonomous vehicles on public transit use. The energy efficiency of the vehicle fleet, cleaner engine exhaust and the widespread uptake of electric vehicles will remain the decisive contributors to reducing negative environmental impacts of passenger transport. Car sharing vehicles, are on average more fuel efficient and more likely to be electric vehicles, and thus can make a supporting contribution.

1 :: Introduction

The mobility sector is currently undergoing a series of fundamental changes, including a shift towards non-fossil fuels, autonomous driving and to mobility as a service. Car sharing is a crucial part of this mobility-as-a-service sector. Its rising importance can be explained by several factors: the increasing availability and diffusion of mobile electronic devices and software capabilities; a growing technological connectivity within society; and shifting societal values with respect to mobility in general and specifically regarding cars.

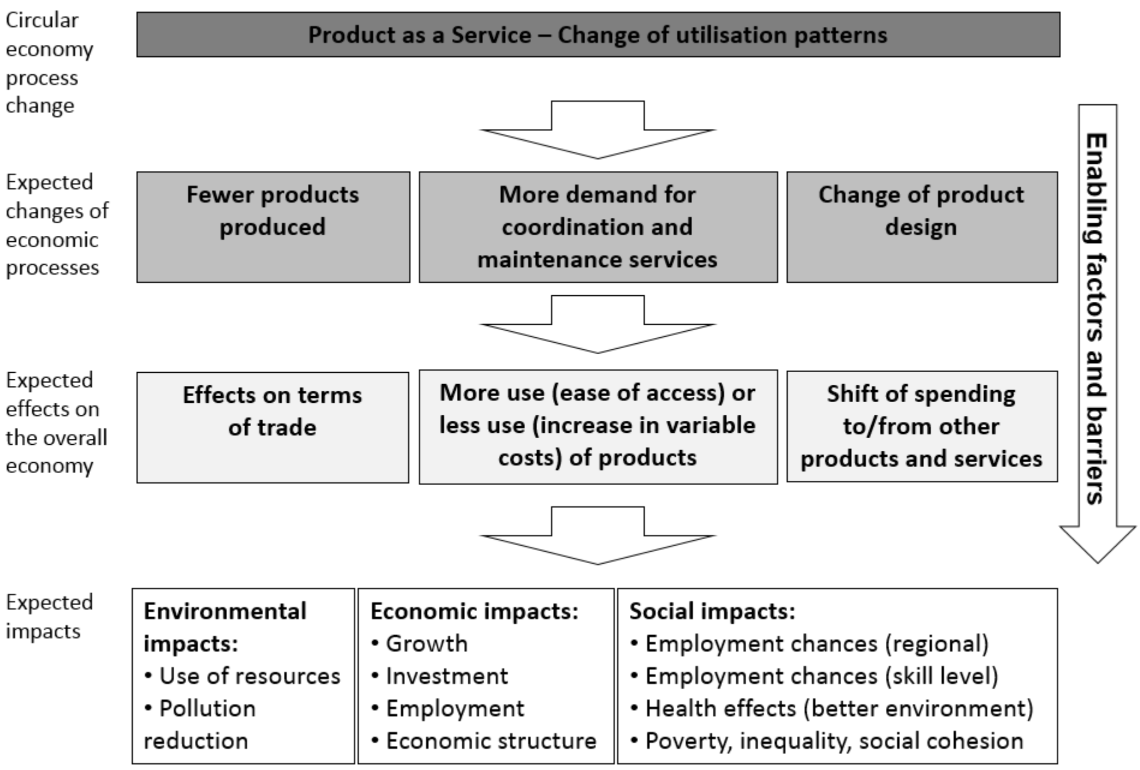
Today, especially for young adults, the ownership of a car no longer plays as dominant role as a symbol for mobility and status as it did just a few years ago (Canzler and Knie, 2015). Driving licenses are increasingly being acquired later and the share of young people among car buyers has been declining for some time (Canzler and Knie, 2015; Schönduwe et al., 2012). At the same time, the demand for mobility is increasing and expected to rise through 2030 (BMVI, 2014a). The car has shifted from being a symbol of status and personal independence to being seen as a rather pragmatic component of a mobility pattern wherein several intermodal means of transport are used, with the modal choice depending on the specific circumstances. The focus has thus shifted toward accessing mobility services in a flexible way rather than possessing a car as such.

This change of expectations towards mobility in general and cars specifically has allowed car sharing to escape its marginal niche to become increasingly mainstream, leading to the question what its future social, environmental and economic impacts could be. Car-sharing vehicles put on a higher annual mileage per vehicle than private cars due to their more intensive use. Car sharing could also mean that fewer cars would be necessary to meet the demand for mobility services. Hence, car sharing has the potential to generate significant social, environmental and economic impacts, ranging from employment effects, energy and resource consumption to significant changes in the modal split.

Car sharing within the context of the circular economy

Product-as-a-service is the underlying concept behind the so-called sharing economy, which is often summarised as “using instead of owning” (Rifkin 2014). As such, product-as-a-service reflects a trend of preferring fluid and frequently digitised goods over tangible goods. This includes digital services and renting, as well as lending and exchanging of goods and services, such as cars and accommodation. Figure 4 shows schematically how the product-as-a-service model affects economic processes and results in various environmental, economic and social impacts.

Figure 4. Impact chain – Product-as-a-Service



Source: own illustration.

As a means of investigating the product-as-a-service phenomenon, the project team selected a final case-study topic of car sharing in Germany for these reasons:

- **Car sharing has transformative potential.** The transportation sector is responsible for a large portion of energy consumption and greenhouse-gas emissions. Car sharing is a transition that is already underway, with car-sharing services rapidly expanding across the globe.
- **The sector is facing rapid changes, contradictory effects and high uncertainties.** Car sharing's future effects are highly uncertain and the effects will differ depending on future technological, economic and policy developments.
- **Germany is an important automotive market.** Germany is one of the world's major car-producing countries. At the same time, it is among the world leaders in adoption of car sharing. Germany offers a rich case study on both the demand and supply sides of car-sharing developments. With Germany a frontrunner country in a new and rapidly evolving sector, the current and near-term developments in Germany also offer one of the best glimpses into possible future developments elsewhere.

This CIRCULAR IMPACTS case study provides a prospective overview of potential changes and impacts related to car sharing in Germany. In line with the CIRCULAR IMPACTS case-study methodology[1], this case study report uses the following stepwise approach to examine possible future scenarios for 2030:

[1] For a full description of the case-study methodology, see Smits & Woltjer (2017).

- Step 1: Defining the baseline
- Step 2: Defining the new business case
- Step 3: Changes in the key sector
- Step 4: Effects on other parts of the economy
- Step 5: The impact on the environment and society
- Step 6: Are alternatives available?
- Step 7: Policy options
- Step 8: Overall conclusions

Though it employs the best available data in its analysis, the case study is explicitly not a forecast of the future—the uncertainties are far too high, especially given the long-term time horizon of 2030 and rapid technological developments. By focusing so tightly on motorised passenger vehicles, it is also does not holistically address the transport sector. However, the results of the scenario analyses do provide useful insights for policymakers wishing to understand the dynamics behind car sharing and considering how best to foster and shape those dynamics through public policy. The quantitative data collected, the method of analysis, and the scenario results are also useful inputs for further research in the field.

2 :: Step 1: Defining the Baseline

This section provides a conceptual understanding of the two business models at the centre of this case study: private car ownership versus car sharing. This case study examines station-based sharing and free-floating sharing. The present market for car sharing in Germany is described, providing details on the structure and magnitude of this rapidly growing mode of transport. With that background knowledge in place, we list the various base-year parameters used in the scenario analysis along with the assumptions used for the BAU scenario for 2030.

2.1 Understanding the business models

The two business models compared in this case study co-exist in both the baseline and circular scenarios. The scenarios are distinguished from one another by the differing degrees to which car sharing is used vis-à-vis private vehicles.

Private motorised transport

In the predominant business model of private motorised transport, the car manufacturer supplies a vehicle to a retailer and the retailer then sells the vehicle to the end consumer. In this model, the consumer takes care of all maintenance costs, such as insurance, taxes and repairs, which are frequently provided by independent garages. In this linear model, the car may be used by several consumers sequentially (via resale of the used vehicle to a new private owner), but the use intensity of the vehicle is relatively low. Eventually, the car is sold or scrapped, in which a portion of the material stream is recycled while the other portion is permanently disposed.

Figure 5 depicts the business model of private motorised transport.

Car sharing

In the car-sharing business model, the car remains in the ownership of the mobility service provider, which could either be the car manufacturer or a service provider. Hence, the maintenance costs are undertaken by the service provider, which is likely to cooperate with a pre-determined set of garages for repairs.

Figure 6 depicts the business model of car sharing.

Figure 5. Predominant model of private motorised transport (cars)

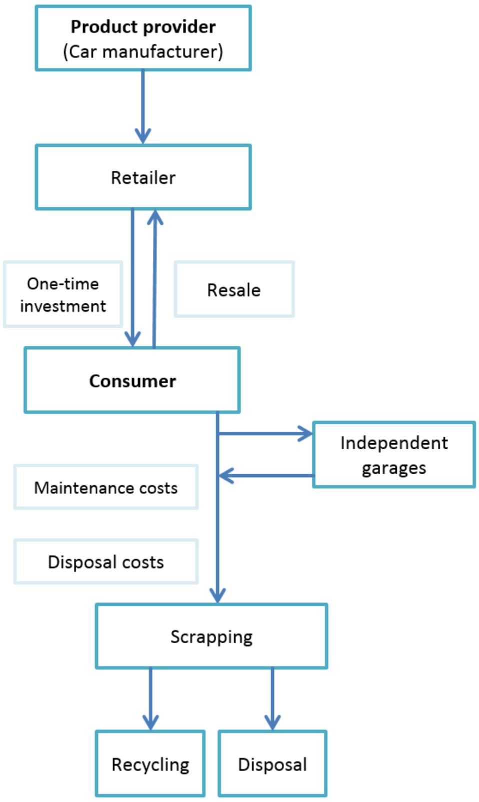
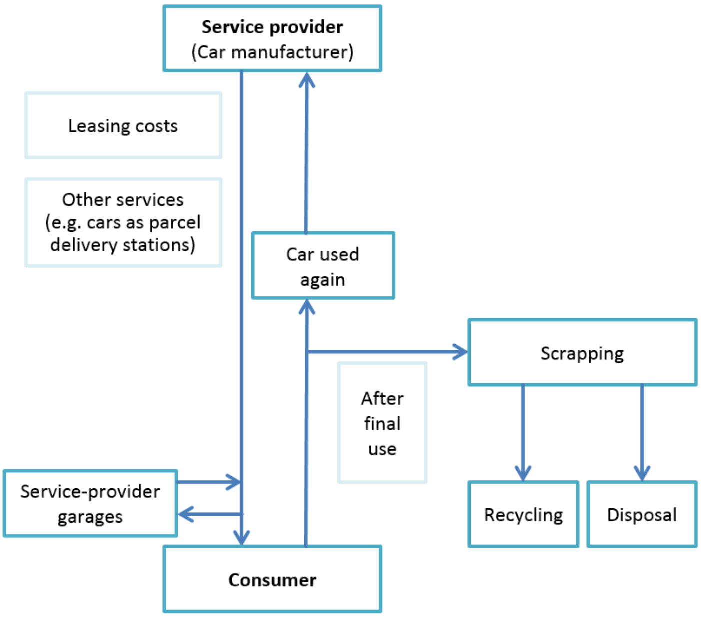


Figure 6. Car sharing model for private motorised transport (cars)



Own illustrations. After its use as a car-sharing vehicle, the vehicle is typically sold as a used vehicle, with the remainder of its life as a private vehicle.

Box 1. The product-as-a service model

For many products, the same person or organisation has both ownership and usage rights. In a product-as-a-service model, however, this can be the case but it does not have to be. Two types of product-as-a-service models are:

- **Models of leasing or renting.** The respective production companies remain the owners of the assets and maintain them, selling the services of those assets to a consumer or business customer (e.g. 'power-by-the-hour', light as a service). A very recent form of this business model in car sharing has been car companies that found daughter companies for short-term rental (e.g. Car2go or DriveNow).
- **Sharing models.** Private companies or non-profit organisations can assume ownership of the products and enable a shared use e.g. in peer-to-peer car sharing

If products are shared, leased or rented instead of owned and used exclusively, three direct impacts could occur:

- Fewer products may be needed due to more frequent utilisation, leading to less value-added in the production sector.
- The additional coordination and maintenance service needed could increase value-added in the respective branches.
- Over the mid and long term, if producers bear the costs of repair, they could change their designs to make products more sharable and longer lasting.
- Indirect impacts also occur as consumer behaviour changes and as the value chains linked to the older and newer economic models adapt.

Types of car sharing

Car sharing means organised, shared use of vehicles by a larger number of people (Pieper et al 2013). This study focuses on two types: station-based car sharing and free-floating car sharing. Peer-to-peer car sharing is not explicitly examined further in this case study, due to the limited data available at present.

Station-based car sharing

With station-based car sharing (e.g. Cambio, Stadtmobil), a driver picks up the car at fixed locations (i.e. stations) and typically brings it back to the same station after use. In Germany, station-based providers now have 10,050 car-sharing vehicles at about 5,000 stations throughout Germany (BCS, 2018a).

