E-mobility

Remaining a niche phenomenon for now – at least without subsidies

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The shift towards alternative propulsion technologies, such as e-mobility, is currently the biggest challenge for the global auto industry. So far, this structural change is driven mainly by government regulation and not so much by market forces. Take, for example, CO_2 emission targets for new cars: average emissions of new passenger cars are to decline by 50% in the EU between 2018 and 2030.

At the moment, electric vehicles only have significant market shares if they are heavily subsidised. Take Norway, where almost 56% of total new car registrations during the first three quarters of 2019 were for electric cars, compared to only 2.6% in the EU as a whole. While the share of e-cars has more than doubled since 2015, e-mobility remains a niche phenomenon.

By 2021 at the latest, the CO_2 emissions of all new passenger cars in the EU are to be reduced to 95 g/km on average. If the auto industry fails to reach this goal, it will have to pay fines. The share of electric vehicles will have to rise to 10-15% of all new car registrations (from currently 2.6%) if the sector as a whole is to avoid paying fines. This is evidently a major challenge.

By 2030, 30-50% of all new car registrations in the EU will need to be for electric cars if the CO_2 emissions target for newly registered cars is to be reached. However, it is still unclear if and when customers can be convinced of buying an electric car without heavy subsidies.

While e-cars can help to reduce carbon emissions in the EU, the favourable climate effect will be smaller than many supporters of electric mobility expect. E-mobility remains a very expensive way of avoiding carbon emissions. State subsidies for e-mobility prove once again that cost efficiency is not in the focus of climate protection measures. Rather, the energy and mobility transition lead to more and more subsidies.

A higher market share of e-cars will lead to job losses in the German auto industry. However, the effect will probably be manageable because the transition is evolutionary and demographic developments look set to reduce the workforce anyway. All things equal, value added is likely to decline as well. The losses will be higher if production of cars with combustion engines is replaced by e-car production to a large extent and if batteries are mostly imported.

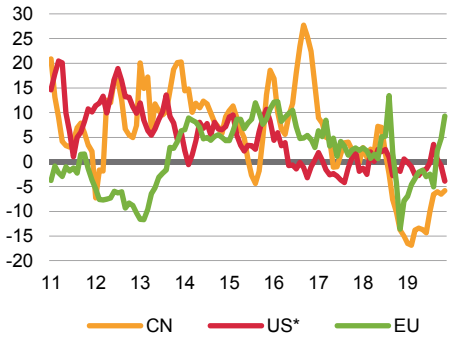
German carmakers are not the only ones which have to deal with the new regulations that aim to implement e-mobility. From today's vantage point, the German auto industry is better prepared for the electric mobility future than Germany as an industrial location for car producers. In fact, a number of factors on the cost side have deteriorated over the last few years.

E-mobility: Remaining a niche phenomenon for now – at least without subsidies

Three major challenges for the auto industry

Quite weak car demand in all three major markets 1

New passenger car registrations/sales, % yoy, 3M mov. avg.



* Light vehicles

Sources: ACEA, BEA, CAAM

The auto industry is faced with three major challenges. The first is the global slowdown in growth caused by the trade conflict. Demand for cars has been shrinking in all three major markets (China, the US and the EU) for many months now. This is weighing on both output and capacity utilisation. The sector's profits are coming under pressure. A cyclical decline in employment is likely or has already started in some cases. Cyclical fluctuations are nothing new for the sector, and as a rule, they are manageable. Moreover, global demand for cars looks set to pick up moderately in 2020. Recent data already suggest that demand may have bottomed out.

Second, the auto industry is investing in technologies for connected and (partially) autonomous driving and in solutions for preventing traffic jams and accidents. The "digital car" is slowly taking shape. Car and ride sharing are also gaining importance, particularly in cities. Cars are and will be used in other ways than before. Overall, competition from companies from other sectors, such as IT or data companies, is increasing. This structural technology shift is driven by market forces and not by governments; quite the contrary. In some areas, regulation is lagging behind technology.

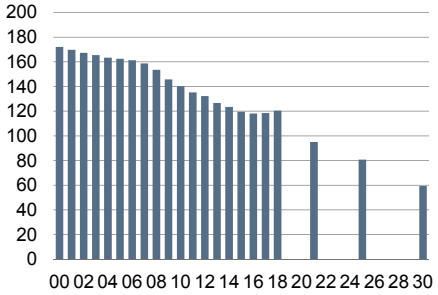
The "digital car" is taking shape

The third and, we believe, biggest challenge to the auto industry is the shift in propulsion technologies. One reason why we regard this development as the biggest challenge is that it is driven largely by government regulation and not so much by market forces. This is a significant difference from the trend towards the "digital car". Take, for example, CO_2 emission limits for newly registered cars: emissions of new passenger cars are to decline by 50% in the EU between 2018 and 2030. Competition from relatively new players in the e-mobility sector (such as Tesla) is accelerating the shift towards new propulsion technologies. However, electric mobility tends to need subsidies to reach significant market shares (we will deal with this issue in more detail later on). This means that government regulations force car producers to develop and market vehicles with propulsion technologies that do not yet convince the customers – and it is unclear if and when customers will adopt them. Our report focuses on this latter challenge.

Carbon emission targets set the course

EU sets ambitious targets for CO_2 emissions per car 2

Average CO_2 emissions of new passenger cars* in the EU, g/km



* Historical development, targets for 2021 and 2030

Sources: EEA, EU Commission, Deutsche Bank Research

For decades now, environmental and climate-policy regulation has focused on cars. Just think of fuel taxes, vehicle taxes and emission standards. In terms of climate policy, CO_2 emission limits for newly registered cars are particularly important. The EU has set itself two important targets:

— By 2021 at the latest, the CO_2 emissions of all newly registered passenger cars in the EU are to be reduced to 95 g/km on average. This standard will already apply to 95% of all newly registered cars in 2020.

— By 2030, the average CO_2 target will be reduced by another 37.5% compared to 2021 (with an intermediate target of -15% by 2025). This is equivalent to just above 59 g/km[1] or an average consumption of 2.6 litres of petrol for a distance of 100 km.

While other countries have introduced similar carbon emissions limits, the EU has set the most restrictive thresholds. In 2018, cars in the EU emitted 120.6 g of carbon per km on average. The limits are different for each carmaker. Over the last two years, average emissions have been rising slightly, in contrast to the

[1] The EU Regulation 2019/631 does not contain an explicit, absolute target; it only states the percentage by which emissions are to be reduced.

