Electromobility 2035

Effects on the economy and employment through the electrification of the powertrain of passenger cars

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Summary

This study focuses on the economic effects of the phenomenon of electrification of the powertrain in automobiles (e-mobility). This development involves considerable challenges at enterprises and the political level. Using the scenario technique, a number of assumptions were made and integrated into the analytical tool QINFORGE.

In the beginning of the scenario, the underlying assumptions have a positive effect on the economic development. However, at the long run they lead to a lower GDP and level of employment. The change in technology leads to 114.000 job cuts in the end of 2035. The whole economy loses nearly 20 billion Euro (0.6 % of the GDP). In the scenario we assume a share of only 23 percent of electric compared to all cars in 2035.

The total turnover of the workforce resulting from the electrification of the powertrain of automobiles will reach 150.000 in the year 2035. If we look at the requirement levels, a differentiated picture emerges. During the initial phase, the technological change will affect helpers and skilled workers. However, in the long run the need for experts and specialists will decrease. In the end, the dynamic of the decreasing demand for experts and specialists exceeds the dynamic of the development of helpers and skilled workers.

A much higher market penetration could lead to stronger economic effects. Furthermore, a higher market share of domestic produced cars and traction batteries could generate more positive economic effects.

At the moment this scenario includes a lot of assumptions where further research is necessary. This applies in particular to the position of the supplier industry, the distinction between different types of fuel and the expansion of other mobility sectors.

1 Electric mobility – status and expectations

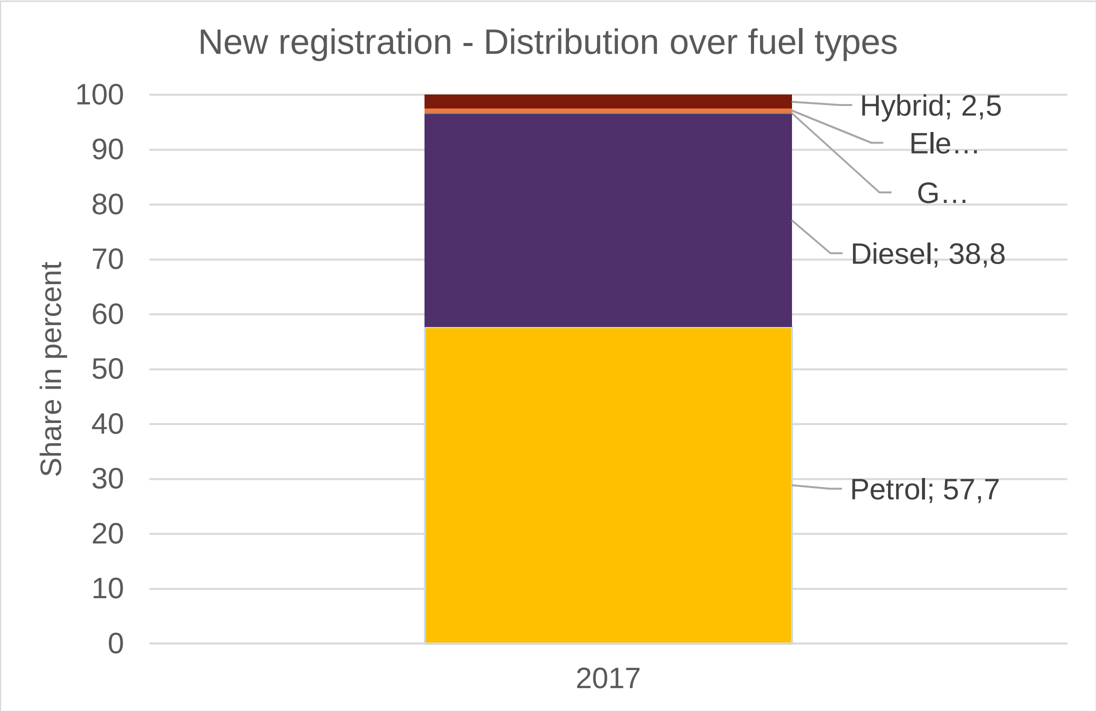
The automotive industry is one of the leading sectors of German industry. Due to its high share of value added, its high export quota and its high direct and indirect number of employees, the automotive industry is regarded as systemically relevant and therefore receives a high degree of political, economic and social attention. This is all the more true today as the industry is currently in a phase of upheaval: Suspected cartels, software manipulation, driving bans for diesel vehicles in cities, the planned end of the combustion engine in France or Great Britain, e-quotas in China or EU fines for increased carbon dioxide emissions from 2020 (<95 grams of CO_2 per kilometre) and 2030 (35% less than 2020) are urging manufacturers to make changes and are currently promoting the development of battery-operated cars. The German automotive industry has announced a model offensive in the field of electric cars for the coming years. However, the presumed lead supplier (NPE 2016: 2) does not have a lead market to the same extent: At 0.7 percent, the share of electric cars in total new car registrations in Germany is very low (Figure 1). The high growth rates of +120 percent (2017) are due to the low starting level. Electric cars account for an even smaller share of 0.12 percent of existing vehicles. In 2017, 53,861 electric cars were registered in Germany.