Free-floating car sharing

With free-floating car sharing (e.g.DriveNow, Car2Go), a driver finds the car-sharing vehicle by mobile phone, drives it to his or her destination, and simply parks the vehicle nearby. Free-floating providers in Germany now provide 7,900 vehicles serving several large urban centres (BCS, 2018a).

Peer-to-peer car sharing

Hiring and renting cars among individuals who do not know each other is known as peer-to-peer car sharing. The mediation between the private car owner and the person searching for a car is provided by a platform (e.g. Drivy), where one can typically register without any cost. For the use of this mediation service, and often insurance, the platform usually charges a fee.

Box 2. Other types of shared mobility

Car sharing is one of several types of shared mobility available today. Other types of shared mobility can also contribute to a more circular economy wherein resources are used more intensively. These other shared-mobility options including the following transportation modes.

Public transport

By far, the most widely used form of shared mobility is public transport. In Germany, urban transit and rail services accounted for 17.2% of passenger trips in 2016 (BMVI, 2017, p. 217).

Ride sharing

Ride sharing allows passengers to be picked up by a driver, either on a peer-to-peer model (wherein passengers share in the travel costs) or as a commercial service (wherein paid drivers chauffeur passengers to their destinations). Forms include platform-based ride sharing (e.g. Blablacar) and dynamic ride sharing (e.g. Flinc) that helps match drivers and passengers in real time. Commercial ride-sharing platforms (e.g. Uber) resemble the taxi-service model in many respects. Ride sharing can also provide pooled transport of several passengers who may not know one another or share only proximate (i.e. not the same) destinations.

Taxis

Taxis are chauffeured vehicles for hire, typically licensed for operation in a specific geography and with regulated fares and metering.

Shared non-car modes of travel

Increasingly, other forms of mobility besides passenger vehicles are being shared via means similar to car sharing; this includes bicycles, mopeds and electric kick scooters.

2.2 Current use of motorised passenger vehicles in Germany

The demand for mobility services in Germany is high and growing. The German government reports that 72 billion passenger trips were made in Germany in the year 2016, with over 80% of these trips made by motorised passenger vehicles (see Table 1).

Table 1. Passenger trips by mode of motorised transport in Germany in 2016

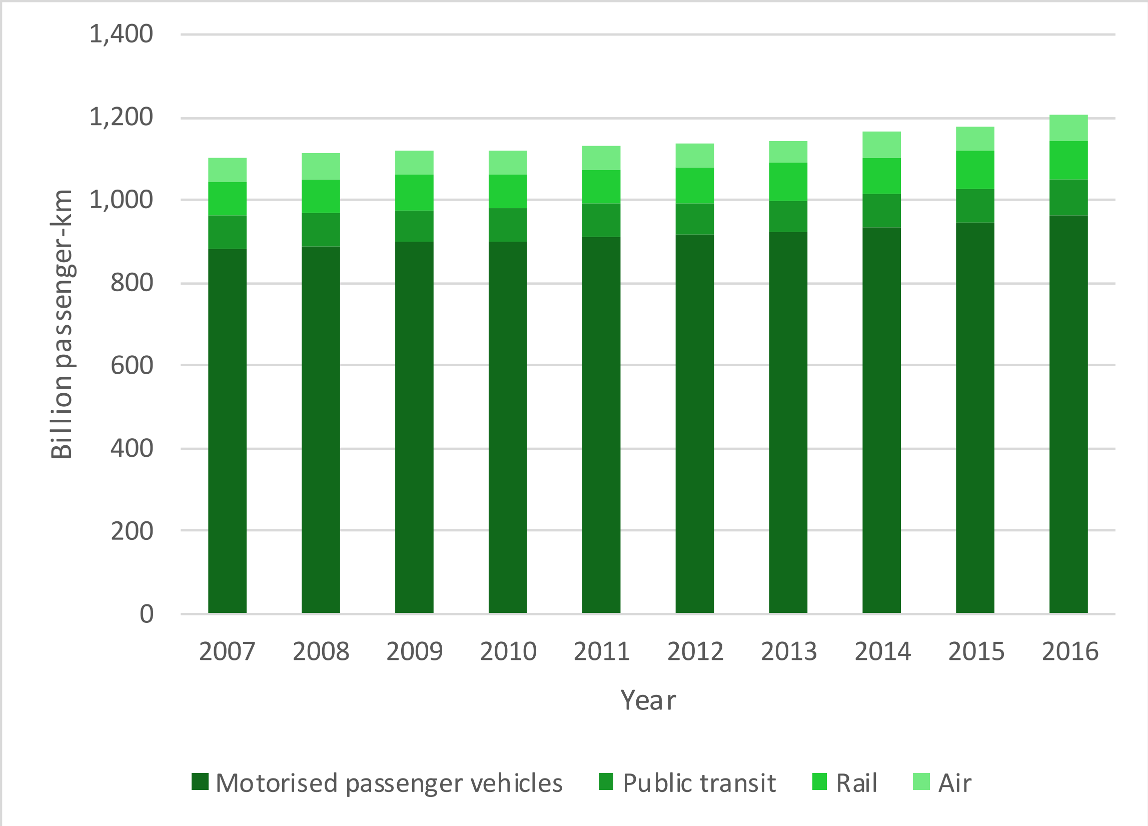
Mode of transport	Passenger trips (millions)	% of total trips
Motorised passenger vehicles	59,512	82.5%
Public transit	9,568	13.3%
Rail	2,830	3.9%
Air	201	0.3%
Total	72,111	100%

Source: BMVI (2017, p. 217)

Passenger kilometres by mode

The distances that passengers are travelling in Germany are also increasing for all modes of transport. Over the 10-year period from 2006 to 2016, the distance travelled in Germany by passengers in motor vehicles has increased by 9.4%. Similar growth has been seen for public transport (transit and rail combined) at 10.9%, while air-travel distances increased by 15% over the period (BMVI, 2017, p. 219). Figure 7 provides an overview of passenger-kilometres by mode of transport over the most recent decade for which statistics are available (2007-2016).

Figure 7. Passenger-kilometres by mode of motorised transport in Germany (in billions)



Data source: BMVI (2017, p. 219)

Number of passenger vehicles in Germany

As of January 2018, there were nearly 46,475,000 motorised passenger vehicles registered in Germany (Kraftfahrt-Bundesamt, 2018a). In recent years, the number of vehicles has increased by about 1.3% annually (BMVI, 2017, p. 133).

Fuel types and emission standards

The most commonly used fuels for passenger cars in Germany as of 2018 are petrol (65.5%) and diesel (32.8%) (Kraftfahrt-Bundesamt, 2018a). The number of electric vehicles increased to 53,861 (a dramatic increase of 53.3% over the previous year) and the stock of plug-in hybrid vehicle to 44,419 vehicles (an even higher annual growth of 111.8%) (Kraftfahrt-Bundesamt, 2018a). Though this growth rate of e-mobility is significant, electric vehicles (BEV and PHEV) remain a very small share of the vehicle fleet at only 0.2% (i.e. 2/10 of 1%).

The number of passenger cars with the currently best emissions class (Euro 6) rose to nearly 9,318,000 vehicles and Euro 6 vehicles now make up 20% of the motor-vehicle fleet in Germany (Kraftfahrt-Bundesamt, 2018a). Most passenger cars in Germany only comply with the weaker emission classes Euro 5 and 4 (about 28% and 31%, respectively) (Kraftfahrt-Bundesamt, 2018a).

Transport emissions in Germany

Over the period 1995-2014, exhaust-gas volumes of nitrogen oxides (NOx) dropped by 55% and particulate-matter (PM) emissions dropped by 68% (UBA, 2017b). These emission reductions would have been even higher if the vehicle-kilometres travelled by passenger vehicles in Germany had not been increasing over the same period. The increasing share of diesel-powered vehicles over the period also prevented further emission reductions in NOx and PM than would have happened otherwise (UBA, 2017c).

During the period 1995-2014, motorised passenger vehicles produced less greenhouse-gas emissions per passenger-kilometre in Germany. However, the passenger-kilometres travelled by these vehicles increased by 17% over the period 1995-2014 (UBA, 2017c). The rise in demand for mobility largely offset gains in vehicle efficiency, leading to a modest reduction of 2% in the overall carbon emissions of cars from 1995 to 2014 (UBA, 2017b).

This dynamic within the car sector in Germany is an example of the rebound effect, wherein efficiency gains are partly, completely or over-compensated by increases in overall consumption. From 1990 to 2014, while the total GHG emissions in Germany declined by 27.7%, the GHG emissions of the transport sector decreased by only 2.6% in that period (UBA, 2017b).

Greenhouse gases from traffic have even risen recently. Germany’s Federal Environmental Agency estimated that 2016 GHG emissions were 1.8 million tonnes (1.1%) higher than they were in 1990 (UBA, 2017b). A central climate-policy challenge for the German is how to ensure the transportation sector contributes to achieving the country’s emissions targets.

Box 3. The German automotive industry

The automotive industry plays a crucial role in the German economy, with Germany currently the fourth largest automobile-producing nation in the world (after China, the USA and Japan) (BMWI 2017).

Employment in the German automotive industry

There were 820,200 employees working in the production of automobiles and automotive parts. Compared to the previous year, this number has risen by 1%, and is now at its highest level since 1991 (VDA, 2018). The sector includes manufacturers of motor vehicles and engines (479,800 employees), parts suppliers (305,200 employees) as well as manufacturers of automobile frames, trailers and accessories (35,200 employees) (VDA, 2018).

Turnover and gross value added

The German manufacturers of automobiles and engines accounted for a revenue of 331.3 billion euros in 2017, which was 5% higher than in the previous year (VDA, 2018). The overall gross value added of the vehicle manufacturing sector was 139 billion euros, which corresponds to about 5% of total gross value added in Germany. (Statistisches Bundesamt, 2018, p. 20).

2.3 Current use of car sharing in Germany

In Germany, the number of people using car sharing has grown rapidly in recent years. As of January 2018, there were 2,110,000 customers registered with 165 car-sharing providers in 677 different German cities and communities (BCS, 2018a). Compared to the previous year, 80 additional cities and communities now offer car sharing (BCS, 2018a). In absolute numbers, Berlin is the city with the most car-sharing cars. However, when calculated per 1,000 inhabitants, Karlsruhe has the highest car-sharing density (BCS, 2017b).

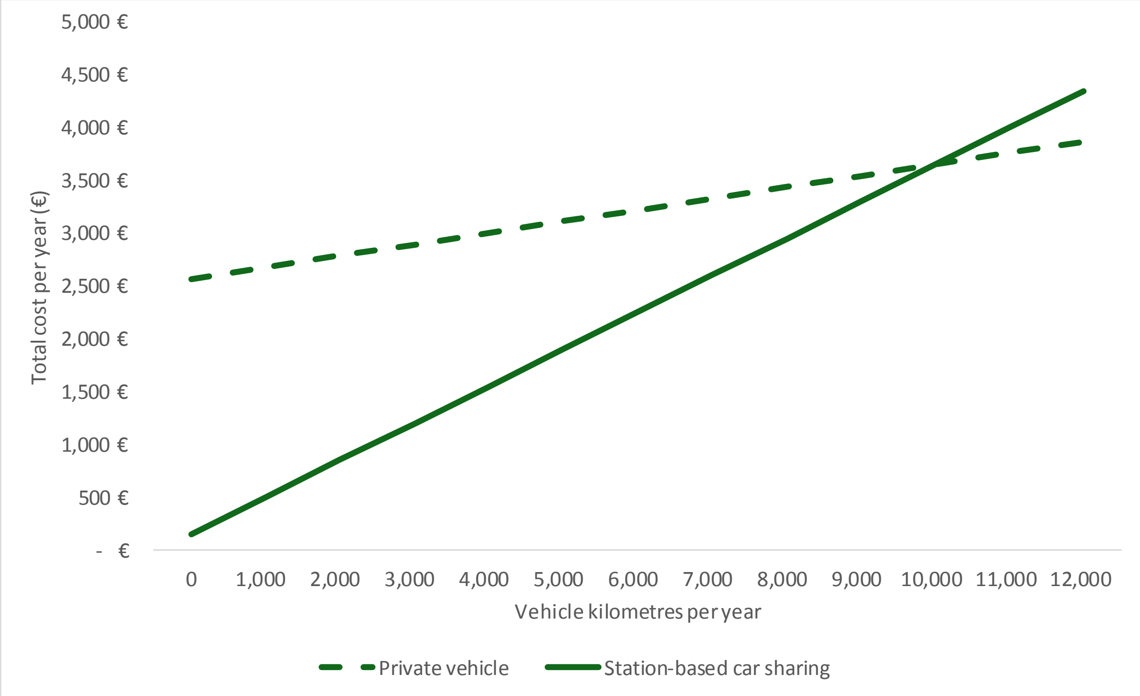
Though the car-sharing sector is growing quickly in Germany, it remains a small portion of overall motor-vehicle transportation. We estimate that in 2017, about one billion passenger-km were provided by car sharing. This represents about 0.1% (i.e. 1/10 of 1%) of total motor-vehicle passenger-km in Germany in 2017, which totalled 965.5 billion passenger-km in 2017 (BMVI, 2017, p. 219). Currently, ten percent of car-sharing vehicles in Germany are electric or hybrid vehicles (BCS, 2018b), a percentage share that is around 100 times higher than the national passenger car fleet (Kraftfahrt-Bundesamt, 2017).