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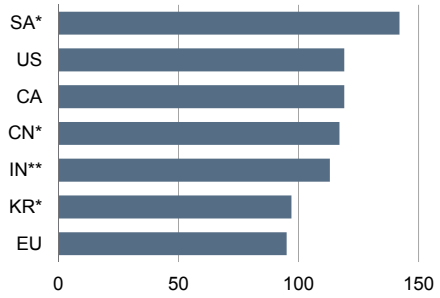
CO_2 targets in the EU particularly ambitious 3

CO_2 targets for new passenger cars in selected countries, g/km



EU, USA and Canada: 2021
* 2020
** 2022

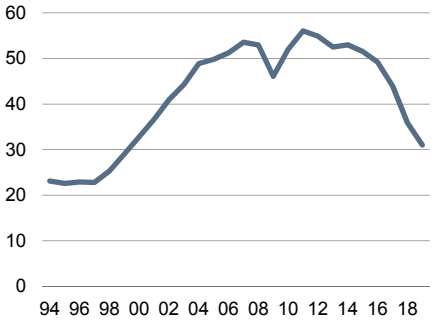
Sources: ICCT, VDA

Calculation method for the fines 4

If a car producer sells 1 million cars per year in the EU and misses its specific carbon emissions limit by 5 g/km, the producer will have to pay a fine of EUR 475 m.

Diesel share in the EU has been declining for some years now 5

Share of diesel cars in total new passenger car registrations in the EU*, %



* Until 2015 EU-15 only; 2019: Estimate

Source: ACEA

The regulation treats BEVs as zero-emission vehicles

long-term trend. To some extent, this is due to the fact that the diesel scandal as well as stricter regulation in many countries and the discussion about driving bans have reduced the number of newly registered diesel cars. Back in 2015, 51.5% of all newly registered cars in the EU had a diesel engine. By 2018, the percentage was down to 35.9%, and it is likely to decline further in 2019. As diesel cars emit less CO_2 per kilometre, this development pushed up the average carbon emissions of newly registered cars.

Fines on the horizon – electric cars will reduce average emissions

The EU Regulation foresees fines for car producers which exceed their specific CO_2 emission targets. These fines amount to EUR 95 per gram by which the actual emissions exceed the company-specific target and are to be paid for each car sold by the company in the EU. It seems increasingly likely that the auto industry as a whole will miss the target of 95 g/km set for 2021. On average, carbon emissions would need to decline by more than 21% compared to 2018 to reach this goal. Put differently: Within only three years, the carbon emissions per kilometre would need to be reduced by the same percentage as during the ten years between 2008 and 2018. This would require huge investments in smaller, better-performing engines (downsizing), in lighter vehicles and, of course, in electric cars. To put it cautiously: from today's vantage point, the limits for 2020/21 appear highly ambitious, at least for the auto industry as a whole. Some producers, however, are on a good way towards achieving their targets.[2]

Share of electric cars has to rise above 30% in the EU by 2030

The target can be met only if the share of electric cars in total new car registrations rises considerably by 2021. And this is even more true for the considerably lower target for 2030. Battery-electric vehicles (BEVs) are treated as completely emission-free vehicles by the regulation. Any carbon emissions occurring during the electricity production are not taken into account. As a result, BEVs will reduce the average for a carmaker's model range. Based on the current test cycle, fuel consumption and, of course, CO_2 emissions figures are low for plug-in hybrid electric vehicles (PHEVs), too, even though these cars can only cover short distances on their electricity reserves and cause quite high emissions if their internal combustion engine powers them.

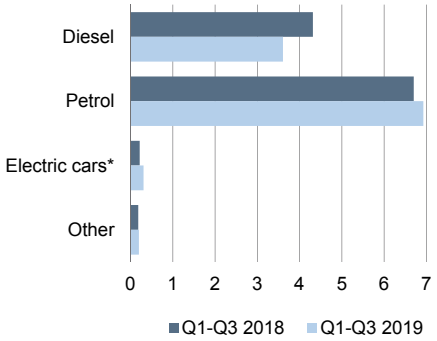
Moreover, carmakers can benefit of additional credits towards the 2020/21 targets for certain types of cars. For example, cars whose carbon emissions are below 50g/km according to the test cycle count double towards the average target (so-called "super credits"). The factor will be reduced from 2 to 1.67 by 2021 and to 1.33 by 2022; it will no longer apply afterwards. In addition, different car producers can aggregate emissions across their complete range of models in order to reach their carbon targets. This option is already being used and will continue to apply in 2021. Despite these special rules, the goal is ambitious, and the auto industry will face its first serious test in 2020/21.

It is possible to sketch several scenarios for the future fleet mix. They give a first impression of how large the market shares of the different propulsion systems need to be in order to reach the goals for 2020/21 or 2030. Depending on technical progress in the area of internal combustion engines and the relative shares of BEVs and PHEVs, the latter will need to make up 10-15% of total new car registrations in 2021, seeing that the super credits still apply in that year. By

[2] Our Equity Research colleagues published a comprehensive study at the beginning of 2019 which details by how much individual carmakers will have to reduce their emissions and which measures they have already taken. See Rokossa, Tim et al. (2019). Full speed into a low emissions future: Who can make it and at what cost? Deutsche Bank Research. London.

Petrol is dominating 6

New passenger car registrations in the EU by propulsion technology, m units

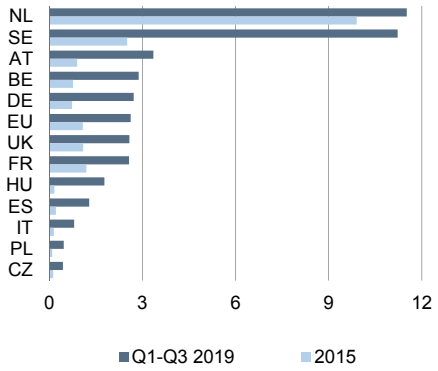


* BEVs, PHEVs, range extender, fuel cell

Source: ACEA

Electric cars have a high market share in the Netherlands and Sweden 7

Share of electric cars* in total new passenger car registrations in selected countries



* BEVs, PHEV, range extender, fuel cell

The market share of Norway (55,6% in the first three quartersof 2019) is not shown due to scale reasons.

Source: ACEA

2030, the market share of BEVs and PHEVs would have to rise to 30-50%. That this goal is a long way off right now.

Market share of electric vehicles is rising, but remains low

During the first three quarters of 2019, the share of BEVs and PHEVs in total new car registrations in the EU amounted only to 2.6% (source: ACEA). Roughly 1.7% of this total were BEVs, and the remainder PHEVs. Compared to 2015 (combined share of BEVs and PHEVs: 1.1%), the share of e-cars in new registrations has more than doubled. Nevertheless, they are still a niche phenomenon. This is true outside Europe, too: The combined global market share of BEVs and PHEVs amounted to just above 2% in 2018 according to the International Energy Agency (IEA, no newer figures available).