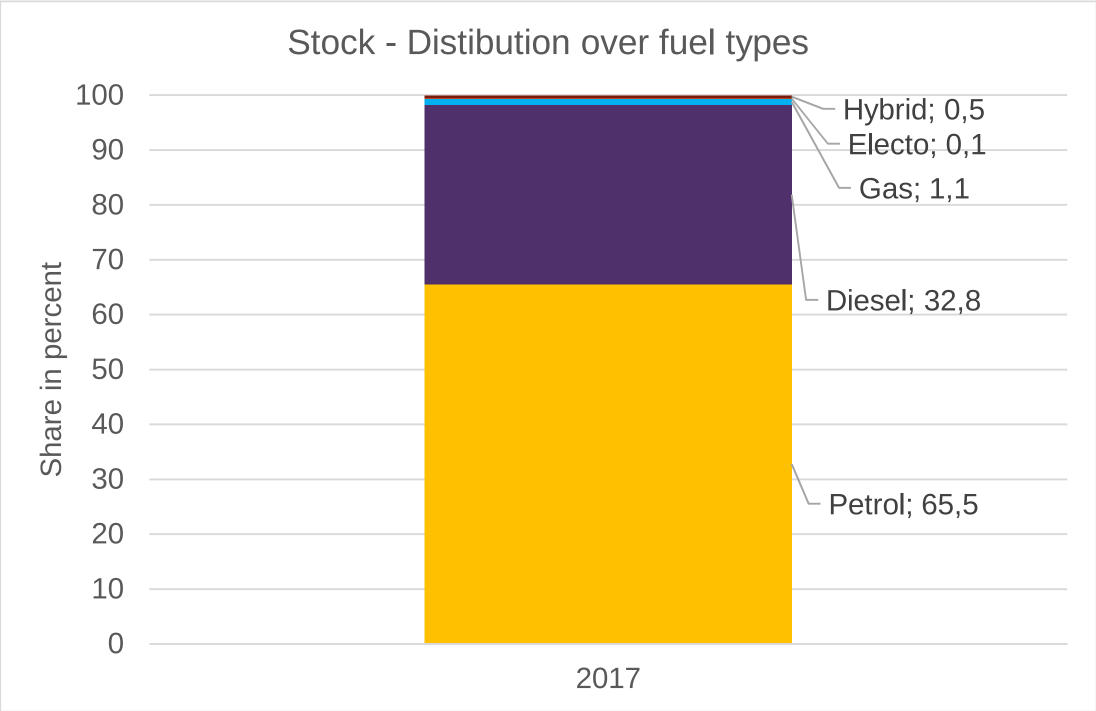
The Federal Government is promoting the electrification of the German car market with various measures: In 2016, a package of measures was made available with an investment volume of almost one billion euros. The package primarily includes three market incentive programmes, which on the one hand provide for purchase premiums for electric vehicles of up to 4,000 euros, on the other hand 200 million euros will be made available to improve the charging infrastructure and, finally, at least 20 percent of the federal vehicle fleet is to be electrified. In addition, electric vehicles will be exempt from motor vehicle tax. In addition, there are funding programmes that support research and development work in the field of "renewable mobility". According to the current progress report of the National Platform for Electric Mobility (NPE 2018), however, the target of 1 million electric cars in Germany by 2020 cannot be achieved. The target will probably not be reached until 2022.

Due to a lack of infrastructure, the short range of batteries and the still high purchase price, sales based on the combustion engine will continue to dominate in the coming years. Nevertheless, in view of the developments outlined above, a substantial change in the way vehicles are powered is to be expected.

Some studies have so far dealt with the economic and, in particular, labour market-specific effects of electrifying the powertrain. Particularly because electric cars contain significantly fewer and simpler parts and the largest and most important component - the battery and the battery cells required for it - is not yet manufactured in Germany or by German manufacturers or suppliers (NPE 2016b), there are fears of higher job losses in the course of the advance of electric mobility.

Figure 1: New passenger car registrations and passenger car stock by fuel type in 2017





Source: Kraftfahrtbundesamt (KBA)

Table 1: Employment effects of electrification of the powertrain in the literature - sorted by year of publication

Source	Employment effects
ELAB 2010	- In all scenarios, a stable to rising employment situation is expected in powertrain production. - However, there may be major shifts and upheavals in the value chain. - Net effects are determined
TAB 2012	- 0.8 percent increase in GDP by 2030 - Employment growth of 230,000 persons - Net effects are determined
Schade et al. 2014	- Depending on the scenario, positive or negative employment effects are expected. - Net effects are determined
NPE 2016	- A comprehensive promotion of electromobility will create about 25,000 new jobs by 2020 in the automotive sector alone compared to a "passive" scenario that continues the current promotion. - In addition to the job gains from the construction and operation of the charging infrastructure and fiscal effects, 30,000 additional jobs will be created by 2020. - Gross effects are determined
ECF 2017	- More employment especially in the area of production and installation of charging infrastructure. - Less employment in the production of internal combustion engines. - Higher growth overall. - Battery production site crucial. - Gross effects are determined
Ifo 2017	- 600,000 industrial jobs directly and indirectly affected.. - Jobs in SMEs in particular would be threatened. - About 13 percent of the gross value added of German industry would be affected. - Net effects are determined
ELAB 2018	- The overall employment effect will be negative in all scenarios. - The range extends from -11 percent to -53 percent in personnel requirements. - The increase in employment in the production of alternative powertrains cannot compensate for the reduction in personnel requirements for combustion engines.. - Results are more negative when productivity gains are taken into account. - Net effects are determined