According to Firnkorn and Shaheen (2014), two key methodological challenges make empirical evaluations of car sharing difficult: 1) impacts only stabilise over a timeframe of years; and 2) there is a lack of consistent standards for car sharing evaluations, with results strongly dependent on the method chosen.

Generally, car ownership is linked to various factors, such as the personal situation of a person (e.g. family structure) or the accessibility of different modes of transport. Additionally, policy decisions can have a significant impact on consumers' behaviour, e.g. the introduction of city tolls or parking fees.

The extent to which car sharing makes economic sense for a person is closely related to the distance driven per year. As shown in Figure 8, driver-owned cars have fixed costs that must be paid regardless of how far the vehicle is driven, making private ownership more expensive than car sharing at a low annual mileage. On average, a person would need to drive more than 10,000 kilometres per year until the cost of a private car becomes cheaper than the cost of using car sharing (BCS, 2017a).

Figure 8. Average cost comparison: driver-owned car versus car sharing



Source: Adapted from BCS (2017a). In this comparison, the driver-owned car is one of the 10 cheapest compact cars in Germany. The monthly costs were calculated using the ADAC car cost calculator, while the car-sharing rate is a standard rate of a station-based provider without any discount. Fixed costs for car sharing include the registration fee, security package and the basic price of membership.

Table 2 shows a cost breakdown. A significant portion of private-car costs are fixed costs or depreciation, which are typically considered only at the time of purchase but not taken into account in everyday decision-making regarding the costs and benefits of making a particular trip.

Table 2. Average annual costs per driver-owned car and car sharing costs (8,000 km per year, 667 km per month) in EUR

	Driver owned cars	Car sharing
Fixed costs	€960	€176
Costs for repair	€298	-
Operating costs / travel costs	€605	€2,780
Loss in value	€1.620	-
In total	€3,483	€2,956

Source: Adapted from BCS (2017a). The monthly costs were calculated using the ADAC car cost calculator, while the car-sharing rate is a standard rate of a station-based provider without any discount. Fixed costs for car sharing include the registration fee, security package and the basic price of membership.

One of the central questions related to the use of car sharing is the extent to which private cars are replaced by the use of car-sharing services. Box 4 provides a brief overview of recently estimated and observed replacement rates relevant to the German context.

Box 4. Replacement of private cars and passenger kilometres due to car sharing – as overview

Private-car replacement

Studies examining the question of private-car replacement rates have returned widely differing results. Reported replacement-rate figures dependent on the car-sharing scheme (e.g. free-floating or station-based), location-specific factors (e.g. availability of public transport) and also the study design itself. Findings of recent studies include:

- One car-sharing vehicle (free-floating and station-based) replaces three private cars on average (team red, 2015, p. 19).
- One car-sharing vehicle (free-floating and station-based) replaces four to eight vehicles. (MOMO, 2010, p. 80).
- One car-sharing vehicle (station based) replaces 16 private cars (team red, 2018).
- One car-sharing vehicle (station based) replaced 8 to 20 private cars (BCS, 2016, p. 4).
- Fifteen percent (15%) of users of station-based car sharing reported that they shed their private vehicle due to car sharing, while 7% of users of free-floating car sharing reported this (Giesel & Nobis, 2016, p. 1).[2]

Together, the above studies identify a range of replaced private vehicles due to car sharing of between 3 and 20 cars.

Reduction in net vehicle-kilometres due to car sharing

A 2015 study of car sharing carried out for the city of Munich found that use of car sharing led to a reduction in total vehicle-kilometres driven. While car-sharing customers drove an additional 11.2 million yearly kilometres via car sharing, the vehicle-replacement effect also led to a reduction of 52.5 million yearly kilometres driven via private vehicles. Thus, for every car-sharing kilometre driven, 4.7 private-vehicle kilometres were not driven by the group that would have been otherwise, yielding a net reduction of 3.7 vehicle-kilometres (team red, 2015, p. 25).

Implications for this scenario analysis

Based on the above data, the following assumptions will be taken into the 2030 scenario analysis:

- **Private-car replacement:** a car-sharing vehicle replaces three private vehicles, yielding a net reduction of two passenger vehicles (Basis: team red, 2015)
- **Reduction in vehicle-kilometres:** for every passenger-kilometre covered via car-sharing vehicle covers, 4.7 private-vehicle kilometres are not driven, yielding a net reduction of 3.7 passenger-kilometres (Basis: team red, 2015)
- However, due to the high degree of uncertainty around these parameters, especially in the long-term future wherein autonomous vehicles are expected to drive down costs and blur the boundaries amongst ridesharing, car sharing and public transport, a third 2030 scenario will relax these two assumptions as a form of sensitivity analysis.

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[2] Applying these findings of Giesel & Nobis (2016) to the 2018 car-sharing data provided by BCS (2018a) would yield a private-vehicle replacement rate of 11 private vehicles per car-sharing vehicle in Germany (a replacement rate of 8 for each station-based car-sharing vehicle and a rate of 14 for each free-floating car-sharing vehicle); author‘s own calculation.

2.4 Base-year parameters

For this case study, the base-year situation was defined by using the most recent reliable data available as of June 2018. The data years for the base-year parameters generally range from 2016 to 2017. The data collected for the base year focus on automotive transport only, including privately owned cars as a whole as well as the use of car-sharing vehicles (see Table 3). Official statistics of the German government were used wherever possible. The car-sharing statistics used were mostly based on the annual statistic reported by the German car-sharing association (Bundesverband CarSharing e.V.) or taken from prior car-sharing studies. If the year 2030 is also shown in the column “Data year” that parameter is also used as an assumption in the 2030 scenarios.

Table 3. Base-year parameters for passenger vehicles: production, stock, lifespan and use

Parameter	Parameter value (Data years)	Source
VEHICLE PRODUCTION		
New vehicles produced for German market (all fuel types)	3,440,000 (2017)	Kraftfahrt-Bundesamt (2018b, p. 1).°
New vehicles produced for German market (electric)	54,492 (2017)	Kraftfahrt-Bundesamt (2018b, p. 1).° BEV and PHEV only.
VEHICLE STOCK		
Total number of motorised passenger vehicles (all fuel types)	46,474,594 (2017)	Kraftfahrt-Bundesamt (2018a, p. 1).° As of 1.1.18.
Total number of motorised passenger vehicles (electric)	98,280 (2017)	Kraftfahrt-Bundesamt (2018a, p. 1).° As of 1.1.18. BEV and PHEV only.
Total number of car-sharing vehicles (all fuel types)	17,950 (2017)	BCS (2018a, p. 1).° As of 1.1.18.
Percentage of car-sharing vehicles that are electric	10.3% (2017)	BCS (2018c, p. 1).° As of 1.1.18. BEV and PHEV only.
VEHICLE LIFESPAN		
Average lifespan of passenger motor vehicle	13 years (2017, 2030)	Kraftfahrt-Bundesamt (2011, p. 9).°
Average lifespan of a car-sharing vehicle (in first use)	3 years (2017, 2030)	UBA (2013, p. 1).° Authors assume vehicles then enter used-vehicle market.
Average remaining lifespan of a car-sharing	7 years* (2017, 2030)	Authors assume all cars reach same average vehicle-

vehicle		kilometres (i.e. 175,000 km) before scrapping.
VEHICLE USE		
Total number of annual passenger-km	965.5 billion (2016)	Kraftfahrt-Bundesamt (2017c, p. 219).°
Total number of annual vehicle-km	625.5 billion (2016)	Kraftfahrt-Bundesamt (2017b, p. 1).°
Total number of annual passenger trips	59.5 billion (2016)	Kraftfahrt-Bundesamt (2017c, p. 217).°
Annual vehicle-km per private vehicle	13,459* (2016, 2030)	Calculated from parameters in this table.
Annual vehicle-km per car-sharing vehicle	30,500* (2016, 2030)	ifmo (2016, pp. 104-5).° Calculation is a weighted average for station-based and free-floating car sharing.
Average private-vehicle occupancy (number of persons)	1.54* (2016, 2030)	Calculated from parameters in this table.
Average private-vehicle occupancy (number of persons)	1.94 (2017, 2030)	BCS (2018, personal communication, 12.07.2018)
Average passenger-km per trip (private vehicles)	16.2* (2016, 2030)	Calculated from parameters in this table.
Average passenger-km per trip (car-sharing vehicles)	36.0* (2016, 2030)	ifmo (2016, p. 105).° Calculation is a weighted average for station-based and free-floating car sharing.
EFFECTS OF CAR SHARING ON VEHICLE COUNTS AND TRAVEL		
Net reduction of passenger vehicles per car-sharing vehicle	2 vehicles (2016, 2030)	team red (2015, p. 19)°
Net reduction in total pkm of motor vehicles per pkm covered by car sharing	3.7 pkm (2016, 2010)	team red (2015, p. 25)°

* Own calculation
° Hyperlink to source data

Production-related impacts

This case study includes an analysis of the expected climate impacts of both vehicle production and use. Table 4 provides an overview of the estimated average greenhouse-gas emissions (measured in CO_2e) stemming from automobile production. Average-value estimates, differentiated for fossil-fuel vehicles as a whole and electric vehicles as a whole are provided based on Helms, et al (2016).

Table 4. Base-year parameters for vehicle production

Parameter	Parameter value (Data year)	Source data used
CO_2e emissions (kg) per vehicle produced (fossil-fuel vehicles)	6,700§ (2016, 2030)	Helms, et al (2016, p. 79)°
CO_2e emissions (kg) per vehicle produced (electric vehicles)	10,100§ (2016, 2030)	Helms, et al (2016, p. 79)°

§ Own estimate of average value based on provided data
° Hyperlink to source data

Use-related impacts

Table 5 provides the average climate impacts for fossil-fuel and electric vehicles, respectively. According to the German Ministry for Environment (UBA), due to several factors (average size, age and power-train differences), car-sharing vehicles emit 16% less CO_2 per kilometre on average than private passenger vehicles (UBA, 2013).

Table 5. Base-year parameters for vehicle use

Parameter	Parameter value (Data year)	Source data used
Average CO_2 emissions (kg) per vehicle-km (private vehicle; fossil-fuel)	.216* (2016)	UBA (2018, p. 1)° Note: Calculated from source data (.140 kg per pkm) using average vehicle occupancy for private vehicles (see Table 3)
Average CO_2 emissions per vehicle-km (private vehicle; electric)	.117§ (2015)	Schallaböck & Fischedick (2012, p. 9)°
Carsharing per-km climate impacts, as % of private cars	84% (2013, 2030)	UBA (2013, p. 1)°

* Own calculation
§ Own rough estimate of average value based on provided data
° Hyperlink to source data

The above parameters were entered into a spreadsheet model to establish the functional relationships amongst these variables, both for the base-year results as well as their role as bases for the 2030 scenarios.

2.5 Business-as-usual scenario for 2030

2.5.1 Scenario definition

In the BAU Scenario 2030, car sharing continues its rapid growth while largely retaining its present-day definition as a mix of station-based and free-floating car sharing. In this scenario, ridesharing is not considered nor do autonomous vehicles make large inroads into driving down costs and blurring the boundaries amongst various shared-mobility schemes. By 2030, ½ of 1% of passenger-kilometres are covered by car sharing in the BAU scenario. This represents ambitious compound annual growth of around 12% per year but is not a fundamentally disruptive transformation.

Also in this scenario, German public policy and automobile-industry innovation are able to steer the passenger-vehicle sector toward a set of technological innovations that contribute to the country being able to achieve its greenhouse-gas emissions targets. For the specifics of how this is accomplished, the BAU 2030 scenario is based on recent scenarios developed by Öko-Institut for Agora Verkehrswende (2018), which provides a set of parameters for our scenario model, wherein an acceleration of electro-mobility puts 5 million electric vehicles (BEV and PHEV) on the road in Germany by 2030. More importantly, however, the scenario assumes significant improvements in the average fuel efficiency of new vehicles over the 12-year period will dramatically drive down average greenhouse-gas emissions per vehicle-kilometre.

The Circular 2030 scenarios also use this same set of underlying vehicle-efficiency achievements, the assumption of 5 million electric vehicles and the assumption that 20% of car-sharing vehicles are electric by 2030. Using this same set of assumptions in all scenarios isolates the effect of the circular-economy aspects of interest in this case study

2.5.2 Assumptions

Table 6. Additional assumptions for the 2030 BAU Scenario

Parameter	Parameter value (Data year)	Source data used
Total number of annual passenger-km (as in government forecast before applying BAU 2030)	991.8 billion (all 2030 scenarios)	BMVI (2014, p. 5)
Total number of electric vehicles (BEV and PHEV)	5 million (all 2030 scenarios)	Agora Verkehrswende (2018, p. 5)°
Percentage of car-sharing vehicle stock that is electric (BEV and PHEV)	20% (all 2030 scenarios)	Own assumption. As car-sharing vehicles are only used 3 years in that application, they are on average newer, so a higher % of electric vehicles is reasonable.
Average CO_2 emissions (kg) per vehicle-km (private vehicle; fossil-fuel)	.146§ (all 2030 scenarios)	Agora Verkehrswende (2018, p. 10)°
Average CO_2 emissions per vehicle-km (private vehicle; electric)	.059 (all 2030 scenarios)	Schallaböck & Fischedick (2012, p. 9)°
Percentage of passenger-kilometres covered by car sharing	0.5% (i.e. 1/2 of 1%)	Assumption: Corresponds to 12% compound annual growth rate (see text above).

