Today we are seeing more and more regions of the world in which people’s lives and mobility are increasingly shaped by the automobile. There are already more than 900 million passenger cars around the world. In the world’s highly developed economies, the level of passenger car ownership is currently 123 passenger cars per 1,000 inhabitants. In emerging markets and developing countries, the level of car ownership is often still below 100 passenger cars per 1,000 inhabitants. With increasing incomes, the pace of growth of passenger car ownership has picked up in many emerging markets (Chamom et al. 2008; RAND/ifmo 2014). By the middle of the century, the global passenger car fleet could grow to around 2 billion with a global population of roughly 9.6 billion people. With rising levels of car ownership and an increasingly urbanised environment, the question arises as to how auto-mobility can take place in the future, and in particular how it can be as sustainable as possible.

In Germany, the economy and people’s incomes continue to grow and this means that levels of private consumption and expenditure on transport may also continue to rise. However, in contrast to the global population, the German population is falling – from 81 million people today to around 77 million people by 2040, which means 4 million inhabitants less. The proportion of younger and middle age groups is falling, while the number of over-65s will increase markedly from 21 to 31%. The number of private households will increase from 40 to 41.3 million, with the average size of households falling from roughly 2 to 1.8 people.

Factors Influencing Car Ownership and Car Use

In order to forecast levels of passenger car ownership and passenger car mileages, factors that may influence passenger car ownership and use were examined using the latest mobility investigations and consumer surveys (DiW/TNS 2013). Socio-economic factors influencing auto-mobility can be divided up into drivers and constraints. The factors that drive the availability and use of passenger cars include employment and a high income, which is generally also associated with a higher level of education. Greater auto-mobility enables urban community structures to expand into the surrounding area (suburbanisation). The strongest drivers of auto-mobility include car ownership by women, women have been catching up men for...
many years when it comes to levels of car owner-ship (catch-up effect). And older people also use a passenger car more frequently nowadays than they did 10 years ago, which is also evident from the much higher levels of expenditure on mobility by young senior citizens.

The factors that inhibit the availability and use of passenger cars include the mobility behaviour of younger people. Younger people have a different attitude to owning a car and are increasingly lean on information and communication technology. As a consequence, younger people have access to a car less often than they did 10 years ago, but the impact of the way that younger people spend their money cannot (yet) be reliably assessed on the basis of the data that has been collected thus far. Longer periods of academic education and/or vocational training mean that the achievement of passenger car mobility is being pushed back to older age groups. Alongside the trend towards suburbanisation, the level of urbanisation in Germany continues to increase to the detriment of rural areas. Changes to household structures are also curbing levels of passenger car ownership and use; more and more single-person and two-person households and fewer and fewer children in the households are resulting in less auto-mobility.

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A (single) Trend scenario up to 2040 has been developed and quantified for the future development of passenger car ownership and mileages in Germany. The key results for passenger car ownership, the passenger car fleet and mileages are as follows:

**Car ownership**

The level of passenger car ownership in the German population (including legal entities) will rise from around 544 today (2013) to almost 570 in the second half of the 2020s – and then decrease to 558 passenger cars per 1,000 inhabitants in 2040. The level of car ownership across all inhabitants (excluding legal entities) was 498 passenger cars per 1,000 inhabitants in 2013. It will peak in 2028 with a figure of 522 cars per 1,000 inhabitants and then revert back to 510 passenger cars per 1,000 inhabitants by 2040. One main reason for this fall is the partial decline in the level of car ownership among men. The level of car ownership among men will reach its peak in 2016; it will decline from the figure today (2014) of 645 cars to 609 cars per 1,000 men by 2040. In addition, the level of car ownership among the male age groups below 34 years of age and that of the over-75s is falling slightly, while younger old people up to 75 years of age are still increasing their level of car ownership. Finally, the number of people in the age groups with the highest car ownership levels (from roughly 35 to 60 years of age) is shrinking.