While electric cars certainly have advantages…

Many policymakers, parts of the media, NGOs and some auto industry representatives often emphasise the advantages of e-mobility. In most cases, they point to lower CO_2 emissions. It is true that most comparisons of the different engine types conclude that electric cars are more climate-friendly across the value creation chain and their complete lifecycle than comparable cars with an internal combustion engine. While emissions are higher during the production of electric cars (including the production of raw materials for their batteries) and the recycling process, they do better than combustion engines during the actual driving phase, particularly if a significant share of the electricity consumed comes from renewable sources. Nevertheless, the total CO_2 emissions of electric cars are much higher than many supporters claim or at least hope. They depend on several factors, such as the total mileage driven during the car's lifetime and the size of the battery. In many cases, the mileage of e-cars has to be quite high to beat combustion engines in terms of total carbon emissions. This is, of course, quite paradoxical in terms of climate protection. In any case, BEVs are definitely not zero-emission vehicles.[3]

There is less dissent about other advantages of electric cars. Their local pollution and noise emissions are considerably below those of cars with combustion engines. In addition, electric cars may offer better handling characteristics than traditional vehicles, for example in terms of acceleration. And they may be cheaper to maintain because they have fewer moving parts than cars with internal combustion engines.

... there are many reasons behind their low market share

Despite these advantages, most customers still have the well-known disadvantages of electric cars in mind when it comes to the buying decision. The first of these disadvantages is the higher price. While prices for electric and combustion-powered vehicles have converged in the premium segment, the differences in the volume car segment are still considerable (excluding potential subsidies). In addition, the charging infrastructure is inadequate, charging times are long, the mileage is relatively small, the lifetime of the battery may limit the

[3] See, for example, Fraunhofer ISI (2019). Die aktuelle Treibhausgasemissionsbilanz von Elektrofahrzeugen in Deutschland. Working Paper Sustainability and Innovation No. S 02/2019. Karlsruhe. Moreover: Zellner, Reinhard (2019). Zu viel CO_2 aus dem Verkehr: Ist Elektromobilität die Lösung? In: Nachrichten aus der Chemie, 67, März 2019. Frankfurt am Main. The following article triggered intensive discussions in Germany because it takes a very dim view of the climate protection effects of electrical mobility: Buchal, Christoph, Hans-Dieter Karl and Hans-Werner Sinn (2019). Kohlemotoren, Windmotoren und Dieselmotoren: Was zeigt die CO_2-Bilanz? In: ifo Schnelldienst 8/2019. Munich.

car's lifetime and the reselling value of electric cars is low or at least uncertain. Different settlement and pricing systems at public charging stations may frustrate customers in real life. Of course, not all potential buyers attach the same importance to each of these disadvantages of electric cars. Taken together, however, they are key reasons for customers' reluctance to adopt e-mobility. At the same time, demand trends are not the only reason for the low market share of electric cars. Delivery times for some electric cars may be quite long. Still, the demand side plays a key role for the slow uptake of electric cars.

Subsidies play a major role in promoting e-mobility

Electric cars have a high market share in Norway

As of now, electric vehicles only have significant market shares if they are heavily subsidised. Take Norway, which has introduced massive tax breaks for electric cars, subsidies for charging, lower road fees and other privileges on the road. Moreover, the government promotes the expansion of the charging infrastructure. As a result, BEVs and PHEVs made up c. 56% of total new car registrations during the first three quarters of 2019. Norway benefits from two factors in its endeavour to promote e-mobility. First, the country is quite prosperous, not least due to oil and gas exports, and is therefore better able to afford such subsidies and infrastructure investments than less wealthy countries. Second, hydropower is the most important source of electricity in Norway, thanks to the topography and low population density. Hydropower comes with low carbon emissions and can be quite well controlled and stored. For these reasons, e-mobility is indeed a climate-friendly option in Norway. However, the conditions are different in most other countries.

Changes to subsidy regimes may turn out to be a regulatory risk

In the Netherlands, too, generous tax breaks, for example for the purchase of e-cars, have led to a quite high market share of BEVs and PHEVs, at 11.5% of total new car registrations during the first three quarters of 2019. However, the development in the Netherlands also shows that changes to the subsidy regime may create considerable regulatory risks for the auto industry. Sales of PHEVs dropped from almost 40,000 in 2015 to only about 3,200 in 2018, mainly because the tax break programme for this type of e-cars ran out. Instead, the government now promotes BEVs, whose share in total new e-car registrations rose from just above 9% in 2015 to 90% in 2018. The share of PHEVs dropped accordingly. This example shows to what extent subsidies affect demand.

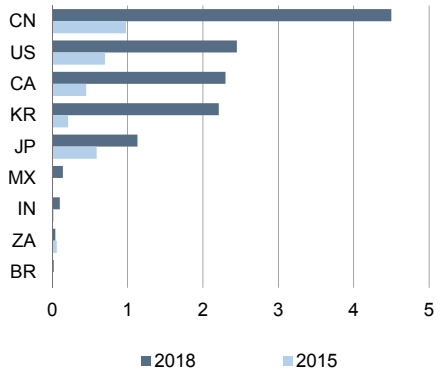
Demand depends on subsidies

In Germany, the combined market share of BEVs and PHEVs amounted to 2.7% of total new registrations in the first three quarters of 2019. Here, too, both the government and carmakers themselves subsidise purchases of electric vehicles. BEV buyers can claim a subsidy of EUR 4,000 per car, PHEV buyers of EUR 3,000. Policymakers decided at the "car summit" at the German Chancellery at the beginning of November 2019 to raise the subsidy for BEVs and PHEVs with an official price of less than EUR 40,000 EUR 6,000 and EUR 4,500, respectively. The government and the carmakers will continue to share the related expenses. In addition, the government intends to promote the expansion of the charging infrastructure.

Electric cars sales in Germany should be boosted by the decision to offer a more advantageous tax treatment of electric company cars than of combustion-engine cars. The taxable employee benefit of e-cars will be 0.5% of the official price, instead of 1% for combustion engines, and the distance between the employee's home and their place of work will increase the employee benefit only by 0.015% per km instead of 0.03%.