* Own calculation
§ Own rough estimate of average value based on provided data
° Hyperlink to source data

3 :: Step 2: Defining the Circular Scenario

Departing slightly from the CIRCULAR IMPACTS case-study methodology laid out by Smits & Woltjer (2017), this case study will include two circular scenarios for 2030. The reason for this is the high degree of uncertainty surrounding the assumptions related to how car sharing will affect other modes of transport in 2030.

In the first circular-economy scenario (titled Circular "Green" 2030), car sharing experiences disruptive growth while acting as a catalyst for reducing private-vehicle ownership and use.

In the second circular-economy scenario (titled Circular "Gray" 2030), the disruptive growth of shared mobility attract users from public transport, while the dynamics associated with autonomous vehicles (lower costs, higher convenience) lead to an increase in the number of motor vehicles and their travel. The concept of "car sharing" as used today is no longer of central importance in a world of multimodal shared mobility.

In both circular scenarios, there is disruptive growth, with 2.5% of the passenger-kilometres in motorised passenger vehicles taking place via car sharing (shared mobility in the Circular "Gray" scenario). While this percentage seems small, it would mean car-sharing passenger-kilometres rise to a level equivalent to 28% of public transport's current passenger-kilometres by 2030.

3.1 Scenario parameters

Table 7. Assumptions used in the scenario analysis

Assumption	Circular "Green" 2030	Circular "Gray" 2030
Percentage of passenger-kilometres covered by car sharing	2.5% covered by car sharing	2.5% covered by shared mobility
Net reduction of passenger vehicles per car-sharing vehicle	Reduction of 2 vehicles	Increase of 0.1 vehicles (10%)
Net reduction in total pkm of motor vehicles per pkm covered by car sharing	Reduction of 3.7 pkm	Increase of 0.1 pkm (10%)

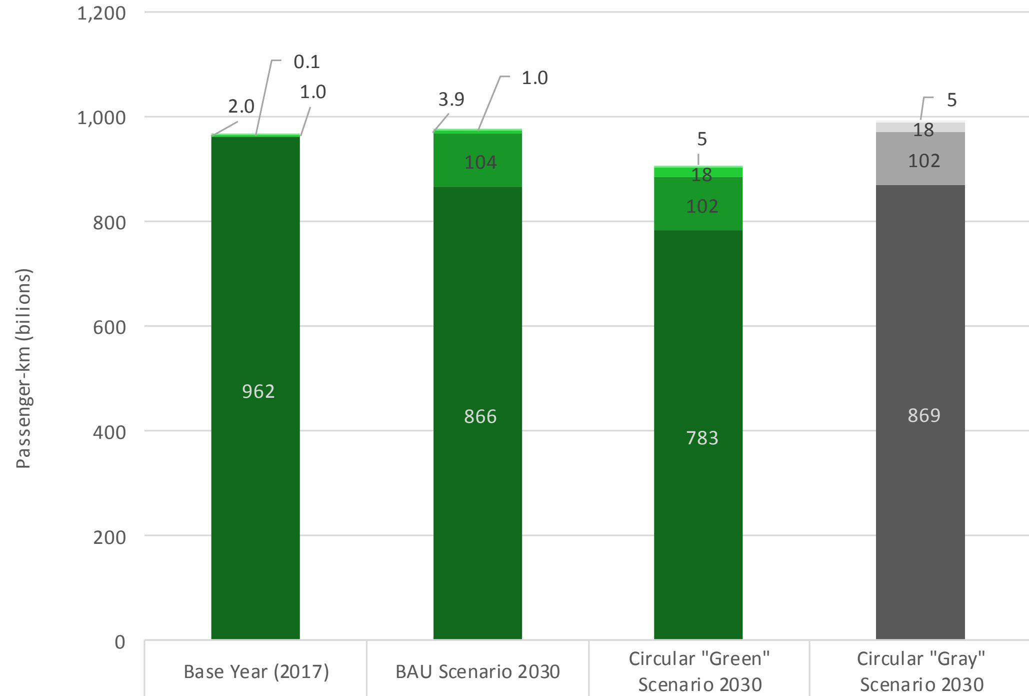
With all the scenarios and parameters defined, the various scenarios were analysed using a spreadsheet model.

4 :: Step 3: Changes in the Key Sector

4.1 Scenario results

Effects on passenger-km. Figure 9 shows the case-study results for the annual passenger-km travelled in Germany by motor vehicles in 2030, breaking them down by use application (private car or car sharing) as well as energy source (fossil fuel or electric). Including the base year of 2017 allows a comparison to today's situation. In the Circular "Green" scenario, the total passenger-km of motorised passenger vehicles is reduced by 7% compared to the BAU scenario, whereas the Circular "Gray" scenario drives an increase of 2% in passenger-km.

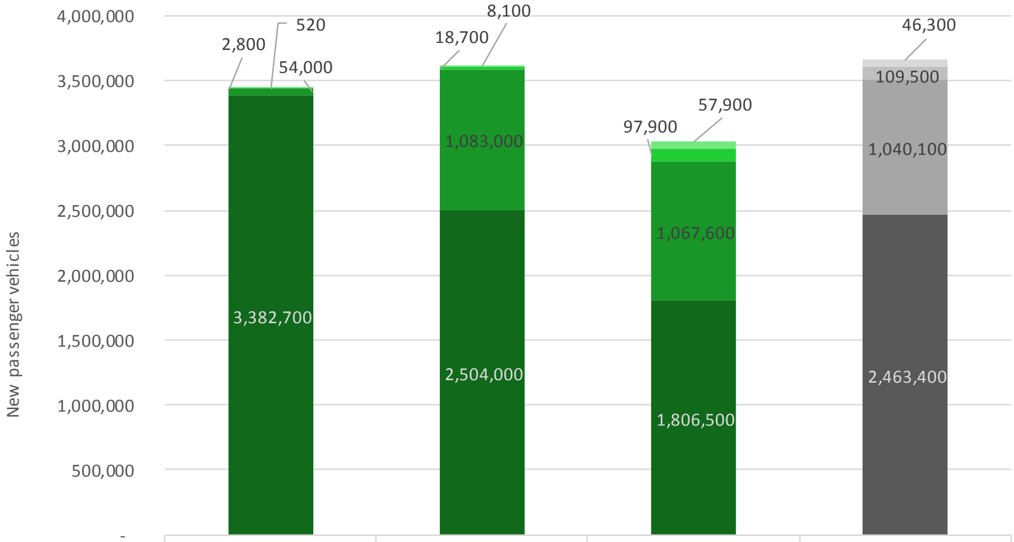
Figure 9. Annual passenger-km in Germany (motorised passenger vehicles)



	Base Year (2017)	BAU Scenario 2030	Circular "Green" Scenario 2030	Circular "Gray" Scenario 2030
Car sharing (electric)	0.1	1.0	5	5
Car sharing (fossil-fuel)	1.0	3.9	18	18
Private electric cars	2.0	104	102	102
Private fossil-fuel cars	962	866	783	869

Effects on vehicle production. The most dramatic differences amongst the scenarios relates to the production of new vehicles. Currently, the average lifespan of a car-sharing vehicle in that application is three years. After this period of time, car-sharing vehicles are typically sold in the used-car market and become private vehicles.

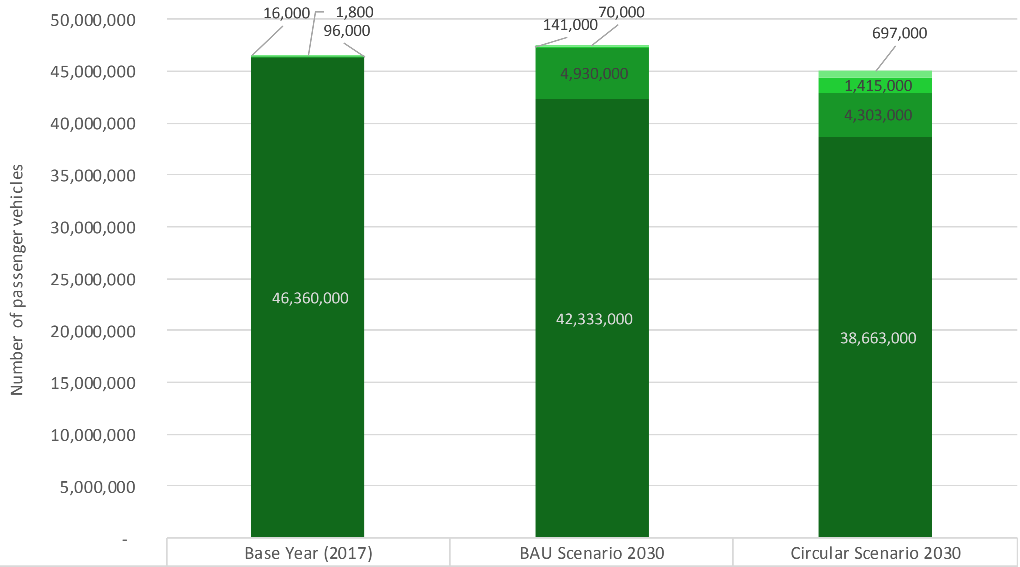
Figure 10. New passenger vehicles in Germany



	Base Year (2017)	BAU Scenario 2030	Circular "Green" Scenario 2030	Circular "Gray" Scenario 2030
Car-sharing cars (electric)	520	8,100	57,900	46,300
Car-sharing cars (fossil-fuel)	2,800	18,700	97,900	109,500
Private cars (electric)	54,000	1,083,000	1,067,600	1,040,100
Private cars (fossil-fuel)	3,382,700	2,504,000	1,806,500	2,463,400

The circular scenario does differ significantly from the BAU scenario in the way that increases in car sharing could alter the make-up of the vehicle fleet (Figure 11). In the BAU scenario, without a significant share of car sharing and barring changes in usage rates of passenger vehicles, the number of cars would increase by 0.5%, in line with the expected increase in passenger-km. The circular scenario, subject to the underlying assumptions about passenger-km per vehicle, would enable the size of the passenger-vehicle fleet to decrease slightly in Germany compared to 2017. As per the scenario definitions, in each 2030 scenario, the electric-vehicle fleet (BEV and PHEV) reaches five million units. In the circular scenario, the fleet of fossil-fuel vehicles is reduced quite substantially by 2030, by 8%.

Figure 11. Passenger-vehicle stock in Germany



	Base Year (2017)	BAU Scenario 2030	Circular Scenario 2030
Car-sharing cars (electric)	1,800	70,000	697,000
Car-sharing cars (fossil-fuel)	16,000	141,000	1,415,000
Private cars (electric)	96,000	4,930,000	4,303,000
Private cars (fossil-fuel)	46,360,000	42,333,000	38,663,000

In this case-study analysis, former car-sharing vehicles were assumed to achieve the same lifetime vehicle kilometres, on average, as their private-use counterparts. This means, however, that due to their intensive first use in car sharing, former car-sharing vehicles can be expected to have a total useful life of only 10 years on average (compared to 13 years for private vehicles).

5 :: Step 4: Expected Effects on Other Parts of the Economy

This section further examines potential effects of increased car sharing and shared mobility on the automobile sector. It then analyses potential effects on public transport (the main alternative mode of transport to car sharing).

Due to the dynamic trends taking place in the mobility sector, it is challenging to forecast future economic responses to car sharing. Box 5 summarises various projections of vehicle sales and emerging business opportunities.

Box 5 Impact of car sharing on the automotive industry and the difficulty of forecasting dynamic trends

The following studies estimated sales, revenue and business opportunities arising from emerging trends in the automotive industry:

- BCG estimated car sharing would decrease private-vehicle purchases by 792,000 vehicles worldwide in 2021 (slightly more than 1% of projected new-car sales in markets where car sharing is available). For 2021 in Europe, the number of vehicles sold for car-sharing (96,000) would decrease private-car sales by 278,000 (BCG, 2016).
- BCG also estimated that car sharing would increase business opportunities (also for car manufacturers, who may provide mobility services) amounting to global revenue of €4.7 billion in 2021. Europe is expected to be the biggest revenue-generating region (€2.1 billion), followed by Asia-Pacific (€1.5 billion) and North America (€1.1 billion) (BCG, 2016).
- McKinsey estimated that car sharing would lead to opportunities beyond selling mobility services or building purpose-built vehicles, including gaining costumer data, testing new technologies and ensuring the fleet emission compliance (via electric vehicles) (McKinsey, 2017).
- The expansion of autonomous vehicles is seen as the real “game changer” for the automotive industry and the mobility sector with dramatic impacts on business models, revenue and mobility patterns (BCG, 2017; McKinsey, 2017; PwC, 2017).

5.1 Potential modal shifts

It was beyond the scope of this case study to model the intermodal effects of the 2030 scenarios. In this section, we address the issue qualitatively, highlighting some numerical findings from recent literature, which is characterized by a high degree of uncertainty regarding the impacts of shared mobility and autonomous vehicles on the modal split.

5.1.1 Potential effects of car sharing on modal shift

The findings in the literature on the estimated and observed effects of car sharing on the modal split, specifically related to public transport, range from positive effects (increased use of public transport) to negative effects (decreased use of public transport). This is because the effects of car sharing on the modal split depends highly on the availability, characteristics and prices of the public transport and car-sharing services.