Women are making up an increasing proportion of car owners. The level of car ownership among women will increase from 358 cars per 1,000 women today to 414 in 2040. The ratio of female car ownership, i.e. female vs. male car ownership, will also increase significantly from today’s figure of 56% to 68% in 2040. The increasing level of car ownership among women will in fact cause the level of ownership in the middle age groups (45–75 years of age) to rise as a whole, particularly among 60- to 70-year-olds.

**Passenger Car Ownership and Mileages**

<table>
<thead>
<tr>
<th>Male</th>
<th>Female</th>
<th>Male</th>
<th>Female</th>
<th>Male</th>
<th>Female</th>
<th>Male</th>
<th>Female</th>
<th>Male</th>
<th>Female</th>
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<td>18–34</td>
<td>358.5</td>
<td>282.9</td>
<td>364.2</td>
<td>297.5</td>
<td>352.6</td>
<td>307.8</td>
<td>344.9</td>
<td>313.7</td>
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<tr>
<td>35–64</td>
<td>939.9</td>
<td>575.0</td>
<td>935.4</td>
<td>620.1</td>
<td>901.8</td>
<td>655.6</td>
<td>895.7</td>
<td>680.3</td>
<td></td>
</tr>
<tr>
<td>65+</td>
<td>820.2</td>
<td>265.0</td>
<td>804.1</td>
<td>314.1</td>
<td>777.3</td>
<td>363.9</td>
<td>696.4</td>
<td>343.1</td>
<td></td>
</tr>
<tr>
<td>Total male/Female</td>
<td>642.8</td>
<td>358.3</td>
<td>646.4</td>
<td>391.8</td>
<td>631.1</td>
<td>413.8</td>
<td>609.1</td>
<td>413.7</td>
<td></td>
</tr>
<tr>
<td>Total including legal entities</td>
<td>544.4</td>
<td>564.6</td>
<td>568.3</td>
<td>557.5</td>
<td></td>
<td></td>
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</tbody>
</table>

**Motivation by Age Group (Cars per 1,000 Inhabitants)**

**Drivers → More Auto-mobility**

- Higher labour force participation
- Longer periods of training
- Higher income
- More people
- Mobility behaviour of older people
- Expenditure on transport by young senior citizens
- Expenditure on transport by younger people
- Urbanisation
- Car ownership among older people
- Fewer children

**Constraints → Less Auto-mobility**

- Expenditure on transport by young senior citizens
- Expenditure on transport by younger people
- Longer periods of academic education and/or vocational training
- Changes to household structures
- suburbanisation
- The level of urbanisation in Germany continues to increase to the detriment of rural areas.
- Mobility behaviour of older people
- Fewer children
- Car ownership among older people
- Urbanisation
- Car ownership among younger people
- More people
- Mobility behaviour of younger people
- Expenditure on transport by young senior citizens
- Expenditure on transport by younger people
- Urbanisation
- Car ownership among older people
- Fewer children
In relation to passenger car transport in industrialised countries where there is a high level of car ownership, peak car is now often spoken about; this means that at some point levels of passenger car ownership or mileages reach a peak and then begin to decline. This phenomenon is being seen in the USA and in Great Britain, but also in Germany – generally among younger people (IFMO 2013). Is peak car also around the corner for Germany? And if so, when?

For all three passenger car indicators (motorisation, fleet and mileage), a peak will be reached in Germany in the 2020s. Comparing indices, the size of the German passenger car fleet will reach its peak slightly later than the frequency of use of passenger cars as expressed by the total passenger car mileage by German passenger cars per year. The decline in the passenger car fleet is partly attributable to the decline in the number of people. By contrast, the reduction in the level of passenger car ownership is reflective both of shifts in the age structure of the population and of a change in the mobility behaviour of groups within the population.

Consequently, a peak for passenger car ownership and use is looming in the 2020s. However, the peak is very flat; in fact, it is rather like a plateau. All three passenger car indicators will continue to be at the level of the previous decade or even of today in 2040. There will therefore not be a peak car in the sense of a sudden collapse in levels of passenger car ownership and use. As the mobility behaviour of people and groups is relatively stable, passenger car mobility only changes very gradually with the pace of generational change and due to the effect of age structure.