Source: see studies

Table 1 gives an overview of the expected employment effects in the literature researched. The effects on the labour market differ markedly, from positive to negative employment effects. This inconsistency can be traced back to the different underlying assumptions, to the different modelling and forecasting methods and finally to the consideration of gross and net effects. The difference between gross and net effects lies in the fact that only the direct and indirect effects of a measure are taken into account in the gross effects, but that consequential effects such as substitution or budget effects are not included in the analysis.[1]

2 Modelling, Scenario Technique, Definitorics

2.1 Modelling

As already mentioned above, the available studies on the subject also differ in their choice of methods. While the majority of the analyses are based on literature analyses, surveys and simple empirical analyses using scenario techniques (ELAB 2010, ELAB 2018, ifo 2016, NPE 2016), there are only a few approaches that use complex economic models to estimate employment effects (TAB 2012, Schade et al. 2014, ECF 2017). All three of the latter studies build on input-output tables in economic modelling. While TAB (2012) and Schade et al. (2014) use the ASTRA model, ECF 2017 uses the Cambridge Econometrics E3ME model. Both model types used are multi-country models. However, while the ASTRA model follows the approach of a System Dynamic Model (Lehr et al. 2011), Cambridge Econometrics' input-output model E3ME is a macroeconometric forecasting and simulation model whose properties go beyond those of a general equilibrium model. The models are also used in conjunction with scenario techniques.

[1] The difference between gross and net effects is mainly found in the analysis of the transformation of the energy system. Here the investment in renewable energies and its impact on employment is seen as a positive gross effect. If rising energy costs are taken into account in the analysis, which could be expected as a result of the restructuring of the energy mix, - the macroeconomic employment effects would be classified as a net effect (Dehnen et al. 2015).

Method box 1: QuBe-project

The BIBB-IAB qualification and occupational projections (QuBe project), which were developed in cooperation with the Gesellschaft für Wirtschaftliche Strukturforschung (GWS), use model calculations to show how the supply of and demand for qualifications and occupations can develop in the long term. Several data sources are coordinated as a data basis. As official representative statistics of the Federal Statistical Office, in which one percent of all households in Germany participate annually, the microcensus (last survey year 2015) provides information on the population and the labour market. The national accounts (in the preceding projection up to 2016) form the basis for the projection of the overall economy. The register data of the employees subject to social insurance contributions (SVB) and the exclusively marginally employed (AGB) of the Federal Employment Agency (BA) provide additional information on the number of employed persons by occupation and the corresponding wages paid (in the present projection up to the year 2015). The results are differentiated by up to 144 KldB 2010 three-digit figures (occupational groups).

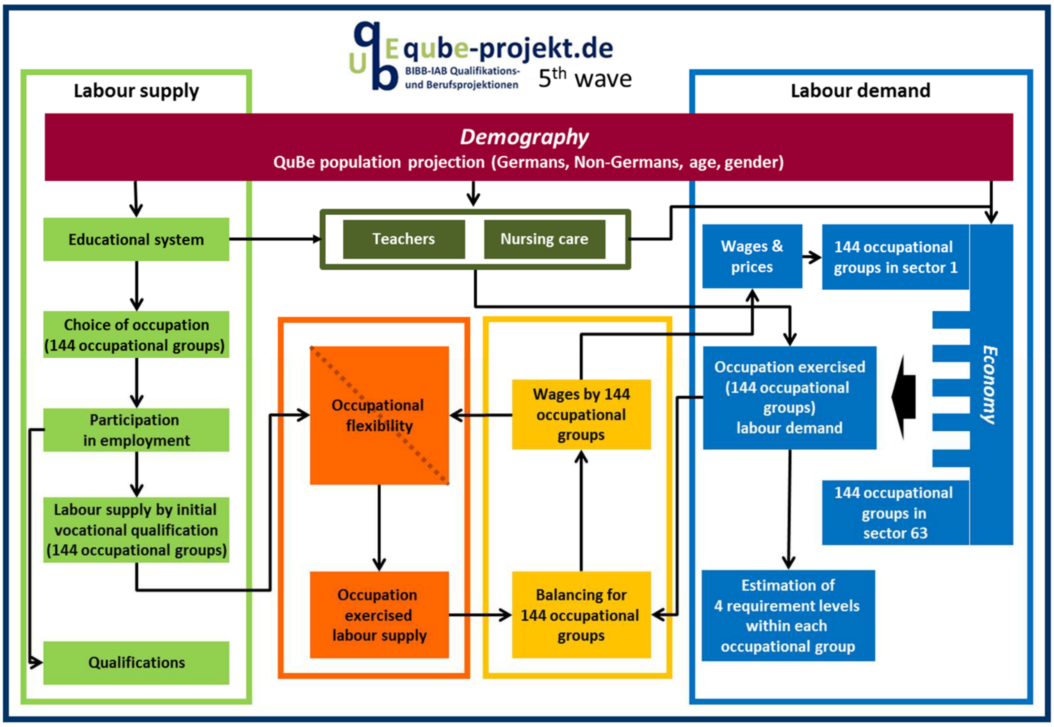
The unique selling point of the QuBe project lies in the linking of the labour supply after a learned occupation with the occupation-specific labour demand through the use of occupational flexibility matrices. This makes it possible to draw up a professional balance of the labour market by comparing the labour force and employed persons according to occupational groups.