Several studies highlight a distinction between station-based and free-floating car sharing schemes. Station-based car sharing users are more likely to use public transport (Lichtenberg and

Hanel, 2007) and less likely to have a private car, compared to the general population (Sioui et al., 2013)

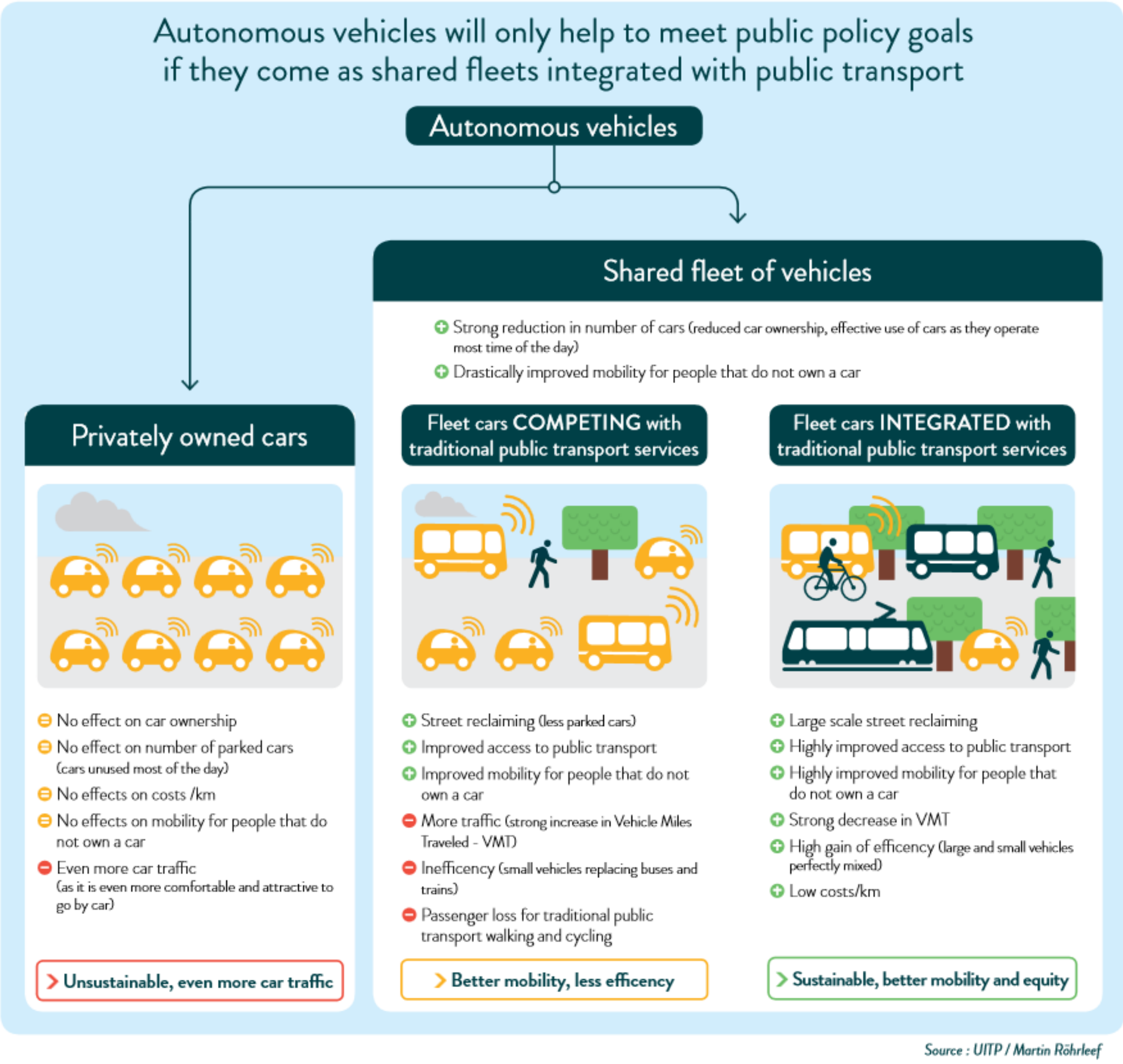
However, other studies indicate that free-floating car sharing users are also more likely to possess public-transport passes, signifying they are likely to use public transport intensely (Kopp & Axhausen, 2015). These users also walk and cycle more than average consumers (Katzev, 2003).

Both station-based and free-floating car sharing users show a multimodal mobility pattern when compared to non-car sharing users (Wilke, 2007). Hence, on average, car sharing enriches the modal mix of its user (Chatterjee et al., 2013). This does not stem mainly from an environmental agenda, but because car sharing users are so-called “mobility optimizers” (Maertins, 2006), who are flexible and who choose whatever transport mode is the most suitable. Hence, car-sharing users could also drive more or even buy a car, if this mode of transport appears to be the most convenient one and car sharing acts as an introduction to the advantages of having access to a private vehicle. A US study, for example, showed an overall decline in public transit as 589 car-sharing members reduced rail use and 828 reduced bus use, while 494 increased rail use and 732 increased bus use (Martin & Shaheen, 2011).

5.1.2 Potential effects of autonomous vehicles on modal shift

Future trends, such as the rise of autonomous and connected vehicles could lead to very different futures for urban mobility patterns, depending mainly on policies, new business models and consumers behaviour. If these new autonomous cars are primarily privately owned, there would be negative impacts on roadway congestion (UITP, 2018). If these cars are shared but competing with public transport services, there would be more cars on the street, since sitting in such car would potentially not require a driving license and costs for that service are low (Bischoff et al., 2017; Bösch, et al., 2018; UBA, 2017a). The access to public transport and mobility services general would be improved, but many people would opt for these robo-taxis instead of public transport, which would increase congestion and reduce the share of other modes of transport such as walking and cycling (UITP, 2018). It is possible that in the future, autonomous and connected vehicles are not only shared, but also integrated into public services. In that way, less vehicles would be necessary in order to transport the same amount of people, compared to the non-integrated scenarios. In this scenario, transport costs would be lower and society’s overall mobility would be higher (UITP, 2018). Figure 12 illustrates the implications of three potential uses of autonomous vehicles: 1) as privately owned cars; 2) as fleet cars competing with public transport; and 3) as fleet cars integrated with public transport.

Figure 12. Potential effect of autonomous vehicles on modal shift



Reproduced from UITP (2018, p. 5).

5.1.3 The impact of autonomous vehicles – estimations

The literature estimating how many robo-taxis would be required to replace public transport vehicles in German cities is very limited. Bischoff et al. (2017) have estimated, that in Berlin about 50,000 shared autonomous vehicles would be needed to replace 1,500 busses and 600 trams. Bienzeigler (2017) modelled for different numbers of robo-taxis the impacts on private motorised vehicles and public transport in Cottbus, concluding that both would be reduced in numbers.

6 :: Step 5: The Impact on Society

Since car sharing is a form of joint usage, it requires increased organisation, social interaction and a "will to share". Hence, car sharing is highly dependent on the societal trends that make such consumer behaviour possible. At the same time, car sharing as mode of transport has significant impacts on society and the environment.

6.1 Societal impacts

The social impacts from car sharing can be positive or negative. Since many of them are socio-economic effects, they are highly linked to business models and overall changes in the mobility sector.

Access to mobility services and socio-demographic profiles

Currently, most of the free-floating car-sharing users are young, highly educated men, living in urban areas, while the socio-demographic profile of station-based car sharing users is more heterogeneous (ifmo, 2016). It could be expected that with car sharing further entering the mainstream, the socio-demographic profile of their users becomes more diverse. At the moment, using car sharing is cheaper than using a private car when a person's annual travel distance remains below 10,000 kilometres (BCS, 2017a).

Currently, car-sharing services are easiest to access in urban areas. In terms of accessibility, car-sharing services of private operators are currently not competing with public transport services in rural areas. Public transport in many cases is a crucial mode of transport for disabled and elderly people or individuals without a driver's license. However, with autonomous vehicles, these dynamic would likely change.

Health impacts

Biker and pedestrians enjoy positive health effects due to their mode of transport. Since car sharing potentially triggers a multi-modal transport pattern, where walking or using a bike is more likely, these health benefits could reach a larger share of people (Baptista et al., 2014).

Social cohesion

It is possible, that sharing as such, including car sharing, could increase social interaction and thereby social cohesion within society (Agyeman et al., 2013). Botsman and Rogers (2010) suggest that amongst other reasons, it is social motivations that drive sharing economy participation. However, Böcker and Meelen (2017) concluded that for car sharing, economic motivations are dominant. Such effects could be more relevant for peer-to-peer car sharing and ride sharing.

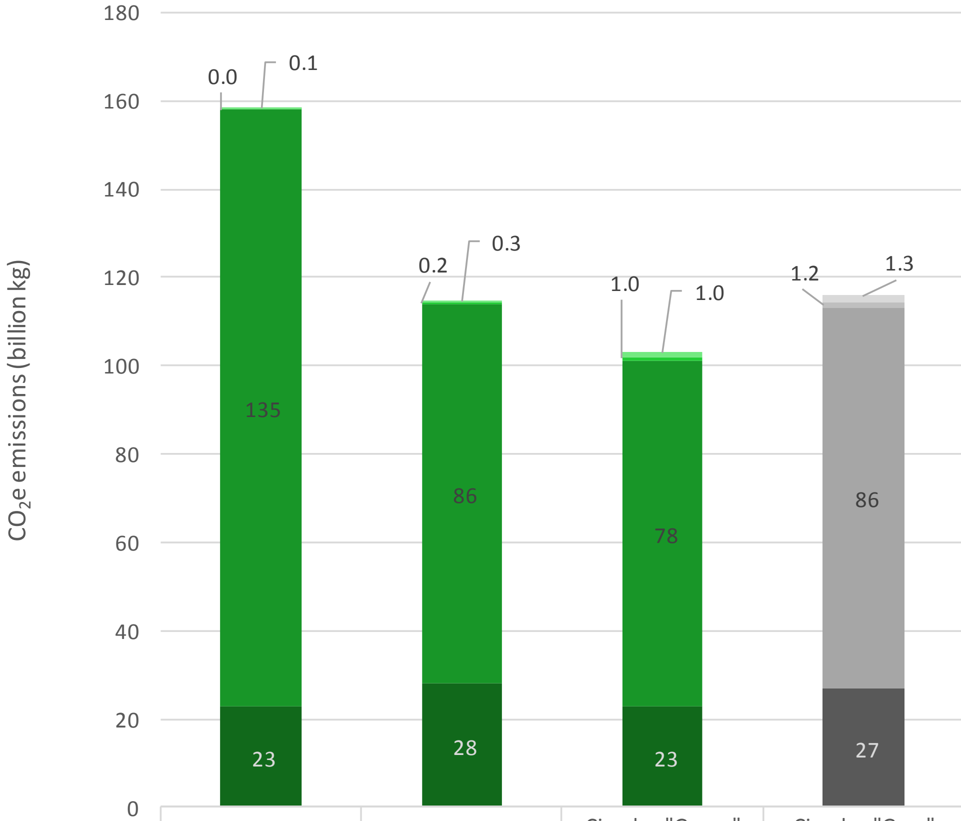
6.2 Environmental impacts

Car-sharing can have several positive or negative environmental impacts, due to the composition of the car-sharing fleet, changes in car ownership and respective implications for the modal split or total demand for mobility.

Car-sharing and transport emissions

Significant reductions in greenhouse-gas emissions are evident in all the 2030 scenarios vis-à-vis present-day emissions (see Figure 13). The calculations include both: production-related and use-related greenhouse-gas emissions. The most important factor behind the significant drop in 2030 emissions from present-day levels is the authors’ underlying assumption of an ambitious rise in the average energy-efficiency of vehicles of all fuel types combined with a shift to electric vehicles. By contrast, the additional contribution of car sharing is modest. The BAU scenario delivers CO_2e emissions reduction of 28% by 2030 compared to 2017. In the Circular “Green” scenario, the additional car sharing reduces the total emissions a further 10% beyond those achieved in the BAU 2030 scenario. By contrast, the Circular “Gray” scenario generates no climate benefits compared to the BAU scenario, with emissions actually increasing by 1%.

Figure 13. CO_2e emissions from motorised passenger vehicles in Germany



	Base Year (2017)	BAU Scenario 2030	Circular "Green" Scenario 2030	Circular "Gray" Scenario 2030
Car sharing cars (use)	0.1	0.3	1.0	1.3
Car sharing cars (production)	0.0	0.2	1.0	1.2
Private car (use)	135	86	78	86
Private cars (production)	23	28	23	27

Note: the decrease in CO_2e emissions for the 2030 scenarios results primarily from ambitious gains in vehicle-fleet efficiency (at levels in line with Germany achieving its climate targets).

Composition of the car-sharing fleet

Currently, a higher share of car-sharing cars are electric or hybrid vehicles when compared to private cars (BCS, 2018b; Kraftfahrt-Bundesamt, 2017). This is because car-sharing cars are used in cities, where the shorter reach of such cars is not very relevant. At the same time, the providers of car-sharing services, which are often car- manufacturers, can present themselves as environmentally friendly. While many car-sharing users for the first time try electric vehicles, also a positive effect on sales of these cars could be expected. Having a significant number of electric or hybrid car-sharing vehicles also allows different actors to test electric mobility at a large scale and to finance the required recharging infrastructure. Since the share of electric cars of all private vehicles is expected to grow, this pioneering work of electric car-sharing services will become less relevant. However, since car-sharing cars are more utilized than private cars, a higher acquisition cost for car-sharing cars would be economically feasible in the future as well. At the same time, the life span of car-sharing cars is shorter compared to private vehicles. These factors could foster the use of more expensive, but efficient cars in car-sharing schemes and the overall accelerated renewal of the auto stock. At the same time, the shorter life span of car-sharing cars leads to an increased consumption of energy and resources in their production.