Electric mobility not important in many emerging markets 8

Share of electric* cars in total passenger car sales in selected countries



* BEVs and PHEVs

Source: ACEA

Mixed picture outside Europe

Outside Europe, the combined share of BEVs and PHEVs amounted to 4.5% in China in 2018, i.e. almost double the value for 2017. China, too, tries to support the purchase of electric cars, for example by price subsidies, tax breaks and privileges on the road. In addition, the government supports the expansion of the charging infrastructure. Moreover, registration fees for traditional cars have risen considerably in some regions, causing many customers to choose subsidised electric cars. However, China recently cut subsidies for electric cars, which immediately led to a decline in demand.[4]

In addition to the subsidies, China introduced a quota of 10% for electric cars in 2019. A points system allows producers which do not meet this quota to acquire points from producers with a higher share of e-cars. As a rule, industrial policy considerations play an important role for China's drive to promote e-mobility. Chinese carmakers lag considerably behind their competitors from Europe, the US, Japan or Korea in terms of combustion engines. The targeted support for e-mobility aims to create a domestic industrial sector which is competitive right from the start. In addition, e-mobility helps to reduce local air pollution in Chinese cities. Climate policy plays a less important role. According to the IEA, 66% of Chinese electricity generation is based on coal-fired power plants, making e-cars less climate-friendly.

In the US, BEVs and PHEVs had a share of 2.5% in total light vehicle sales in 2018. Again, the government offers price subsidies and tax breaks for electric cars.

E-mobility plays virtually no role in poorer countries

E-mobility practically non-existent in India or Brazil

Not all countries can afford the necessary subsidies for electric cars and an expansion of the charging infrastructure. This is evident from the market shares of e-cars in poorer countries. According to the IEA, the market shares of BEVs and PHEVs were (sometimes considerably) below 0.2% in Brazil, India, Mexico or South Africa in 2018. While cars and car parts are produced in these countries, they mainly serve as production locations for foreign companies. Their governments therefore have no reason to support a "domestic" car industry with a focus on e-mobility. In eastern European EU countries, too, the share of BEVs and PHEVs in total new car registrations is usually below 1% (Q1-Q3 2019). Only in Hungary did it recently reach 1.8%, thanks again to subsidies.

CO_2 emission targets for 2030: Three scenarios

Technological progress and government subsidies are key for the success of e-mobility

Let us return for a moment to the EU CO_2 emission targets for 2030. The German auto industry alone is making two-digit billion euro investments each year in order to accelerate technological progress with alternative engine technologies and offer attractive electric cars. Nevertheless, it is uncertain how quickly technological progress can be achieved and how big it will be. In addition, there is some uncertainty about the long-term subsidy regime in the EU. Future demand for e-cars will depend to a large extent on technological progress and the extent of government support for e-mobility.[5]

[4] See Bloomberg (2019). China considers cutting electric-car subsidies again. Online release on 8 November 2019.

[5] We already identified these two variables as key factors for the future demand for e-cars in a study back in 2011. See: Heymann, Eric et al. (2011). Electromobility: Falling costs are a must. Deutsche Bank Research. Current Issues. Frankfurt.

We can imagine several scenarios for the future development in demand for electric vehicles until 2030.

— In an optimistic scenario, technological progress towards e-mobility is quick, prices for cars in the mass segment decline significantly and the cars can cover longer distances. Under these circumstances, a sufficient number of buyers voluntarily decide to get an electric vehicle, even if there are no subsidies. In this scenario, carmakers can comply with the CO_2 emission targets.

— In a second scenario, technological progress is slower. While the market share of e-cars rises as well, it does so mainly thanks to subsidies. In case of state subsidies, the money used for this purpose is not available for other issues any more (such as climate policy). And if the auto industry itself cross-subsidises purchases of electric cars, the margins decline and/or higher expenses have to be offset elsewhere. If the subsidies are sufficiently high, the auto industry will comply with the emission limits. However, this compliance is only achieved thanks to subsidies, whose expenses must be set off against the successfully avoided non-compliance fines.

Cross-subsidies weigh on returns

— In a third scenario, the market share of electric cars increases as well, but not sufficiently to meet the carbon limits. Technological progress is too slow, which is why the disadvantages of electric cars prevail for too many customers. As a result, the auto industry has to pay fines.

None of these scenarios will materialise as described above. Scenario 2 is to some extent similar to what is currently happening in Norway. Scenario 3 roughly describes the status quo in those EU countries where the subsidies are not generous enough to increase the market share of electric cars. And as of yet, there is no real-life example for scenario 1.

Subsidies versus fines

From a purely economic vantage point, the key question for the auto industry is whether it is cheaper to increase investment in e-mobility, downsizing etc. and, if necessary, to subsidise sales of a sufficient number of electric cars to comply with the CO_2 limits in 2020/21 and 2030, respectively, or to pay the fines if the carbon limits are exceeded. However, economic considerations are not the only factor for the answer. Missing the carbon limits would not only result in fines, but also in reputational damage for the companies affected.

Expenses for European carmakers will be in the two-digit billion area

According to a recent study by our Equity Research colleagues, European carmakers' total expenses for reaching the emission limits for 2021 will sum up to about EUR 22 bn. Paying the fines may quite possibly be the cheaper option for some companies. In any case, the average margin per car will decline. Companies are trying to offset higher expenses by intensifying cooperation and cost-cutting programmes, which also eat into the margins of suppliers. In addition, car prices will probably rise.[6] If demand for e-cars by retail and business customers remains insufficient, carmakers may increase the market share of electric cars by including them in their own car fleets or having more cars registered on behalf of their retailers. However, both options would cost money.

Broader range of models

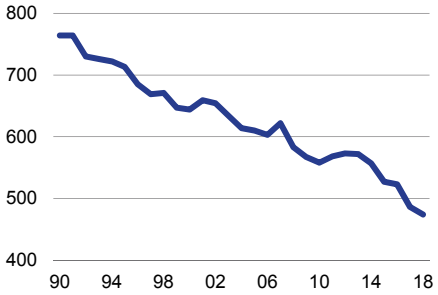
Additional supply to stimulate demand

As we explained earlier in this report, demand-side considerations are the main reason for customers' reluctance to buy electric cars. Customers are cautious because electric cars have objective and subjective disadvantages. Criteria

[6] See Rokossa, Tim et al. (2019). CO_2 fog starting to clear? Deutsche Bank Research. London.

CO_2 intensity of German electricity generation is declining 9

CO_2 emission factor of the German electricity mix, gram CO_2 per kWh



Source: Federal Environment Agency

such as environmental friendliness play only a minor role in buying decisions. However, from 2020, numerous new electric vehicle models will probably stimulate demand. A larger model range coupled with state and corporate (cross-) subsidies looks set to have an impact on buying decisions. Nevertheless, increasing the EU-wide market share of BEVs and PHEVs from 2.6% to 10% and more by 2021 appears ambitious. As it is so often the case in climate policy, much depends on customer behaviour.