The present results are based on the base projection of the fifth projection wave. This is based on the methods of the previous waves (Helmrich & Zika 2010; Maier et al. 2014; Maier et al. 2016, Zika et al. 2012) and includes further innovations. For the determination of personnel requirements in nursing, education and teaching, detailed modules ("nursing" and "teaching") have been developed which take into account not only the demand for labour but also the economic consequences for the health and social services. Like the revised household module, which determines the number of households with German and non-German board members, these modules are based on the QuBe population projection.

The QuBe project follows an empirical concept in the basic projection: Only behaviour patterns that can be proven so far are projected into the future. Changes in behavior that cannot be detected in the past are therefore not part of the basic projection. This also applies to the modeled market adjustment mechanisms. The following illustration gives a rough overview of how the model works.

Further information can be found here www.QuBe-Projekt.de; results for download are available here www.qube-data.de

Figure 2: QINFORGE **at a glance**

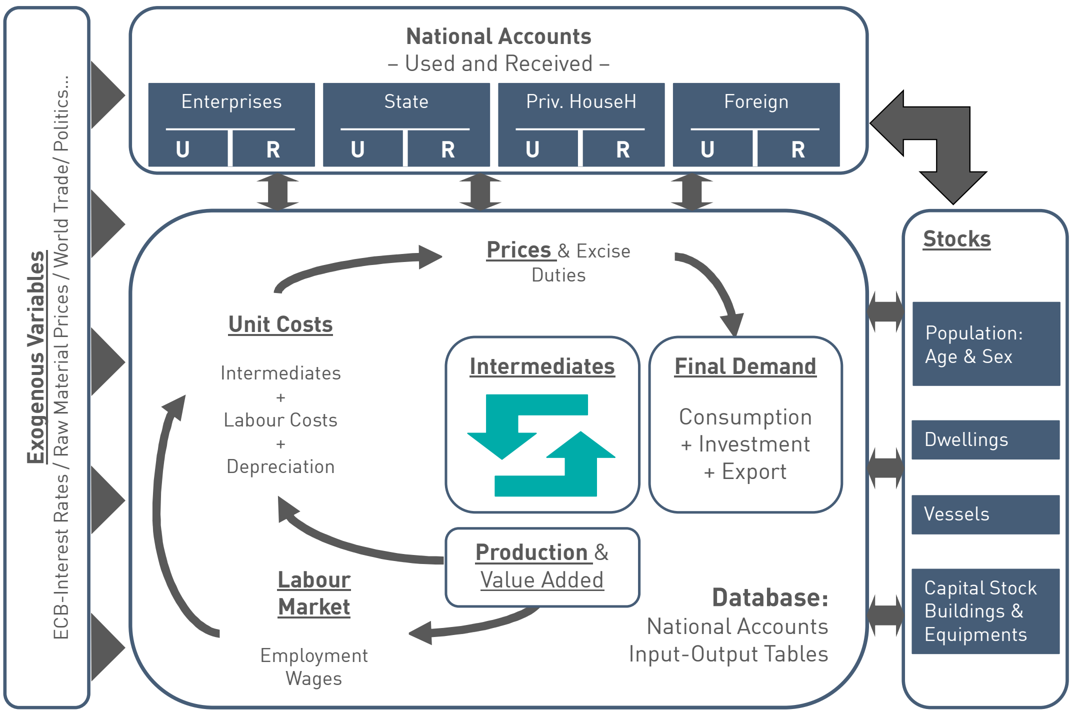


Source: QuBe-project

Method box 2: The IAB/INFORGE-model

The IAB/INFORGE model is a deeply disaggregated econometric forecasting and simulation model for Germany, developed by the Gesellschaft für Wirtschaftliche Strukturforschung (GWS) and operated and updated continuously since 1996 (Ahlert et al. 2009). The model is based on the construction principles "bottom-up" and "full integration". "Bottom-up" means that the individual sectors of the economy are modelled in great detail and the macroeconomic variables are formed by aggregation in the model context. This allows both a complete representation of the individual sectors in the overall economic context and in the intersectoral interdependence as well as an explanation of the overall economic context, which the national economy understands as the sum of its sectors. "Complete integration" refers to a model structure with an illustration of interindustrial interdependence and an explanation of the income use of private households from income generation in the individual sectors (Figure 2). Export demand is determined by the world trade model TINFORGE (Wolter et al. 2014), which projects the bilateral trade links of 154 countries and one region. The import demand for German products forecast in TINFORGE determines Germany's goods exports via bilateral trade matrices.

Figure 3: IAB/INFORGE at a glance



Source: QuBe-project

The method we have chosen follows the approach of complex economic modeling in conjunction with scenario techniques, as also pursued by ECF (2017), TAB (2012) and Schade et al. (2014). The macroeconometric input-output model INFORGE used here is similar to the E3ME model in many areas. However, the focus is not on multi-country modelling, but on mapping labour demand not only by sector, but also by occupations and requirement levels. The bottom-up structure also allows industry-specific assumptions to be made.