Car ownership and its implication

The implications of car sharing on ownerships (see Box 4) are hard to assess. Together, the literature studies identifies a range of replaced private vehicles due to car sharing of between 3 and 20 cars. Such replacement of private cars leads to several beneficial environmental impacts, such as a decreased demand to parking space. Since car-sharing users have to pay the full operational costs of vehicle use, while for the use of private cars many costs are “hidden”, there is an incentive to drive less by car. Hence, car sharing potentially triggers multi-modal mobility, including the use of public transport or bikes. Based on the literature, this case study assumed that for every passenger-kilometre covered via car-sharing vehicle, 4.7 private-vehicle kilometres would not be driven, yielding a net reduction of 3.7 passenger-kilometres (team red, 2015). At the same time, individuals who would not own a private car, due to the significant acquisition costs, could shift from other modes of transport to car sharing.

Modal shift

The impacts of car sharing on the modal split, specifically related to public transport, range from positive to negative effects. This is because the effects of car sharing on the modal split depends highly on the availability, characteristics and prices of the public transport and car sharing services (see Section 5.1). Several studies assessed station-based car sharing to be more environmental friendly, than free-floating car sharing schemes (Lichtenberg and Hanel, 2007; Sioui et al., 2013).

Car sharing impacts on land take for transport infrastructure & urban space use

Avoided land take by car, due to a higher use of car sharing is not a focus area of the calculation of this case study. However, a brief literature review was done to provide an overview regarding these effects.

According to a study from the German car sharing association (Bundesverband CarSharing) with infas Institute from 2016, a station-based car sharing vehicle replaces between 8 and 20 private cars, which results in gained spaces at the road between 36 and 99 meters (BCS, 2016). This however, assumes private cars are being parked on the street, while a share of these park also on private property or in subterranean garages.

Generally, car sharing potentially lowers the demand for transport infrastructure partially, since an increased use of cars would decrease the demand for parking areas. However, since car sharing is a type of motorised individual traffic, this effect is smaller than for public transport or bike traffic.

7 :: Step 6: Are Alternatives Available?

Public transport

Public transport is a good alternative for car sharing, because it is circular by definition, since few transport vehicles are used by a large number of people. Additionally, public transport often is cost-effective and accessible for most people. Public transport fares are frequently subsidised throughout the world. Generally, such steady support is necessary to pay for transport infrastructures, such as a metro network, thereby achieving economies of scale (Santos et al., 2010).

Pedestrians

Walking is a good alternative to car sharing over short distances due to its positive social impacts (e.g. health), low cost, and environmental benefits. Walking can play an important role in local transport schemes. Urban planning can lead to very different shares of people walking. Policies that can incentivise walking include crime reduction, well-maintained pavements, street furniture, safe crossings with short waiting times and lower speed limits (Santos et al., 2010).

Bicycles

Like walking, biking is environmentally less resource intensive and also socially beneficial (positive health impacts, cost-effective). Globally, there is an increasing use of pedelecs (Prill 2015) and bicycles in general (Lanzendorf and Busch-Geertsema 2014, Parkin 2012, Pucher and Buehler 2012). The drivers of increasing use of bicycles are decreasing prices for motorized bicycles, new bike sharing suppliers and increasing demand for bike traffic, due to increasing environmental behaviour and its benefits in term of flexibility. Other promoting actions are providing extensive cycling rights, bike parking lots and respective traffic education or integrating biking with public transport (Pucher & Buehler, 2008).

Autonomous and connected mobility

Autonomous and connected mobility could potentially transport a large number of people. Since such vehicles could communicate with each other and potentially interact with people using other modes of transport, this way of transport could be safer than automotive transport today. However, there is a risk that the use of such vehicles induces additional traffic, since costs are potentially lower and no license is required for their use (UBA, 2017a). In a potential future wherein many cars are autonomous and shared, new business models could emerge. Generally, autonomous cars could potentially offer mobility services at very low prices. These low prices could even decrease if, for example, advertising films are shown in the vehicles or vehicles pass by stores as monetization strategies. Theoretically, such mobility services by autonomous vehicles could be offered at no cost. Such cost structures and business models could have significant impacts on congestion and urban planning. However, such predictions are highly speculative.

8 :: Step 7: Policy Options

8.1 Need: Adaptive and holistic transport policy mix

In order to achieve a sustainability transition in the traffic sector, a policy mix that is effective, technology-neutral, predictable, cost-effective and enforceable is preferable (Damert & Rudolph, 2018). A policy mix should take into account that environmentally beneficial transport modes can also have negative externalities (e.g. car sharing) or may not be suitable to replace less beneficial transport modes completely (e.g. bikes).

A policy mix that addresses these negative externalities, without picking a specific technology or mode of transport, first reduces or eliminates subsidies to the transport sector that are environmentally harmful. As a second step, the undesired outcomes should be avoided be pricing their underlying drivers. For the case of congestion and lack of parking lots, this could be city tolls. As a third step, it is important to provide environmentally beneficial transport modes. This includes providing bicycle lanes, good public transport services and potentially parking lots for car sharing.

With respect to car sharing, station-based schemes seem to be environmentally more beneficial, which is why they should be preferred. As a fourth step, monitoring and ongoing adaption of the policy mix are necessary to cope with future challenges in the transport sector. These challenges might include a dissolution of the boundaries between pure car sharing, public transport and partly privately owned cars, since these business models seem to get more similar as new technologies expand. The key question for policy makers is either to embrace new transport services and to combine their services with those from public transport, or strengthen the boundaries between the two transport schemes. Generally, car sharing leads to the greatest environmental benefits when it is linked to other modes of transport, including not only public transport, but also bicycle and pedestrian traffic. To exploit these synergies, it is not sufficient to support only car sharing but also multi modal transport as such.

8.2 Policies that directly support car sharing

Parking spaces for car-sharing vehicles

In September 2017, Germany's Car Sharing Act entered into force. Among other things, this created the basis for the federal states (Länder) to waive parking fees for car sharing vehicles. The law was drafted by the Federal Ministry for Transport and Digital Infrastructure (BMVI) together with the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB). It defines car sharing, including both station-based and free-floating car sharing (Bundesgesetzblatt, 2017). Besides giving car-sharing cars an advantage via lower parking fees, it is additionally possible to establish pick-up and drop-off point in public space, which is especially relevant for station-based car sharing providers. Via this measure, intermodal transport, including car-sharing schemes, can be fostered by the federal states.

Linking car sharing with public transport

Supporting car sharing in rural areas, by combining public transport with car sharing providers, would potentially enhance transport services in such areas. Currently, several regional transport associations are establishing new billing, payment and tariff models, integrating the services of different providers (for example eTicket RheinMain). In order to link various transport modes, such intermodal mobility points, where parking lots are combined with transport station, could be established (Öko Institut, 2012).

Public procurement

Public institutions could use car sharing where feasible and cost-effective. A good example of such green public procurement is the municipality of Bremen, where the bodies of the municipality use car sharing in order to reduce costs, the number of cars on the street and parking lots (Bremische Bürgerschaft, 2013). Oslo also aims to increase the use of their (soon electric) public vehicles by sharing them amongst city-hall employees and citizens (WEF, 2018).

Start-up grants

To support car sharing directly, public finance start up-grants could be used to lower market-entry barriers (Shaheen et al., 2004). However, major car-sharing players are already in the market, potentially limiting the appeal of this instrument.

8.3 Policies that indirectly support car sharing

Reviewing the commuter allowance

The commuter allowance in Germany is used to claim tax relief for travel expenses related to commuting and therefore incentivising private car use and urban sprawl. Model calculations show that abolishing this flat rate could reduce carbon dioxide emissions by 2.6 million tonnes per year by 2030 (UBA, 2016). In order to reduce negative environmental impacts, while not affecting low-income households, countermeasures could address income tax rates.

Box 6 Germany-specific environmentally harmful subsidies

There are several Germany-specific policies that are supporting the use of private cars, that should be reviewed in order to restructure the transport sector to an environmentally and socially less harmful one.

Company car privilege. The company car privilege ("Dienstwagenprivileg") offers the opportunity for the car holders to reduce their income tax by 1 percent of the cars listing price at their first registration (UBA, 2016). Since company cars are firm-owned vehicles that can also be used for private reasons, such a tax reduction incentivises private-car use.

Subsidised diesel fuel. Diesel fuel is subsidised in Germany. At 47.04 cents/l, its energy tax rate is 18.41 cents/l lower, compared to the tax rate of 65.45 cents/l for petrol (UBA, 2016). Taking VAT into account, the tax benefit for diesel fuel is even higher (21.9 cents/l) (UBA, 2016). This subsidy has led to an increase of the number of diesel cars and increased the cars average weight and size (BUND, 2018).

Vehicle taxes

Vehicle taxes, introduced as an annual tax or tax dedicated to purchasing or selling a car, would make private-car use more expensive and therefore incentivise other modes of transport. Additionally, the tax level could be tied to the size, engine, weight or emissions standards of the car (Brand et al., 2013; Pasaoglu et al., 2016). Thus, cars could have a higher tax level overall, with those vehicles having the most negative impacts are taxed proportionally higher.

City toll

City tolls are an effective instrument to internalize environmental and social costs (including costs to the municipalities) linked to street traffic (BUND, 2018). Car sharing cars or electric vehicles could be excluded from such a toll. Oslo, for example, is gradually introducing restrictions on cars entering its centre, while providing priority lanes for shared, electric vehicles. In the beginning, priority lanes where granted for every electric vehicle, but this led to congestion (WEF, 2018).

Banning specific cars

On a national level, several countries (e.g. Norway, the Netherlands, France, Germany, the UK, China or India) have made announcements indicating that they eventually will ban the production and sale of cars that run on fossil fuels. On a regional and local level, cities like Athens, Madrid, Mexico City, Paris or Stuttgart announced plans to ban diesel cars by 2030 or earlier (WEF, 2018).

Liveable cities and integrated transport planning

Car sharing is just one element of an integrated system of urban design and transport. Public authorities need to be open to a changing mobility landscape while finding ways to guide those developments in ways that foster liveable cities, greater resource efficiency and environmental benefits.

9 :: Step 8: Overall Conclusions

Car sharing is neither a scapegoat nor a saviour. It is one part of a broad and diversifying multi-modal transport regime. The overall growth of car sharing and the extent of its impacts are highly dependent on its interlinkages with and effects on other transport modes, especially public transport. The environmental and social benefits of car sharing are higher when it acts as a catalyst for the increased use of environmentally friendly modes of transport. Therefore, policies addressing car sharing need to be well embedded in the overall transport-policy landscape. Thus, policies providing free parking spaces for car-sharing vehicles should be aligned with policies that address the externalities of unsustainable transport (e.g. via tolls for cars or withdrawing subsidies for private cars) while facilitating the development of multi-modal transport systems that can move high numbers of people in environmentally friendly ways (e.g. by financing bicycle lanes and public transport).

The car-sharing case study also points to broader conclusions about circular-economy transitions, especially ones related to the sharing economy. Public transport is a form of shared mobility itself, one that long predates the advent of smartphone-enabled car-sharing services. The case has helped make it clear that understanding the full impacts of circular-economy transitions requires examining a broader set of effects than product- or service-specific replacements of a linear process with a circular one.

The environmental effects of car sharing, especially its impacts on car ownership, appear to be more significant for station-based car sharing compared to free-floating car sharing (Giesel & Nobis, 2016). However, some free-floating systems might compensate for the lower rate of customers abandoning their car with their high number of customers per vehicle. Generally, it is challenging to assess based on present data whether customers using free-floating car sharing systems are less likely to abandon their car because of the car sharing system, or whether free-floating systems attract more households that hold on to private car ownership.

The overall growth of car sharing and the extent of its impacts are highly dependent on its interlinkages with others modes of transport, especially public transport and bicycles. Only if these environmentally and socially beneficial modes of transport are growing also will car sharing show its ability to act as a catalyst for increased multi-modal transport. The best environmental balance is achieved when car sharing is combined with other modes of transport, including public transport.

Many car-sharing studies cited in this report cover only the consumer behaviour of early adopters, since despite of its growth, car sharing is still a relatively niche phenomenon. Thus, these results may not fully reflect the possible effects of car sharing at a larger scale. The calculations carried out within this case study aimed to offer a glimpse of a mobility landscape with widespread use of car sharing. The overall results show that there is a high degree of uncertainty regarding the potential future impacts, making further monitoring and research necessary.