**Peak Car in Germany?**

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**Peak Car Indices (1995 = 100)**
as 12,156 electric cars and 2,081 other cars. Changes to the mix of propulsion systems among the passenger car fleet are due to the fact that there is a persistent trend whereby almost 50% of new vehicles registered are powered by diesel (dieselisation). With the alternative propulsion systems, passenger cars that are electrically powered, in particular hybrid vehicles, are displaying above-average growth among new vehicle registrations.

On the other hand, among existing cars electrically powered passenger cars only account for 0.2% of the fleet, whereas passenger cars with a combustion engine, which means a gasoline, diesel or gas engine, account for 99.8% of German passenger cars. And of the approximately 100,000 cars with an electric motor, most of them – namely hybrids – have a combustion engine as well.

The supply of fuel follows the propulsion technologies used for the fleet of cars. The existing fleet of passenger cars is supplied with power mainly from gasoline and diesel fuels. In 2012, passenger cars consumed 19.7 million tonnes of gasoline and 14.6 million tonnes of diesel (DIW 2013).

To date only biofuels have managed to gain substantial market shares, mainly in the form of admixtures to fossil fuels (Fritsche et al. 2012). However, biofuels are subject to technical limits on admixture and they have to meet strict sustainability requirements. Other alternative fuels such as gas fuels (LPG, CNG), electric energy and also hydrogen currently still play only a fairly minor role in the mixture of fuels used in passenger cars. Today the share of biofuels in the fuel mix is close to 6%, whereas gas fuels make up approx. 2%.

The environmental benefits of alternative fuels (lower emissions) are usually contrasted with drawbacks in terms of economics, energy storage and handling. Moreover, setting up and maintaining an alternative or additional infrastructure for generation and distribution of alternative fuels demands high levels of investment and correspondingly high passenger car fleets.

One key issue for the fleet of passenger cars in the future is the relationship between cars with a combustion engine and cars with electric propulsion systems. Combustion engines are continuing to be developed and are becoming more efficient. But compared to combustion engines, electric propulsion systems (plug-in hybrids, battery-operated electric vehicles and fuel cell vehicles) display much higher levels of motor efficiency. In addition, electric propulsion systems do not produce any direct emissions. However, the efficiency and life-cycle assessment differ for combustion engines and electric motors over the entire chain, much less than the level of motor efficiency.

The most significant trend evident with passenger car propulsion technologies is the increasing electrification of passenger cars with a combustion engine, in the near and medium future passenger cars will be powered by a combination of electric propulsion and a combustion engine – the hybrid car. Hybrids combine many advantages of both propulsion technologies, including efficiency, power and range.

Professional scenario development for the future fleet of passenger cars is based on a combination of two methods: one is the Trend scenario which continues passenger car trends of the recent past and is based on a trend analysis which continues passenger car trends of the recent past and is based on increasing use of biofuels, and an Alternative scenario which is based on an increasing use of biofuels, and an Alternative scenario which is very ambitious in terms of energy policy and climate conservation.

Increasing use of biofuels, which is very ambitious in terms of energy policy and climate conservation and will involve much greater and faster changes in the passenger car sector. The Alternative scenario examines in particular the potential impacts of increased electrification of propulsion systems and fuels. In addition to electric mobility, recent discussions have increasingly touted natural gas as another alternative source of power and fuel for passenger cars (Shell 2013). In order to shed light on the potential of gas propulsion systems and gas fuels in car transport, a gas mini-scenario is also looked at as an alternative version of the Trend scenario.

In principle electric mobility is a “disruptive technology” (Christensen 1997) which might one day completely replace an established technology. Nonetheless there is – both in passenger cars and in the overall car fleet – much evidence of evolution rather than technological revolution among the passenger car propulsion systems. The product of this technology evolution is the hybrid car.
Increasing pace of automotive change and that new registrations will rise to 3.3 million passenger cars per annum. Even if the new car registration figures are higher, the average age of the existing fleet will continue to rise, specifically from today’s figure of 8.8 to 9.4 years in the Alternative scenario and to as much as 10.6 years in the Trend scenario.