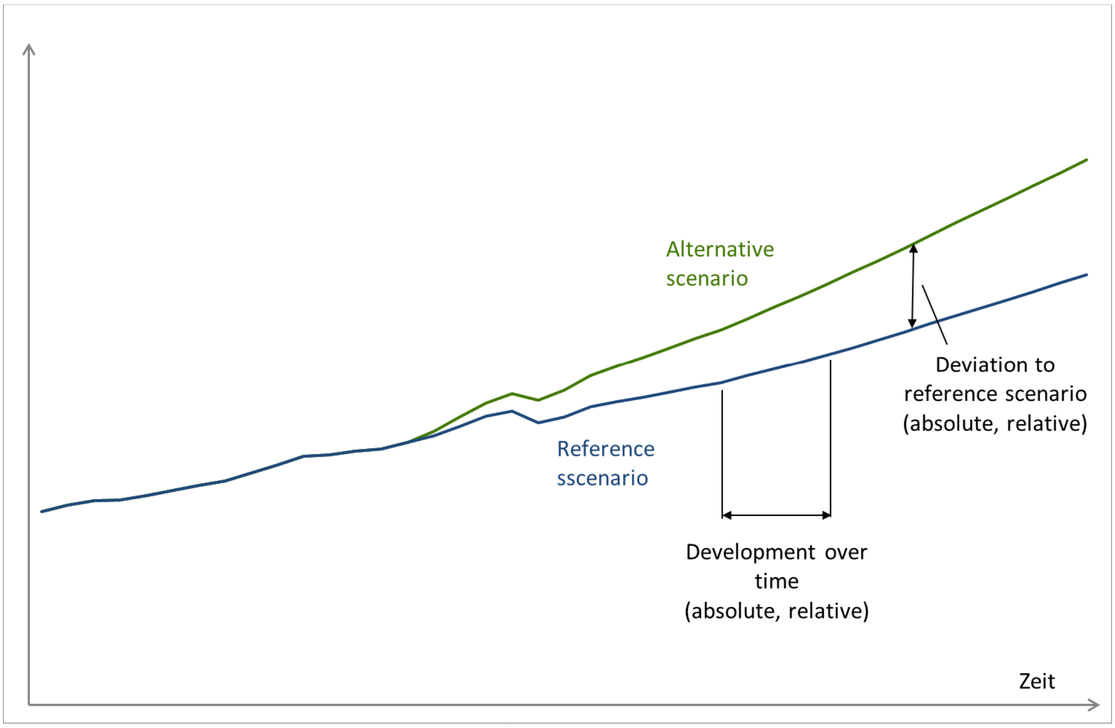
INFORGE is the economic core of the QINFORGE model, which was extended within the framework of the QuBe project (see Method Box 1). INFORGE is described in detail in Ahlert et al. (2009). Its most important properties can be found in method box 2.

2.2 Scenario technique

The effects of certain (economic, technological, social) developments are usually examined by means of "what-if" analyses in order to calculate the implications of diverging assumptions. The comparison of two scenarios reveals the implications of different assumptions. One scenario is the reference scenario, which represents plausible and consistent future developments. In an alternative scenario, other assumptions are varied, e.g. with regard to economic or demographic development. The model relationships remain unchanged, so that differences in the results can be attributed solely to the changed assumptions. The results can be presented over time for one scenario or by comparing two scenarios at the same time (Figure 4). In the model framework used here, Wolter et al. (2016) already carried out such a scenario analysis on the effects of Economy 4.0 in Germany. In the present study, the scenario technique is used to quantify the effects of electrification of the powertrain on the economy and employment.

The reference scenario used is the base projection of the BIBB-IAB qualification and call field projection (QuBe base projection), which was published as part of the 5th wave of the QuBe projection (Maier et al. 2018; method box 1). The development described therein already contains assumptions regarding the development of the degree of motorisation, new registrations and the total number of passenger cars. There is no differentiation by engine type and must be taken up in the form of assumptions in the scenario development. Further consequences of electrification, which go beyond the endogenous measure of motivation, such as investment and further training requirements, cost implications for batteries, chemicals or plastics or shifts in trade, must also be part of the assumptions made.

Figure 4: Application of the scenario technique



Source: QuBe-proejct

The detailed modelling of the sectors with their cost structures on the basis of the input-output calculation of the Federal Statistical Office and the detailed presentation according to 63 sectors, 144 occupations and 4 requirement levels is particularly valuable for scenario analysis. Thus changes of the production method in the industries, as well as the occupation and requirement structures are depictable after industries.

2.3 Definition of electro mobility

The Federal Motor Transport Authority defines electric vehicles as "vehicles with exclusively electric drive" (KBA 2017: 6). This definition of electric cars is narrower than that of the Federal Government, which, in addition to purely electrically powered cars, also understands combinations of electric motors and small combustion engines and hybrid vehicles rechargeable on the power grid as electric vehicles. We follow the definition of the Federal Motor Transport Authority (Kraftfahrtbundesamt), according to which in the following only passenger cars with electric drive are considered. This also includes fuel cell vehicles, which are also classified as electric cars, as they use electrical energy for locomotion and store it temporarily in traction batteries. However, hybrid vehicles with at least two different types of drive fall within the "residual range" of passenger cars. In addition, only passenger cars are considered in the following. Light trucks, small vans or sprinters are not included in the analysis.