10 :: References

Agora Verkehrswende. (2018). *Die Fortschreibung der Pkw-CO2-Regulierung und ihre Bedeutung für das Erreichen der Klimaschutzziele im Verkehr*. Retrieved from https://www.agora-verkehrswende.de/veroeffentlichungen/die-fortschreibung-der-pkw-co2-regulierung-und-ihre-bedeutung-fuer-das-erreichen-der-klimaschutzziel/

Agyeman, J., McLaren, D., & Schaefer-Borrego, A. (2013). *Sharing cities*. Retrieved from https://www.scribd.com/document/339738772/Agyeman-Mclaren-Schaefer-borrego-Sharing-cities

Baptista, P., Melo, S., & Rolim, C. (2014). "Energy, environmental and mobility impacts of car-sharing systems: Empirical results from Lisbon, Portugal". *Procedia-Social and Behavioral Sciences*, 111, 28-37. Retrieved from https://www.sciencedirect.com/science/article/pii/S2214140513000054

BCG (Boston Consulting Group). (2016). *What's Ahead for Car Sharing? The New Mobility and Its Impact on Vehicle Sales*. Retrieved from https://www.bcg.com/publications/2016/automotive-whats-ahead-car-sharing-new-mobility-its-impact-vehicle-sales.aspx

BCS (Bundesverband CarSharing e.V.). (2016). *Neue bcs-Studie: Mehr Platz zum Leben - wie CarSharing Städte entlastet*. Retrieved from https://carsharing.de/sites/default/files/uploads/bcs_factsheet_nr.2_0.pdf

BCS (Bundesverband CarSharing e.V.). (2017a). *Bis zu einer Fahrleistung von 10.000 Kilometern ist CarSharing auf jeden Fall günstiger*. Retrieved from https://www.carsharing.de/zu-fahrleistung-10000-kilometern-ist-carsharing-auf-jeden-fall-guenstiger

BCS (Bundesverband CarSharing e.V.). (2017b). *CarSharing-Städteranking 2017*. Retrieved from https://carsharing.de/alles-ueber-carsharing/carsharing-zahlen/carsharing-staedteranking-2017

BCS (Bundesverband CarSharing e.V.). (2018a). *Datenblatt CarSharing in Deutschland: Stand 01.01.18*. Retrieved from http://www.carsharing.de/sites/default/files/uploads/datenblatt_carsharing_in_deutschland_stand_01.01.2018_final.pdf

BCS (Bundesverband CarSharing e.V.). (2018b). Pressemitteilung, 26.02.2018 "Zahl der CarSharing-Kunden überspringt die 2 Millionen Marke". Retrieved from http://carsharing.de/sites/default/files/uploads/pm_carsharing-bilanz_2018_1.pdf

BCS (Bundesverband Carsharing e.V.) (2018c). *Aktuelle Zahlen und Daten zum CarSharing in Deutschland*. Retrieved from https://carsharing.de/alles-ueber-carsharing/carsharing-zahlen/aktuelle-zahlen-daten-zum-carsharing-deutschland

BFE (Bundesamt für Energie). (2006). *Evaluation Car-Sharing*, Schlussbericht, Interface Institut für Politikstudien, INFRAS. Retrieved from www.bfe.admin.ch/php/modules/publikationen/stream.php?extlang=de&name=de_606183202.pdf&endung=Evaluation%20CarSharing

Bienzeisler, L. (2017). Verkehrliche Auswirkungen einer autonomen Carsharingflotte. ATZ-Automobiltechnische Zeitschrift, 119(7-8), 66-71. Retrieved from https://sci-hub.tw/10.1007/s35148-017-0064-2

Bischoff, J., I. Kaddoura, M. Maciejewski and K. Nagel (2017). *Re-defining the role of public transport in a world of Shared Autonomous Vehicles*. Retrieved from: http://transp-or.epfl.ch/heart/2017/abstracts/hEART2017_paper_24.pdf

BMU (Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit). (2016). *Integrated Environmental Programme 2030*. Retrieved from https://www.bmu.de/en/publication/shaping-ecological-transformation-integrated-environmental-programme-2030/

BMVI (Bundesministerium für Verkehr und digitale Infrastruktur). (2010). *Mobilität in Deutschland 2008, Ergebnisbericht, Struktur – Aufkommen – Emissionen – Trends*. Retrieved from http://www.mobilitaet-in-deutschland.de/pdf/infas_MiD2008_Abschlussbericht_I.pdf

BMVI (Bundesministerium für Verkehr und digitale Infrastruktur). (2011). *Elektromobilität – Deutschland als Leitmarkt und Leitanbieter*. Retrieved from https://www.bmvi.de/SharedDocs/DE/Publikationen/G/elektromobilitaet-deutschland-als-leitmarkt-und-leitanbieter.pdf?__blob=publicationFile

BMVI (Bundesministerium für Verkehr und digitale Infrastruktur). (2014a). *Verkehrsprognose 2030*. Retrieved from https://www.bmvi.de/SharedDocs/DE/Artikel/G/verkehrsprognose-2030.html?nn=12830

BMVI (Bundesministerium für Verkehr und digitale Infrastruktur). (2014b). *Verflechtungsprognose 2030.* See Table 2, p. 5. (Motorisierte Individuellverkehr 2030; Verkehrsleistung in Mrd. Pkm). Retrieved from http://www.bmvi.de/SharedDocs/DE/Anlage/VerkehrUndMobilitaet/verkehrsverflechtungsprognose-2030-zusammenfassung-los-3.pdf?__blob=publicationFile

BMVI (Bundesministerium für Verkehr und digitale Infrastruktur). (2016). *Verkehr und Mobilität in Deutschland*.

BMVI (Bundesministerium für Verkehr und digitale Infrastruktur). (2017). *Verkehr in Zahlen 2017/2018*. Retrieved from https://www.bmvi.de/SharedDocs/DE/Publikationen/G/verkehr-in-zahlen-pdf-2017-2018.html

BMWI (Bundesministerium für Wirtschaft und Energie). (2017). *Branchenfokus Automobilindustrie*. Retrieved from https://www.bmwi.de/Redaktion/DE/Textsammlungen/Branchenfokus/Industrie/branchenfokus-automobilindustrie.html

Botsman, R. and R. Rogers (2010). *What's Mine Is Yours: The Rise of Collaborative Consumption*. Harper Collins.

Böcker, L., & Meelen, T. (2017). “Sharing for people, planet or profit? Analysing motivations for intended sharing economy participation”. *Environmental Innovation and Societal Transitions*, 23, 28-39. Retrieved from https://www.sciencedirect.com/science/article/pii/S2210422416300892

Bösch, P., F. Becker, H. Becker and K.W. Axhausen. 2018. "Cost-based analysis of autonomous mobility services". *Transport Policy*. Retrieved from https://www.sciencedirect.com/science/article/pii/S0967070X17300811

Brand, C., Anable, J., & Tran, M. (2013). "Accelerating the transformation to a low carbon passenger transport system. The role of car purchase taxes, feebates, road taxes and scrappage incentives in the UK". In *Transportation Research* Part A: Policy and Practice 49 (Supplement C), pp. 132–148. DOI: 10.1016/j.tra.2013.01.010.

Bremische Bürgerschaft. (2013). Drucksache 18/401 Stadtbürgerschaft, 18. Wahlperiode, 08.10.13, Antwort des Senats auf die Kleine Anfrage der Fraktion Bündnis 90/Die Grünen, Vorbildfunktion für Bremen: nachhaltige Mobilität der Verwaltung. Retrieved from http://www.gruene-fraktion-bremen.de/fileadmin/media/LTF/fraktionbremen_de/homepage/AntwKlAnfr_Mobilitaet_der_Verwaltung.pdf

BUND (2018). *Grünbuch nachhaltiger Verkehrsinfrastrukturplanung – Zur Transformation des Bundesverkehrswegeplans 2030*. Retrieved from https://www.bund.net/fileadmin/user_upload_bund/publikationen/mobilitaet/mobilitaet_gruenbuch_bvwp.pdf

Bundesgesetzblatt. (2017). *Gesetz zur Bevorrechtigung des Carsharing (Cardsharinggesetz – CsgG)*, Jahrgang 2017, Teil I Nr. 45, ausgegeben zu Bonn am 12. Juli 2017

Canzler, W., & Knie, A. (2015). *Die neue Verkehrswelt. Mobilität im Zeichen des Überflusses: schlau organisiert, effizient, bequem und nachhaltig unterwegs.* Eine Grundlagenstudie im Auftrag des BEE e.V. Retrieved from https://www.innoz.de/de/die-neue-verkehrswelt-mobilitaet-im-zeichen-des-ueberflusses-schlau-organisiert-effizient-bequem-und

CAR (Center for Automotive Research). (2017). *The Impact of New Mobility Services on the Automotive Industry*. Retrieved from http://www.cargroup.org/wp-content/uploads/2017/02/The-Impact-of-New-Mobility-Services-on-the-Automotive-Industry.pdf

Chatterjee, K., Andrews, G., Ricci, M., & Parkhurst, G. (2013). "Qualitative insights into the effect on travel behavior of joining a carshare". *Transp. Res. Rec*. 2359, 76–84.

Damert, M., & Rudolph, F. (2018). Policy options for a decarbonisation of passenger cars in the EU: Recommendations based on a literature review (No. 193). Wuppertal Papers.

Dargay, J., Gately, D., & Sommer, M. (2007). "Vehicle ownership and income growth, worldwide: 1960-2030." *The Energy Journal*. 143-170.

Empirica. (2017). *Wohnungsnachfrage und Mobilität bis 2030 – Haben Stellplätze noch eine Zukunft?* (Vortrag). Retrieved from http://www.infas-praxisforum.de/vortraege/infas_Praxisforum2017_empirica_Zukunft_Stellplaetze_20171120.pdf

Eurostat. (2017). *International trade in motor vehicles*. Retrieved from http://ec.europa.eu/eurostat/statistics-explained/index.php?title=International_trade_in_motor_cars&oldid=328982

Eurostat. (2018). *Passenger cars in the EU – update 2018: source data for tables and graphs. Table 2: passenger cars*. Retrieved from http://ec.europa.eu/eurostat/statistics-explained/index.php/Passenger_cars_in_the_EU#Overview

Firnkorn, J., & Shaheen, S. (2015). "Generic time- and method-interdependencies of empirical impact-measurements: A generalizable model of adaptation-processes of carsharing-users' mobility-behavior over time". *Journal of Cleaner Production*. Retrieved from http://dx.doi.org/10.1016/j.jclepro.2015.09.115

GDI. (2013). *Mobilität 2025, Unterwegs in die Zukunft*. Studie des GDI im Auftrag der Schweizer Bundesbahnen SBB, GDI/SBB, Zürich.

Gehrke, M., & Groß, S. (2014). *Fahrscheinfrei im ÖPNV*. IVP Discussion Paper 03/2014, Berlin. Google Scholar.

Giblin, S., & McNabola, A. (2009). "Modelling the impacts of a carbon emission-differentiated vehicle tax system on CO2 emissions intensity from new vehicle purchases in Ireland". In: *Energy Policy* 37 (4), S. 1404–1411. DOI: 10.1016/j.enpol.2008.11.047.

Giesel, F., & Nobis, C. (2016). "The impact of carsharing on car ownership in German cities". *Transportation Research Procedia*, 19, 215-224. Retrieved from https://elib.dlr.de/109550/2/2016_Giesel_Nobis_The_Impact_of_Carsharing_on_Car_Ownership_in_German_Cities.pdf

Harms, S. (2003). Besitzen oder Teilen. Sozialwissenschaftliche Analyse des Car-Sharings. Verlag Rüegger, Zürich.

Helms, H., et al. (2016). *Weiterentwicklung und vertiefte Analyse der Umweltbilanz von Elektrofahrzeugen*. Umweltbundesamt. Text 27/2016. Retrieved from https://www.umweltbundesamt.de/sites/default/files/medien/378/publikationen/texte_27_2016_umweltbilanz_von_elektrofahrzeugen.pdf

ifmo (Institut für Mobilitätsforschung). (2016). Carsharing 2025 – Nische oder Mainstream? Retrieved from https://www.ifmo.de/files/publications_content/2016/ifmo_2016_Carsharing_2025_de.pdf

InnoZ (Innovationszentrum für Mobilität und gesellschaftlichen Wandel). (2012). *Trends 2030, Mobilität und Logistik*. Innovationsworkshop 2012 der DB AG, InnoZ-Begleitheft, Berlin.

InnoZ (Innovationszentrum für Mobilität und gesellschaftlichen Wandel). (2016). *Mobilitätsmonitor*. April 2016. Retrieved from https://www.innoz.de/sites/default/files/innoz-mobilitaetsmonitor_nr-2_april-2016.pdf

Kamin, S. T., Beyer, A., & Lang, F. R. (2015). *Forschungsschwerpunkte für MTI Innovationen im Forschungsfeld Mobilität und gesellschaftliche Teilhabe*. Abschlussbericht, Institut für Psychogerontologie Friedrich-Alexander-Universität Erlangen-Nürnberg.

Katzev, R. (2003). "Car-sharing: a new approach to urban transportation problems". *Analyses of Social Issues and Public Policy* 3, 65 - 86.

Kaup, G. (2013). Ökonomie des Teilens. 15 Nutzungsgemeinschaften im Überblick. AK Steiermark, Österreich.

Kemfert, C. (2018). Kostenloser öffentlicher Nahverkehr: Nur ein Baustein von vielen. DIW-Wochenbericht, 85(9), 170-170.

Kopp, J., Gerike, R., & Axhausen, K. W. (2015). "Do sharing people behave differently? An empirical evaluation of the distinctive mobility patterns of free-floating car-sharing members". *Transportation*, 42(3), 449-469.