Mix of carbon emission limits and subsidies has environmental and economic disadvantages

A mix of climate-policy tools, which consists of strict carbon emission limits for new cars on the one hand (command and control legislation) and subsidies for electric cars on the other, has been established in the EU and other important car markets. Command and control legislation and technology-specific subsidies have some environmental and economic disadvantages:

— CO_2 limits have limited impact on the actual carbon emissions of a given car. The latter depend on the mileage of the car, the driving behaviour, the engine size and the type of fuel. Instead, a higher taxation of fossil fuels would have a more visible and direct steering effect, as it would have an impact on the use of older cars, too. It should therefore not come as a surprise if a rising number of electric cars does not have a major impact on actual CO_2 emissions in the transport sector. Even beyond 2030, most cars in stock in the EU will have a combustion engine.

— Electric cars are not really zero-emission vehicles, as the production of electricity causes carbon emissions. A higher market share of electric vehicles will simply lead to a shift in emissions from the transport to the electricity sector. The source of the electricity consumed by e-cars is less important, as carbon emissions in the electricity sector are included in the EU Emissions Trading Scheme, which sets a cap on carbon emissions. If e-cars lead to higher demand for power from fossil sources and, in turn, for emission certificates, the emissions trading scheme will make sure that emissions are reduced elsewhere. Average electricity sector emissions per kWh (which have been declining for years now) may be used to calculate the actual carbon emissions of electric cars. And in countries which do not have an emissions trading scheme, e-cars may even lead to higher carbon emissions compared to combustion engines. This may be the case if a large share of the necessary electricity is generated by coal-fired power plants.

— E-mobility is a particularly expensive way of avoiding carbon emissions. The money could be used for other purposes or other measures to reduce carbon emissions more drastically. In the spirit of efficiency, it makes sense to avoid carbon emissions at the lowest possible cost. Putting a uniform price on carbon, be it via taxation or emissions trading, would help in this respect. Using an upstream approach, carbon emissions from road traffic might be included in the EU Emissions Trading Scheme. Under this approach, refineries and diesel and petrol importers (and not individual drivers) would participate in the emissions trading scheme; any resultant expenses would be included in fuel prices.[7] For example, the carbon emissions price envisaged by the German government for 2025 (EUR 55 per ton) would raise petrol and diesel prices by less than 15 cents/litre. Carbon prices would probably need to be much higher to dampen transport fuel demand palpably. However, under an emissions trading scheme, the

Emission targets have only a limited effect on actual transport emissions

Calculation example: Carbon emissions and operating expenses 10

A C-segment BEV consumes roughly 20 kWh per 100 kilometres (standard consumption). Based on the average German electricity mix, it causes CO_2 emissions of about 95 g/km, with the trend pointing downwards. Current EU regulation regards this car as a zero-emission vehicle. A diesel-fuelled compact car consumes c. 4.5 litres per 100 km (standard consumption) and causes CO_2 emissions of roughly 119g/km. A gas-fuelled compact car requires roughly 3.5 kg of gas per 100 km and emit 95 grams of carbon per km, i.e. just as much as an electric car.

Assuming an average electricity price of c. 30 cents/kWh, driving 100 km in an e-car costs its owner c. EUR 6. Based on the current diesel prices in Germany, fuel costs for a diesel-fuelled compact car with a standard consumption of 4.5 litres per 100 km will also amount to just below EUR 6. And fuel expenses for a gas car amount to EUR 4.20 (for 3.5 kg) per 100 km in Germany at current prices, as gas benefits from lower taxes.

[7] See Heymann, Eric (2014). CO_2 emissions from cars: Regulation via EU Emissions Trading System better than stricter CO_2 limits. Deutsche Bank Research. Germany Monitor. Frankfurt am Main.

price would lead to carbon emission avoidance in sectors where the costs for doing so are lower. The argument of high CO_2 abatement costs of e-mobility is also valid with regard to public charging infrastructure, which, as a rule, is not profitable yet. Depending on the technology used, costs for installing a charging station may reach the five-digit euro area.[8] In addition, customers do not benefit from considerably lower fuel costs either, at least not as long as electricity and diesel prices in Germany are at their current levels.

— In order to comply with the carbon limits, the auto industry will have to invest in refurbishing factories for electric car production and for retraining employees. In order to offset these expenses, carmakers may decide to shift production capacities to lower-cost countries. Within the EU, the eastern European countries should benefit. For example, German carmakers have recently announced large-scale investments in Hungary. Of course, there are many reasons for taking such decisions (see below).

— Subsidies for electric cars are problematic in that any technology-specific subsidies may lead to neglecting research of other, and potentially better, fuels or propulsion options. In the area of transport, this may apply to natural gas, synthetic fuels or (in the longer run) hydrogen or fuel cells (for heavy-duty traffic). Quite possibly, electric mobility may prevail over other potential alternatives even without subsidies. However, governments should not presume to know which technologies are best suited to reaching a (climate-) policy goal. Attempts to do so often lead to misallocations. Of course, there are always companies which benefit from subsidies. It is helpful for investors, too, if certain business models benefit from state subsidies, as this reduces market risks. However, experience has shown, for example in the area of renewables, that regulatory and market risks continue to exist even for subsidised businesses. After all, the subsidy regime may change if the government cannot afford the subsidies any more or if the political majorities shift. Moreover, foreign competitors may overtake subsidised domestic companies, both in terms of price and in terms of technology, if the latter rely too much on the subsidies and do not pay sufficient attention to productivity or neglect their own R&D efforts. If policymakers decide to back e-mobility, it would make more sense to support the expansion of the public charging infrastructure instead of subsidising the purchase of e-cars directly.

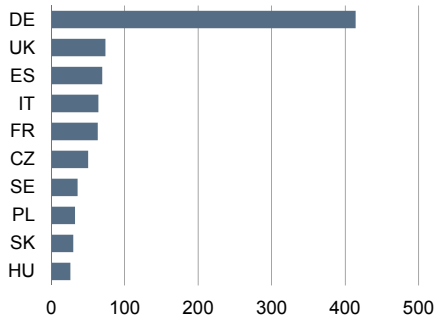
Subsidies may have a negative impact on productivity and innovation

— And finally, subsidies for the purchase of e-cars may be difficult from a social policy vantage point, too. As a rule, higher-income households buy an electric car.

On the one hand, it is useless to enumerate these problems, as the political framework conditions seem to be set in stone until 2030 at least. On the other, doing so is necessary in order to provide a full economic assessment. In the end, the auto industry has to adapt to the regulation.