In terms of propulsion systems, gasoline and diesel-powered cars and their hybridised counterparts will account for three-quarters of new car registrations by 2040 in the Trend scenario, by contrast electric propulsion systems will make up 20%.

The pace of automotive change and thus the proportion of alternative propulsion systems will increase significantly. This is particularly true of electric propulsion systems, which will increase their share of new car registrations to more than 40% by 2040, while pure and hybridised gasoline and diesel-powered passenger cars will fall to 55%.

**Passenger car fleet**

The mix of propulsion systems among the existing fleet of passenger cars changes only relatively slowly in the Trend scenario. Of almost 43 million vehicles in 2040, over 36 million are fitted with conventional gasoline and diesel drive trains and their hybridised versions; 4.7 million of them are fitted with electric propulsion systems (plug-in, electric battery, and fuel cell). In the Alternative scenario, the fleet of electric propulsion systems will grow to a total of almost 10.1 million vehicles – including 5.5 million plug-in hybrids, 3.1 million battery-powered and 1.5 million fuel cell vehicles. The total number of all gasoline- and diesel-powered cars will shrink to 30.7 million vehicles by 2040.

**Energy consumption**

In 2013 German passenger cars consumed around 50 billion litres of gasoline equivalent (LGE) or 1,590 petajoules (PJ) of energy. Gasoline fuels accounted for 55% of domestic consumption, with diesel fuels making up 43%. In the Trend scenario the level of energy consumption will fall by 45% to 27 billion LGE or 868 PJ of energy; in the Alternative scenario it is more than halved, down to just 24 billion LGE or 759 PJ of energy.

By 2040 liquid gasoline and diesel fuels (including biogenic substitutes) will still dominate the passenger car sector: 90% of energy consumed is liquid fuels and in the Alternative scenario the figure is still more than 80%.

In the Trend scenario gasoline and diesel fuels can be admixed with 20% biofuels; biofuel consumption rises from 2.1 to 3.3 billion LGE. In the Alternative scenario electric energy develops by the end of the 2030s to become the most important alternative source of energy. In the Alternative scenario the level of consumption of propulsion electricity rises to 71 PJ; 10% of final energy will thus cover 20% of passenger car mileage. Despite enhanced 10% admixtures, biofuel use will fall to 1.4 billion LGE.

**Greenhouse gas emissions**

The direct greenhouse gas emissions (tank-to-wheel), which fall between 1990 and 2013, are decreasing, but the total CO2 emissions of passenger cars increase by 2040 by around 1% in the Trend scenario and by 17% in the Alternative scenario due to the increasing share of electricity used.
Today passenger cars consume around 15% of final energy and cause around 13% of combustion-related CO₂ emissions in Germany. How sustainably will auto-mobility develop in Germany in relation to national and European energy and climate targets?

Energy targets
Energy transition (Energiewende) targets which are relevant to the transport sector and thus to passenger cars can be gleaned from the energy blueprint (Energierahmenplan) published by the German Government in 2010 (BMWW 2014). There are two targets for energy consumption in the transport sector: compared to 2005, final energy consumption in respect of direct greenhouse emissions, passenger cars can be gleaned from the energy blueprint (Energierahmenplan) published by the German Government in 2010 (BMWW 2014). There are two targets for energy consumption in the transport sector: compared to 2005, final energy consumption should fall by 10% by 2020 and by 40% by 2050. The national final energy target for the entire transport sector would be achieved early by passenger car traffic according to the Trend scenario because a fall in the final energy consumption of more than 10% would be achieved by 2020 and a fall of around 50% would be achieved by 2040.