Kraftfahrt-Bundesamt. (2011). Fachartikel: Fahrzeugalter. See p. 9 (Table 5). Retrieved from https://www.kba.de/SharedDocs/Publikationen/DE/Statistik/Fahrzeuge/FZ/Fachartikel/alter_20110415.pdf?__blob=publicationFile&v=6

Kraftfahrt-Bundesamt. (2017a). *Bestand am 1. Januar 2017 nach Haltern.* Retrieved from https://www.kba.de/DE/Statistik/Fahrzeuge/Bestand/Halter/halter_node.html

Kraftfahrt-Bundesamt. (2017b). *Verkehr in Kilometern der deutschen Kraftfahrzeuge im Jahr 2016*. Retrieved from https://www.kba.de/DE/Statistik/Kraftverkehr/VerkehrKilometer/2016/2016_verkehr_in_kilometern_node.html

Kraftfahrt-Bundesamt. (2017c). *Verkehr in Zahlen 2017/2018*. Retrieved from http://www.bmvi.de/SharedDocs/DE/Publikationen/G/verkehr-in-zahlen-pdf-2017-2018.pdf

Kraftfahrt-Bundesamt. (2018a). *Jahresbilanz des Fahrzeugbestandes am 1. Januar 2018*. Retrieved from https://www.kba.de/DE/Statistik/Fahrzeuge/Bestand/b_jahresbilanz.html

Kraftfahrt-Bundesamt. (2018b). *Jahresbilanz der Neuzulassungen 2017*. Retrieved from https://www.kba.de/DE/Statistik/Fahrzeuge/Neuzulassungen/n_jahresbilanz.html?nn=644522

Kraftfahrt-Bundesamt. (2018c). *Bestand an Pkw am 1. Januar 2018 nach ausgewählten Kraftstoffarten*. Retrieved from https://www.kba.de/DE/Statistik/Fahrzeuge/Bestand/Umwelt/2018_b_umwelt_dusl.html?nn=663524

Kraftfahrt-Bundesamt. (2018d). *Bestand*. Retrieved from https://www.kba.de/DE/Statistik/Fahrzeuge/Bestand/bestand_node.html;jsessionid=5693EE2825A183D37BB16E1DB330E5AC.live11294

Kreisverwaltungsreferat München. (2014). *CarSharing in München*. Retrieved from https://www.ris-muenchen.de/RII/RII/DOK/SITZUNGSVORLAGE/3885709.pdf

Lanzendorf, M. & Busch-Geertsema, A. (2014). "The cycling boom in large German cities – Empirical evidence for successful cycling campaigns". *Transport Policy*. 36, S. 26-33. doi: 10.1016/j.tranpol.2014.07.003.

Lanzendorf, M., & Hebsaker, J. (2017). „Mobilität 2.0–Eine Systematisierung und sozial-räumliche Charakterisierung neuer Mobilitätsdienstleistungen". *Verkehr und Mobilität zwischen Alltagspraxis und Planungstheorie*, 135-151. Springer Fachmedien Wiesbaden.

Lichtenberg, J., Hanel, F. (2007). „Car-sharing und ÖPNV: Nutzen für Beide?" *Der Nahverkehr* 25 A(11), 37–41.

Maertins, C. (2006). Die intermodalen Dienste der Bah: Mehr Mobilität und weniger Verkehr? Wirkungen und Potenziale neuer Verkehrsdienstleistungen. Discussion Paper SP III 2006–2010. Wissenschaftszentrum Berlin für Sozialforschung, Berlin.

Martin, E., & Shaheen, S. (2011). “The impact of carsharing on public transit and non-motorized travel: an exploration of North American carsharing survey data”. *Energies*, 4(11), 2094-2114.

McKinsey. (2017). *How shared mobility will change the automotive industry*. Retrieved from https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/how-shared-mobility-will-change-the-automotive-industry

MOMO. (2010). *The state of European car-sharing*. Final Report D 2.4 Work Package 2. Retrieved from http://www.eltis.org/sites/default/files/tool/the_state_of_carsharing_europe.pdf

Ornetzeder, M., & Rohracher, H. (2012). „Nutzerinnovation und Nachhaltigkeit: Soziale und technische Innovationen als zivilgesellschaftliches Engagement“. *Gesellschaft innovativ*, hg. von Gerald Beck und Cornelia Kropp, 171-190. Wiesbaden: VS Verlag für Sozialwissenschaften.

Owyang, J., Samuel, A. & Grenville, A. (2014). *Sharing is the new buying: How to win in the collaborative economy*. Vancouver: Vision Critical/Crowd Companies.

Öko Institut. (2012). *Machbarkeitsstudie Umweltzeichen für intermodale Mobilitätsangebote*. Retrieved from https://www.oeko.de/oekodoc/1783/2012-483-de.pdf

Parkin, J. (Hrsg.). (2012). Cycling and Sustainability. Bingley: Emerald (Transport and Sustainability).

Pasaoglu, G., et al. (2016). “A system dynamics based market agent model simulating future powertrain technology transition. Scenarios in the EU light duty vehicle road transport sector”. *Forecasting and Social Change* 104 (Supplement C), pp. 133–146. DOI: 10.1016/j.techfore.2015.11.028.

Pieper, N., Heußler, T., Woiseschläger, D., & Backhaus, C. (2013). „Relevanz der Intermodalität für CarSharing-Konzepte“. *Schritte in die künftige Mobilität*. Heike Proff, Werner Pascha, Jörg Schönharting und Dieter Schramm, 379-396. Wiesbaden: VS Verlag für Sozialwissenschaften.

Priddat, B. P. (2015). „Share Economy: mehr Markt als Gemeinschaft“. *Wirtschaftsdienst: Zeitschrift für Wirtschaftspolitik*,95 (2), S. 98-101, Springer.

Prill, T. (2015). Pedelecs als Beitrag für ein nachhaltiges Mobilitätssystem? Eine Analyse zur Akzeptanz, Nutzung und Wirkung einer technologischen Innovation. Unpublished Dissertation, Frankfurt am Main.

Pucher, J., & Buehler, R. (2008). „Making cycling irresistible: lessons from the Netherlands, Denmark and Germany“. *Transport Reviews*, 28(4), 495-528.

Pucher, J. & Buehler, R. (2012). *City Cycling*. MIT Press, Cambridge, Mass.

PwC (PricewaterhouseCoopers), Kuhnert, F., Stürmer, C., & Koster, A. (2017). *eascy – Die fünf Dimensionen der Transformation der Automobilindustrie*.

Rammler, S. (2014). *Schubumkehr. Die Zukunft der Mobilität*. Fischer, Frankfurt am Main.

Rifkin, J. (2014). Die Null-Grenzkosten-Gesellschaft: Das Internet der Dinge, kollaboratives Gemeingut und der Rückzug des Kapitalismus. Frankfurt am Main: Campus Verlag.

Rosinak und Partner ZT GmbH. (2000). *Carsharing. Die Akzeptanz von Carsharing in der näheren Wohnumgebung*. Verkehrswissenschaftliche Untersuchung im Auftrag des Bundesministeriums für Verkehr, Innovation und Technologie. Endbericht, Wien.

Santos, G., Behrendt, H., & Teytelboym, A. (2010). “Part II: Policy instruments for sustainable road transport”. *Research in Transportation Economics*, 28(1), 46-91.

Schade, W. et al. (2011). *VIVER Visionen für nachhaltigen Verkehr in Deutschland*. Working Paper Sustainability and Innovation, 03/2011, Fraunhofer ISI, Karlsruhe.

Schallaböck, K. O., & Fischedick, M. 2012. *Strommix beim Betrieb von Elektrofahrzeugen*. Retrieved from https://wupperinst.org/uploads/tx_wupperinst/Elektromobilitaet_TB_Strommix.pdf

Schönduwe, R., Bock, B., & Deibel, I. (2012). Alles wie immer, nur irgendwie anders? Trends und Thesen zu veränderten Mobilitätsmustern junger Menschen. InnoZ Bausteine Nr. 10, Berlin.

Shaheen, S., Schwartz, A., & Wipyewski, K. (2004). „Policy considerations for carsharing and station cars: Monitoring growth, trends, and overall impacts”. *Transportation Research Record: Journal of the Transportation Research Board*, (1887), 128-136.

Sioui, L., Morency, C., & Trépanier, M. (2013). “How car-sharing affects the travel behaviour of households: a case study of Montréal, Canada”. *Int. J. Sustain. Transp*. 7 (1), 52–69

Smits, M-J. & Woltjer, G. (2017). *Methodology for the Case Studies*. Deliverable 4.1 of CIRCULAR IMPACTS. Retrieved from http://circular-impacts.eu/deliverables/

Sperling, D., & Gordon, D. (2009). *Two Billion Cars: Driving Toward Sustainabilit*y. Oxford University Press

Statistisches Bundesamt. (2018). *Volkswirtschaftliche Gesamtrechnungen - Wichtige Zusammenhänge im Überblick*. Retrieved from https://www.destatis.de/DE/Publikationen/Thematisch/VolkswirtschaftlicheGesamtrechnungen/ZusammenhaengePDF_0310100.pdf?__blob=publicationFile

Steding, D., Herrmann, A., & Lange, M. (2004). *Carsharing – sozialinnovativ und kulturell selektiv? Möglichkeiten und Grenzen einer nachhaltigen Mobilität*. Zentrum für Umweltforschung der Westfälischen Wilhelms-Universität Münster, UFO-Berichte, Band 5.

team red (2015). *Evaluation CarSharing (EVA-CS): Landeshauptstadt München*. Final report. Retrieved from https://www.muenchen-transparent.de/dokumente/3885730

team red (2018). *Analyse der Auswirkungen des Car-Sharing in Bremen*. Final report. Retrieved from http://mf.team-red.de/fileadmin/user_upload/tr_Endbericht_Bremen_web.pdf

UBA (Umweltbundesamt). (2012). *Daten zum Verkehr*. Retrieved from https://www.umweltbundesamt.de/sites/default/files/medien/publikation/long/4364.pdf

UBA (Umweltbundesamt). (2013). *Car-Sharing – Mobilitätsbaustein des Umweltverbundes*. Retrieved from https://www.umweltbundesamt.de/themen/verkehr-laerm/nachhaltige-mobilitaet/car-sharing#textpart-2

UBA (Umweltbundesamt). (2015). *Fahrleistungen, Verkehrsaufwand und Modal Split*. Retrieved from https://www.umweltbundesamt.de/daten/verkehr/fahrleistungen-verkehrsaufwand-modal-split#textpart-3

UBA (Umweltbundesamt). (2016). *Umweltschädliche Subventionen in Deutschland 2016*. Retrieved from https://www.umweltbundesamt.de/publikationen/umweltschaedliche-subventionen-in-deutschland-2016

UBA (Umweltbundesamt). (2017a). Ressourcenleichte zukunftsfähige Infrastrukturen – umweltschonend, robust, demografiefest, Texte | 64/2017.

UBA (Umweltbundesamt). (2017b). *Emissionen des Verkehrs*. Retrieved from https://www.umweltbundesamt.de/daten/verkehr/emissionen-des-verkehrs

UBA (Umweltbundesamt). (2017c). *Fahrleistungen, Verkehrsaufwand und Modal Split*. Retrieved from https://www.umweltbundesamt.de/daten/verkehr/fahrleistungen-verkehrsaufwand-modal-split. Data file retrieved from https://www.umweltbundesamt.de/sites/default/files/medien/384/bilder/dateien/2_abb_gesamtfahrleistungen_2018-05-14.xlsx

UBA (Umweltbundesamt). (2017d). Mitteilung des Statistischen Bundesamts vom 16.01.2017; Werte teilweise aus Statistisches Bundesamt (2016). Fachserie 3 Reihe 5.1. 2015. Bodenfläche nach Art der tatsächlichen Nutzung. Retrieved from https://www.umweltbundesamt.de/sites/default/files/medien/384/bilder/dateien/04-flaechennutzung_terr-03_suv_abbildung_1.xlsx

UBA (Umweltbundesamt). (2018). *Emissionsdaten*. See table „Vergleich der durchschnittlichen Emissionen einzelner Verkehrsmittel im Personenverkehr". Retrieved from https://www.umweltbundesamt.de/themen/verkehr-laerm/emissionsdaten#textpart-2

UITP. (2018). *Autonomous vehicles: A Potential Game Changer for Urban Mobility*. International Association of Public Transport. Retrieved from http://www.uitp.org/sites/default/files/cck-focus-papers-files/PolicyBrief_Autonomous_Vehicles_LQ_20160116.pdf

VDA (Verband der Automobilindustrie). (2018). *Zahlen und Daten*. Retrieved from https://www.vda.de/de/services/zahlen-und-daten/zahlen-und-daten-uebersicht.html

WEF (World Economic Forum). (2018). *Electric Vehicles for Smarter Cities: The Future of Energy and Mobility*. Retrieved from http://www3.weforum.org/docs/WEF_2018_%20Electric_For_Smarter_Cities.pdf

Wilke, G. (2007). *Zukunft des Car-Sharing in Deutschland*. Schlussbericht, Wuppertal Institut fur Klima, Umwelt, Energie GmbH, Wuppertal.

Z_punkt. (2015). *Megatrend Booklet*. Köln: Z_punkt GmbH.

Zukunftsinstitut. (2012). *Megatrend-Map: Die Facetten der Mobilität*. Frankfurt am Main.

11 :: List of Partners

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