German autotomotive industry in the lead 11

Production value in the automotive industry, EUR bn, 2018 or latest available data



Source: Eurostat

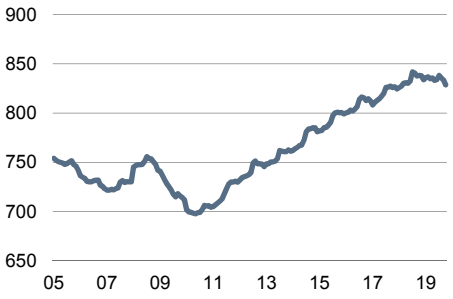
Consequences for Germany as a production location: Risk of job losses; local factors are key for value added

Over the coming years, more and more electric cars will be produced in the EU. Right now, carmakers are refurbishing individual plants for this purpose. So far, electric cars are a niche phenomenon on the production side, too. However, this is going to change if the EU carbon limits are to be complied with. Production structures and the number of employees in the sector will change. BEVs require

[8] See Nationale Plattform Elektromobilität (2015). Charging Infrastructure for Electric Vehicles in Germany. Progress Report and Recommendations 2015. Berlin. This report was published a few years ago. Expenses for installing the necessary charging infrastructure may have declined somewhat in the meantime.

Number of employees declines of late 12

Number of employees in the automotive industry in Germany, '000



Source: Federal Statistical Office

considerably fewer parts and components than cars with a combustion engine. The engine itself, the gearbox and the traditional transmission system are no longer necessary. However, German carmakers and suppliers have specialised on just these parts of a traditional car; in fact, they are global market leaders in these areas. That is why the German auto industry and, in fact, the German economy as a whole will be affected more strongly by the upcoming change than those of other EU countries. By output value, Germany is by far the biggest automotive production country in Europe.

As the market share of electric cars increases, these parts and components will no longer be needed (everything else being equal). At the same time, battery imports will rise, which means that the export surplus in the auto sector might decline in the long run.

In addition, the rising importance of e-mobility will probably lead to job losses. There have been several studies on this issue. The Institute for Employment Research (Institut für Arbeitsmarkt- und Berufsforschung, IAB) expects that job losses in the auto industry will not be fully offset by additional employment in other sectors. According to its study, Germany will lose 114,000 jobs in net terms by 2035.[9] Of course, these long-term forecasts are subject to considerable uncertainties and are based on a number of assumptions, for example on the development of the market share of electric vehicles, their place of production and the place of production of the batteries.

Evolutionary development towards electric mobility and demographical change dampen negative impact on employment

According to the statistical definition pursuant to NACE code 29, the German auto industry recently employed a bit more than 830,000 people. A loss of more than 100,000 jobs would be significant and painful for the affected regions. However, several factors should cushion the negative impact on employment:

Global demand for cars with combustion engines to rise further for now

— The trend towards e-mobility is more evolutionary than revolutionary. The share of e-cars in total global car sales will rise slowly; in many countries, they will play only a minor role in the next few years because they are not supported by the government and the charging infrastructure is inadequate. At the same time, global demand for cars will continue to rise. Even if the market share of electric vehicles increases, this does not mean that demand for cars with combustion engines declines; quite the contrary. Sales of cars with internal combustion engines (including PHEVs) will continue to rise globally. Nevertheless, the average engine size looks set to decline.

— Due to the demographic development, the workforce in Germany will decline from the mid-2020s. Even assuming high net immigration (as well as moderate estimates about the number of births and life expectancy and an unchanged retirement age), the German workforce will decline by c. 4 million people by 2035, compared to 2019. And other EU countries are likely to see their workforce shrink as well. Overall, well-qualified workers will become harder to find in some regions and sectors. This means that job losses in the car industry will not necessarily lead to higher unemployment rates in the long run. They may be offset by demand from other sectors, which suffer from a lack of qualified workers. However, investment in professional training will certainly be necessary. Due to the demographic development, a higher degree of production automation may also be less of a problem than currently assumed. After all, the job losses in the auto sector expected by several studies will take place over a number of years. As the

[9] See IAB (2018). Elektromobilität 2035. Effekte auf Wirtschaft und Erwerbstätigkeit durch die Elektrifizierung des Antriebsstrangs von Personenkraftwagen. IAB-Forschungsbericht 8/2018. Nuremberg. This report also includes an overview of other studies and their results.

baby boomer generation is due to retire during this period, the affected companies and regions will need to shoulder less of a burden and will not be faced with a short-term shock.

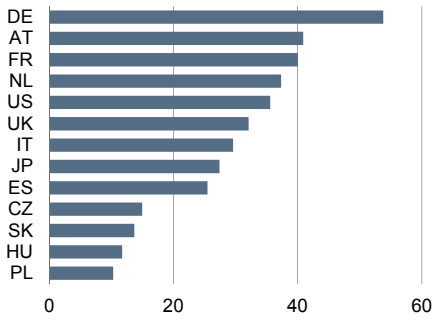
Success of Germany as an industrial location and of the German auto industry depends on many factors

From an economic vantage point, the decline in the workforce seems to be the bigger challenge for Germany and other ageing EU countries than the potential decline in demand for labour due to a technological structural change in individual sectors.

Moreover, we believe that the medium- to long-term outlook and the competitiveness of the German auto industry and of Germany as a car producing country depend on numerous factors, which are not really related to the technology shift towards e-mobility. And the question of when electric cars will obtain a significant market share even without subsidies and of where they are produced is only one of many aspects that are relevant for this issue.

Germany with highest labour costs 13

Labour costs in the automotive industry, EUR per hour



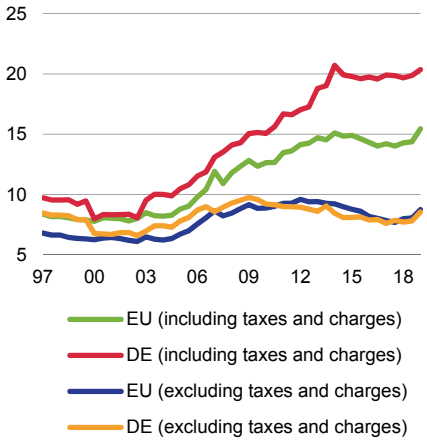
Sources: Eurostat, VDA

Disadvantages in terms of traditional factors

Several traditional factors will actually be key for Germany's future as a car producing country. These include labour costs, labour market flexibility and the availability of highly qualified workers, the tax burden and energy and electricity prices. Labour costs in the German auto industry are clearly the highest in an international comparison. They are more than one-third higher than in France and about five times as high as in Poland or Hungary. Looking at labour market flexibility, policymakers are increasingly critical of the Hartz reforms and have taken them back to some extent. A retirement age of 63 is not an advantage, as it reduces the pool of available qualified workers. And effective average corporate taxes are among the highest in an international comparison, too. In addition, countries such as the US, France, Italy or the UK have already reduced corporate taxes or decided on corporate tax cuts. Germany is therefore at risk of falling back even further in the "tax competition".[10] And finally, corporate electricity prices are the second-highest in the EU, behind Denmark. They are 32% above the EU average, mainly due to taxes, fees and charges.