3 Assumptions

The operationalisation of the electromobility scenario is based on a total of 17 assumptions and 14 quantitative attitudes which, in addition to the necessary investments, concern components on the final demand side as well as the cost structure of individual sectors and the productivity of vehicle construction (cf. Table 2). The complexity of this scenario therefore requires a large number of interventions, whose macroeconomic effects in their entirety cannot be estimated without a model-theoretical background. Individual attitudes can strengthen, weaken or offset each other in their effects - the overall effect is therefore a priori completely open. This makes the determination of the necessary adjustment screws and the assumptions made all the more decisive. These form the output via the model mechanisms and therefore require a precise description and justification.

Table 2 lists all assumptions. They are explained in the following subchapters "General assessment" to "Productivity effect".

Table 2: List of assumptions

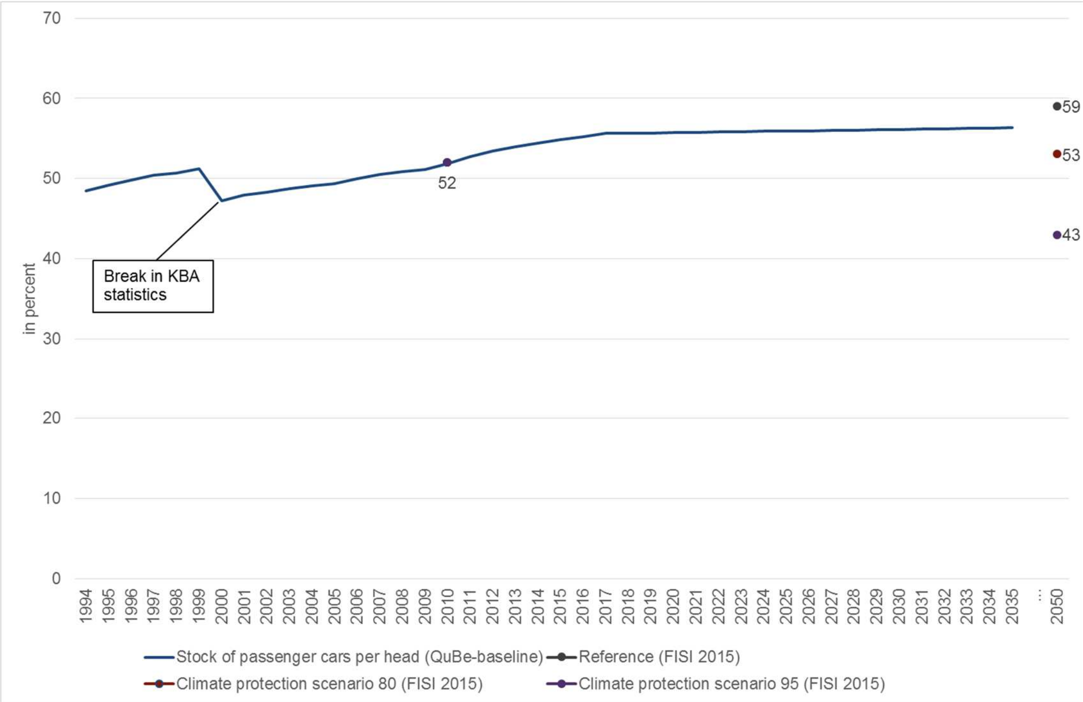
	Assumption	Sub-scenario
1	Degree of motorization	-/-
2	Market penetration	-/-
3	Export	-/-
4	Investment need automotive industry	Electromobility_4
5	Infrastructure 1 – Charging station	Electromobility_4-5
6	Infrastructure 2 – Power system	Electromobility_4-6
7	Import demand of e-cars	Electromobility_4-7
8	Intermediate imports of batteries	Electromobility_4-8
9	Cost effect 1 – Battery	Electromobility_4-9
10	Cost effect 2 – Chemistry	Electromobility_4-10
11	Cost effect 3 – Plastic	Electromobility_4-11
12	Cost effect 4 – Electronic	Electromobility_4-12
13	Cost effect 5 – Further education	Electromobility_4-13
14	Cost effect 6 – Supply industry	Electromobility_4-14
15	Fuel demand 1 – Private households	Electromobility_4-15
16	Fuel demand 2 – Commercial demand	Electromobility_4-16
17	Productivity effects automotive industry	Electromobility_4-17

Source: QuBe-project

3.1 General assessment - assumptions 1 to 3

The **degree of motorisation** - measured on the basis of the population of passenger cars - is used as an important influencing factor for the future achievement of e.g. CO2 emission reduction targets, especially in climate studies (FISI 2015). However, since electrification of the powertrain does not per se imply a change in driving behaviour or even in the demand for motor vehicles, we also assume that there will be no change in the degree of motorisation compared with the reference scenario. This assumption also means that there will be no change in the mobility behaviour of private and commercial consumers of vehicles beyond that assumed in the QuBe baseline scenario. As Figure 5 shows, the degree of motorization is currently just under 55.6 percent. By 2035 the per capita population will increase slightly and by 2035 it will be 56.4 percent. This means that expectations are below the assumptions of the reference scenario from the FISI study (2015). However, it is well above expectations for the climate protection scenarios calculated for FISI (2015).