Climate targets
For greenhouse gas emissions there is no sectoral target but just a national one: in total the (direct) greenhouse gas emissions should be reduced in the period from 1990 to 2020 by 40% and by 2040 by 70%. Furthermore, the European climate and energy policy requires the Member States to hit a binding overall target for greenhouse gas emissions by 2030 of a reduction of 40% compared to 1990. To do this, the intention is that the non-emission trading sectors – including the transport sector – should reduce their greenhouse gas emissions by around 30% in the period from 2005 to 2030 (EU COM 2014). Discussions about further renewable energy and efficiency targets and their binding nature are still ongoing. Finally, the energy and climate package of 2008 also sets an interim target for a reduction in greenhouse gas emissions for the German non-emission trading sector of 14% in the period from 2005 to 2020 (EP/Council 2009).

In respect of direct greenhouse emissions, passenger cars will achieve a reduction of roughly 14% in the period from 1990 to 2040 in both scenarios and from 1990 to 2040 at a good 50% in the trend scenario and more than 60% in the Alternative scenario. The well-to-wheel emissions, which are relevant to the overall level of greenhouse gas emissions, will likewise fall by between 50 and 60% in the period from 1990 to 2040. Differences in the respective energy mix mean that the upstream chain emissions will fall by a greater extent in the Trend scenario (by almost four-fifths) compared to the Alternative scenario (by only around a half).

However, in the delimitation which is chosen for the purpose of making a comparison with the passenger car tank-to-wheel emissions – in contrast to the national trend tables (UBA 2013) – the direct emissions listed also include the emissions from the combustion of biofuels.
The Trend scenario already results in substantial energy savings and reductions in greenhouse gases. Nevertheless, the long-term energy and climate targets represent a real challenge for policymakers do to accelerate the energy transition.

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When it comes to achieving the energy and climate targets, it should be borne in mind that alternative propulsion technologies and fuels are easier to use in the passenger car sector than in other modes of transport; this means that overall targets for the transport sector can only be achieved if passenger cars deliver above-average savings in terms of energy and greenhouse gas emissions.

Nonetheless, in the transport industry and therefore for passenger cars too, the potential for substitution is lower due to the energy storage requirement in transport than in the transformation sector, for instance, or in the other stationary final energy sectors.

Battery-powered and fuel cell passenger cars have clear advantages over combustion engines. However, new drive technologies can only have an impact on the passenger car fleet slowly through new car registrations. To achieve an even faster energy transformation in the passenger car sector, the passenger car fleet would have to be turned over more quickly because even in the alternative scenario the average age of vehicle rises.

But alternative electric drives are still comparatively expensive. In addition, they require— with the exception of hybrids— completely new supply infrastructure. As the technical, economic and also ecological conditions for delivering complete electrification of the passenger car traffic are still not in place, the fully hybridised passenger car is currently a compromise solution for a large number of applications.

Fuels
Additional CO2 savings can also be achieved through low-emission fuels. This is where sustainable biofuels or even gas fuels come into consideration. Liquid biofuels have the advantage that they can be used in the current vehicle fleet and in the existing supply infrastructure—and it is the drive technology and fuels used in the existing vehicle fleet, less than new car registrations, which ultimately dictate the current sectoral CO2 emissions.

Gas fuels also offer emission benefits versus liquid fossil fuels. In order to deliver them, gas-powered passenger cars must account for a substantial share of the existing fleet, but in some respects they still require additional infrastructure. To allow electric drives to finally also deliver greenhouse gas savings, their energy increasing needs to come from renewable energy sources—which is currently only partly the case.

ENERGY AND CLIMATE PERFORMANCE VS. POLICY TARGETS

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<tr>
<th>FINAL ENERGY (TRANSPORT)</th>
<th>DIRECT GHG EMISSIONS (NATIONAL)</th>
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<td>30% 2040</td>
<td>Static var</td>
<td>Performance</td>
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IU 2013: Institut für Mobilitätsforschung (IuM), „Mobilität Y“: The Emerging Travel Patterns of Generation Y, Munich 2013.

KBA 2014a: Kraftfahrzeug-Bundesamt (KBA), Bestand an Kraftfahrzeugen nach Umweltmerkmalen, Flensburg 2014.


Rand 2014a: RAND Corporation, Institute for Mobility Research (IfM), The Future of Driving in Developing Countries, Santa Monica/California 2014.