Taxes and charges are the main drivers of electricty prices in Germany 14

Electricity price for industrial customers*, cents per kilowatt hour



* Annual electriicity consumption. between 500 and 2.000 MWh

Source: Eurostat

Auto industry cluster increases competitiveness

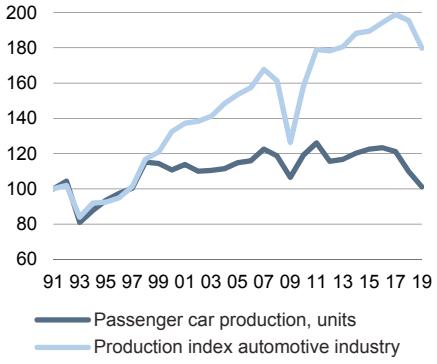
In view of these disadvantages, it seems surprising at first sight that the auto industry plays such an important role for the German economy and that it is internationally competitive. Obviously, the sector has so far succeeded in compensating for these disadvantages. Over time, companies in the German auto industry have established close technological and regional links. This applies to carmakers, suppliers, machinery and equipment providers (e.g. mechanical engineering companies), research and development companies, universities and other research institutions, logistics companies and car dealers and garage owners. This auto industry cluster is probably unique in the world. Competition between carmakers and suppliers also stimulates innovation and productivity.

Moreover, the internationalisation strategy of the German auto industry over the last few decades has helped it to do well in international competition and strengthen Germany as a production location. Producers diversified their procurement chains so that they now get bodies, parts and components from

[10] See Bräuninger, Dieter (2018). German corporate taxes: Growing need for action. Deutsche Bank Research. Germany Monitor. Frankfurt am Main.

Significant qualitative growth 15

Automotive production in Germany, 1991=100

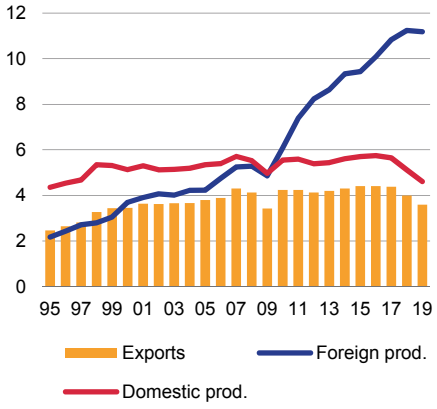


2019: Estimate

Sources: Federal Statistical Office, VDA

German automotive industry becomes more international 16

Passenger car production by German OEMs and car exports from Germany, m



2019: Estimate

Source: VDA

Cost disadvantages of Germany as a producer country

cheaper production sites abroad. Five eastern European countries, above all the Czech Republic, are among the top ten supplier countries for German imports of automotive products. At the same time, the German auto industry has established new factories abroad. Eastern European locations benefited from a cost advantage. In addition, investments abroad are often a way to get a foothold in local markets. This applies, for example, to China, where local content requirements make it necessary to ensure a certain degree of local value added. Car demand in the US, too, is largely being satisfied from US factories of German carmakers. Moreover, German companies deliver to other countries from the US. In addition, foreign production locations help to avoid tariffs and non-tariff trade barriers. In short, there are many reasons to start producing abroad.[11]

Foreign production remains dynamic, domestic production is in a crisis

During the past 20 years, the expansion of the German auto industry abroad did not affect the domestic output. Between 1998 and 2018, German factories always produced more than 5 million cars each year, apart from 2009. This is a satisfactory level in a mature market with high local costs. The output index, which also includes suppliers and qualitative components, such as better equipment of cars, even rose 67% in real terms between 1998 and 2018. Factories abroad are sometimes supplied with engines, transmission systems and other components produced in Germany.

At the same time, the output of the foreign car factories run by German producers has risen by more than 300% (in unit terms) between 1998 and 2018 and is by now more than double the German production. The gap between domestic and foreign output has been widening particularly quickly in recent years. In fact, domestic car production declined significantly for the second time in a row in 2019 and dropped below the 5 million unit threshold. In contrast, foreign production rose 4% in 2018 and stagnated in 2019.

Beyond the global weakness in demand, the decline in domestic production is due to some one-off effects. In 2019, several key models produced in Germany came to the end of their life cycles and are being (or will shortly be) replaced by successor models. Car sales tend to decline towards the end of the life cycle. At the same time, demand for models produced abroad has risen considerably. For example, German carmakers' output in Hungary, South Africa, Mexico and Portugal rose strongly in 2019. Overall, German carmakers maintained or even increased their market shares in important sales markets in 2019 (China) even though domestic production and exports from Germany declined considerably.

Many reasons for recent cost-cutting programmes

Why do we include these fundamental explanations in a study whose main focus is on e-mobility? Because the current discussions about e-mobility have pushed several fundamental questions into the background. One of them is whether the recent decline in German output is a sign of major structural weaknesses of Germany as a car-producing country. Will the German auto industry be able to raise output again to 5 million cars and keep it at this level in the medium term? News of cost-cutting programmes and redundancies at German carmakers and suppliers have been making the headlines recently.[12] The above question is therefore quite valid, particularly in view of the fact that

[11] See Heymann, Eric (2014). The future of Germany as an automaking location. Deutsche Bank Research. Germany Monitor Frankfurt am Main.

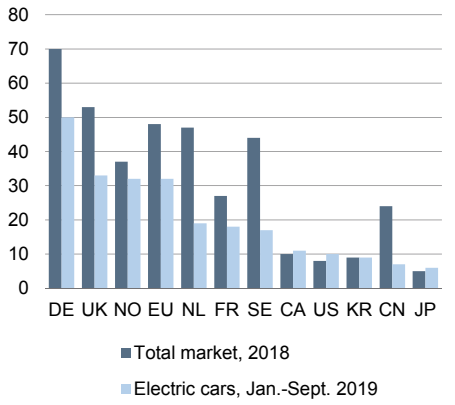
[12] According to official statistics, the negative impact on employment in the German auto industry is still limited. Employment was down only 1% compared to the record level in mid-2018 and up 19% from the beginning of 2010.

many producers and suppliers have announced plans for additional investments abroad.

The reasons for the cost-cutting programmes and the planned job shedding are different. Apart from weak car demand, financial challenges around the transition to alternative propulsion systems, such as e-mobility, certainly play a role. At the same time, the fact that Germany is a relatively expensive country for producers probably was an important reason behind the companies' recent decisions. After all, the German car industry is not planning to invest less at a global level and in the long run. It would therefore be erroneous to conclude that the cost-cutting programmes and redundancy plans announced by some companies in Germany mean that German carmakers are experiencing a structural crisis.