Figure 5: Degree of motorization in different reference scenarios

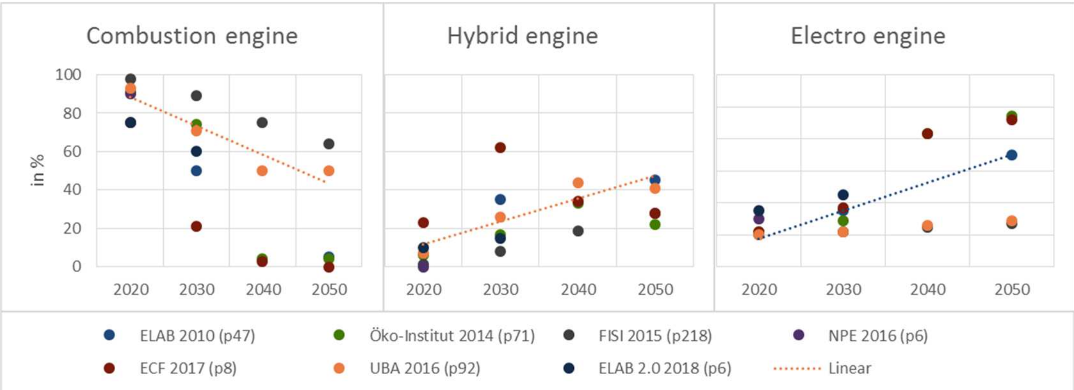


Source: KBA, FISI 2015, QuBe-basline projection

The **market penetration** of electrically powered passenger cars is a decisive assumption for the following analysis, as all other assumptions are based on it. At present, the market penetration of electric vehicles in both new registrations and existing vehicles is very low in Germany (cf. Figure 1). What future market penetration will look like is in fact the result of political, economic, technological and social changes. A mandatory electrical quota - such as that introduced in China, for example, and already discussed at EU level - is currently not foreseeable in Germany. For this reason, the market penetration assumed in the following - which is given exogenously here and does not result endogenously from the model context - is to be seen more as a means to an end for the analysis of employment effects than as the actual determinant. Thus, no prognosis is made for the possibilities of achieving this market penetration, but the effect on the economy and the labour market is considered if an assumed market penetration is achieved.

To derive the assumption regarding the market penetration of electric cars, the assumptions from a large number of studies were collected and combined. Since all studies - similar to the present one - provide an exogenous indication of market penetration, there are usually different target scenarios for market penetration. In the reference scenarios a market penetration is described which could be achieved from today's perspective and without a stronger promotion of electric cars. For this reason, the market shares of electric cars are consistently lower in the reference scenario than in the alternative target scenarios. An overview of the market penetration by fuel type in the reference scenarios is shown in Figure 6. In principle, it becomes clear in all scenarios - albeit to varying degrees - that in the long term the market share between combustion engines and electric motors will shift to the disadvantage of the combustion engine.

Figure 6: Market penetration by fuel type in different reference scenarios

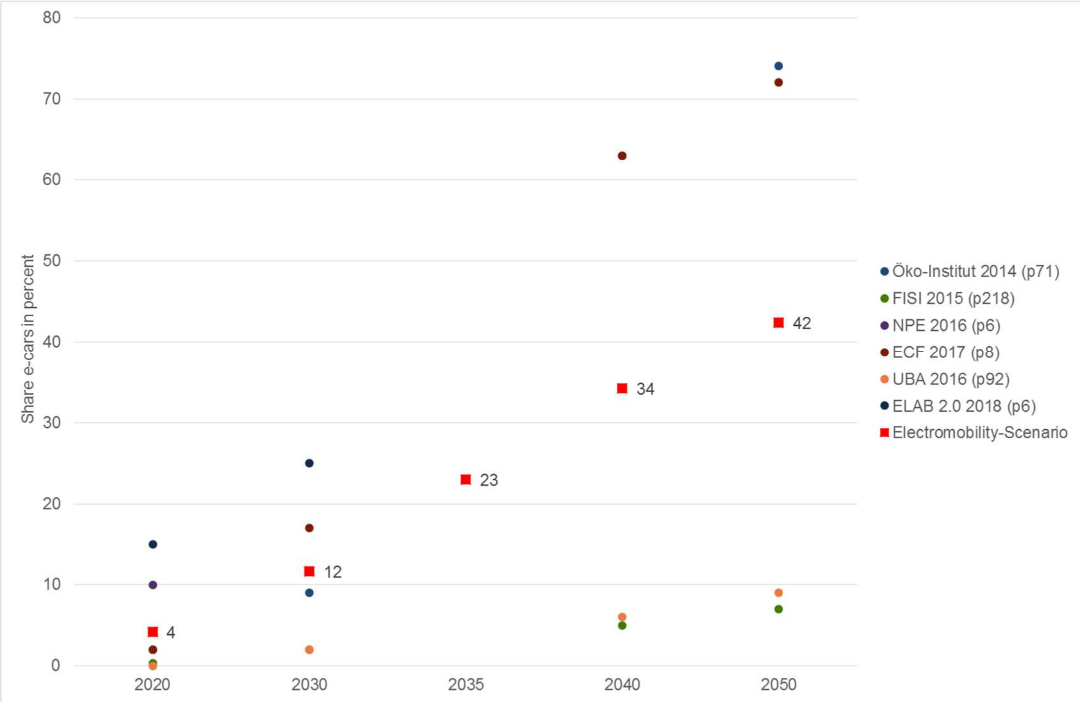


Source: see studies

If an average value is taken over the assumptions, the market penetration of the pure electric drive will be 23 percent by 2035 (see Figure 7).