Market share of German carmakers quite low in terms of e-mobility 17

Market share of German OEMs for electric cars and in total passenger car market, %



Source: VDA

German auto industry better prepared for an "e-mobility" future than Germany as an industrial location for car producers

Looking at the public discussions about e-mobility, one might get the impression that the fate of Germany as a car-producing country and of the German auto industry depends only on the development of this technology and on demand for electric vehicles. However, this is not true. Electric vehicles will certainly gain importance, and the range of available models is expanding quickly. According to the German Association of the Automotive Industry (VDA), German carmakers alone will offer more than 150 electric car models by 2023. German companies were not the first to develop electric vehicles, and their market shares in the electric car segment are below their total shares in many important markets. However, it would not be the first time that the German auto industry subsequently overtakes the pioneers (i.e. in the coming years) and makes customers the best and most wide-ranging offer in the second step. While a number of market observers repeat like a mantra that the German auto industry has completely missed the trend towards e-mobility, we believe that this assumption is wrong. First, e-mobility remains a niche phenomenon for now; its global market share is below 3%. Second, the trend is supported mainly by CO_2 emission regulation on the one hand and subsidies on the other. And third, the competition for the best position in the e-car segment is not a sprint, but a long-term race.

That leaves the question of where the German auto industry is going to build its e-cars in the future. Many of them may be built in Germany, particularly since some factories have already been refurbished. However, this will not necessarily be the case. Other factors will need to be satisfactory as well. Even a product which offers the best available technology will have limited success if it is too expensive because of the cost situation in the country where it is produced. At the same time, conditions in the producing country may be near perfect, but the product will still need to be convincing.

The competition for the best position in the e-car segment is a long-term race

Turning back to the auto industry, it seems that German carmakers can rely on a full product pipeline of e-cars. They are coming late to the party, but, we believe, not too late. At the same time, Germany, as a car-producing country, has lost ground in comparison to other countries in terms of total expenses. And production costs play a major role for the market success of electric cars. Cost disadvantages may be mitigated by scale effects, high capacity utilisation or increased automation. In fact, German companies can rely on decades of experience in these respects, particularly in their home country. And many advantages which Germany can offer carmakers will continue to exist if the share of electric vehicles in total output increases.

All in all, the German auto industry currently seems better prepared for an "e-car" future than Germany as a car producing country. Companies can

respond flexibly to different regional trends in e-car demand, for example by producing electric cars for the Chinese market in China. However, a major shift with regard to corporate expenses (wages, taxes, electricity prices etc.) seems unlikely in the near future. It is difficult to forecast the trend in value added due to the uncertainties; once again, we have developed several scenarios:

Loss of up to 25% in value added is not improbable

— The biggest loss in value added will occur if the increase in BEV output (in value-added terms) is smaller than the decline in the output of combustion-engine cars, engines, transmission systems etc. and if the majority of car batteries is imported. In that case, 10-25% of domestic value added might be lost in the long run.

— A moderate loss of 5-10% in gross value added is likely if a large share of German e-car production is made up by expensive PHEVs, if car batteries are produced in Germany as well and if global demand for combustion-engine cars rises sufficiently strongly and is met to some extent by cars produced in Germany so that any loss of value added from combustion engines and at the supplier level remains small.

— Value added might rise by a maximum of 5% if e-car and battery output does not substitute the output of combustion-engine cars and traditional car parts and components, but comes on top; in that case, new factories may need to be built.

A mix of the first two scenarios seems more likely than the third. All this means that Germany may have to deal not only with job losses, but also with a loss of part of the value added from technologies related to traditional drivetrain. At the same time, other factors which have nothing to do with a car's propulsion system (connectedness, equipment, general research and development etc.) may raise the sector's value added.

Tesla entering Germany: Competition is good for business

Still, the third scenario is not completely unrealistic; remember Tesla's recent announcement that the company plans to build a factory for electric cars and batteries in Germany. After the news broke, the discussion focused on the question whether this move might have a negative impact on German carmakers. We do not think so. After all, competition is good for business. Fierce competition between German carmakers in the premium segment has always been one of the key drivers of technological progress and efficiency gains in the German car industry. Competition has, in fact, been a major advantage for German companies in their quest to gain a good international market position. If another player enters the local market, this is a favourable development in terms of competition.

German carmakers are used to fierce competition

In addition, Tesla will remain a major competitor in the e-car segment even if the company does not produce its cars in Germany, but in other countries. And German carmakers are launching more and more e-car models themselves. Scale effects should help to reduce costs. And for customers, competition is positive anyway. All in all, a little more calm seems warranted. Tesla's investment decision is, in fact, a positive signal for Germany as a production location.

Conclusion

The share of electric cars in total new car registrations in the EU is going to rise in the coming years. If it amounts to 10-15% in 2020/21, the auto industry as a whole will be able to avoid fines for non-compliance with the CO_2 limits; however, this is quite improbable, seeing that the share of electric cars was only

2.6% most recently. It is still unclear if and when customers are convinced of buying an electric car without heavy subsidies. In Germany, the tax treatment of electric company cars should have a positive effect.

E-cars can help to reduce carbon emissions in the EU, as e-mobility will shift emissions from the transport sector to the electricity sector, which is included in the EU Emissions Trading Scheme and thus subject to a cap on emissions. However, the favourable effect on the climate will be small, particularly with regard to the value creation chain as a whole. E-mobility remains a very expensive way of avoiding carbon emissions. State subsidies for e-mobility therefore prove once again that cost efficiency is not in the focus of climate protection measures.

A higher market share of e-cars will lead to job losses in the German auto industry. However, the effect will probably be manageable because the transition is evolutionary. All things equal, value added is likely to decline as well. The losses will rise as production of cars with combustion engines is replaced by BEV production and as batteries are imported. The regulation-driven trend towards alternative propulsion technologies, such as e-mobility, is a major challenge for the global auto industry. It is not a specific problem of German carmakers. From today's vantage point, the German auto industry is better prepared for the "e-car" future than Germany as an industrial location for car producers. In fact, a number of factors on the cost side have deteriorated in Germany over the last few years.

The discussion of the advantages and disadvantages of e-mobility would benefit from more differentiated views. E-cars are already a viable and economic alternative for many private and corporate owners (at least taking into account subsidies). This applies, for example, to urban deliveries or second cars, which can be charged at home or at the place of work. Still, this does not apply to all potential customers. People who need to cover several hundred kilometres each day or who do not have the opportunity to have their cars charged near their homes will not choose an e-car. In addition, it has to be accepted that buying a car is a major financial effort for most households. In spite of state subsidies, consumers tend to exhibit a certain degree of inertia.

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