The studies increasingly diverge in their assumptions as we look further into the future. While the two studies FISI (2015) and UBA (2016) assume only a very weak increase in the market penetration of electric cars of less than 10 percent by 2050, the Öko-Institut (2014) and ECF (2017) believe that a market penetration of over 70 percent is possible. Under the assumptions made here, new registrations of electric cars will reach almost 600,000 in 2035.

Figure 7: Market penetration of electric cars in different reference scenarios



Source: QuBe-project, see studies

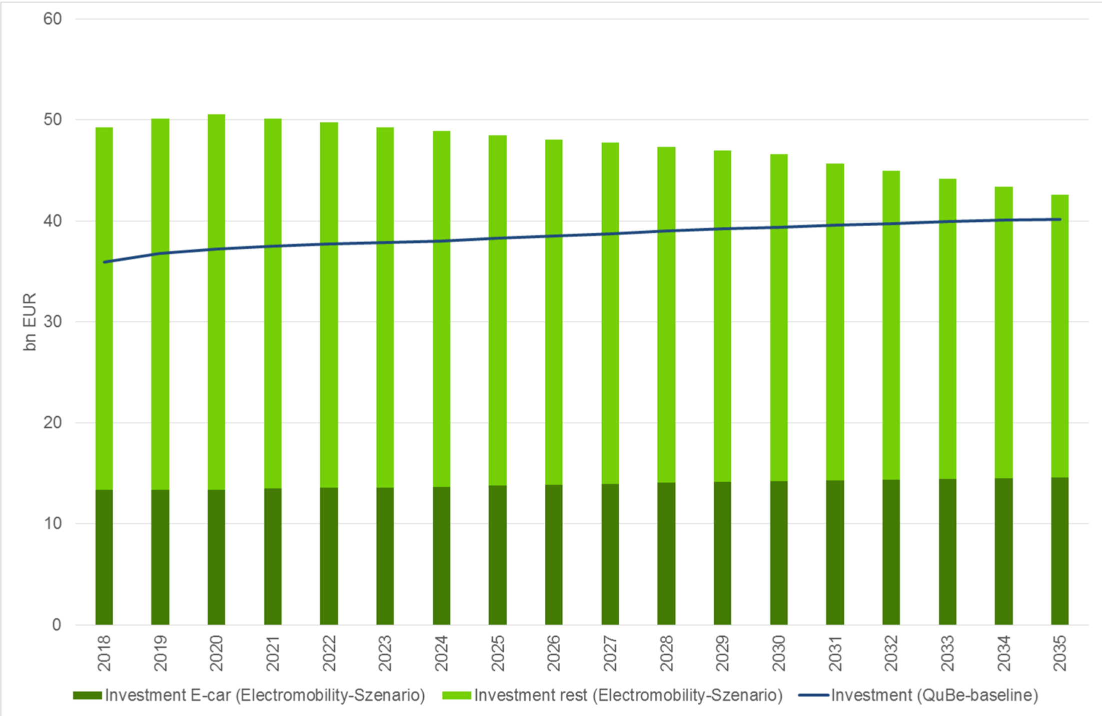
With an **export quota** of 75.5 percent today (Wietschel 2017: 9), around 74,000 electric cars produced in Germany are exported. This means that the export quota for electric cars is similarly high as for burners. According to the McKinsey's Electric Vehicle Index (EVI), Germany holds an 18 percent share of the worldwide production of electric cars. Together with the high export quota, this confirms the image of a leading supplier. For this reason, the present projection does not make any additional assumptions about the (nominal) export development of electric cars. The export volume of motor vehicles will develop along the path given by the basic projection. This assumption is a crucial one for the growth prospects of the automotive industry. If export opportunities would increase (or decrease) due to electrification of the powertrain, Germany could hope for more (or less) growth in the future.

3.2 Investment needs automotive industry

In order to build competence in the manufacture of the electric powertrain, the automotive industry must first invest in research and development. On the other hand, there is a need for investment in the expansion and/or modification of the production platforms so that the electrified vehicles can also be produced. The German Association of the Automotive Industry (VDA) puts the investment requirement of the automotive industry for both at EUR 40 billion for the years 2018 to 2020.

In the scenario, the EUR 40 billion is equally distributed over the years 2018 to 2020 and added to the automotive industry's investments in equipment and other facilities. That is EUR 13.3 billion in additional investments per year.

Figure 8: Investment Needs of the Automotive Industry in the Electromobility Scenario and in the QuBe Base Projection



Source: QuBe-project

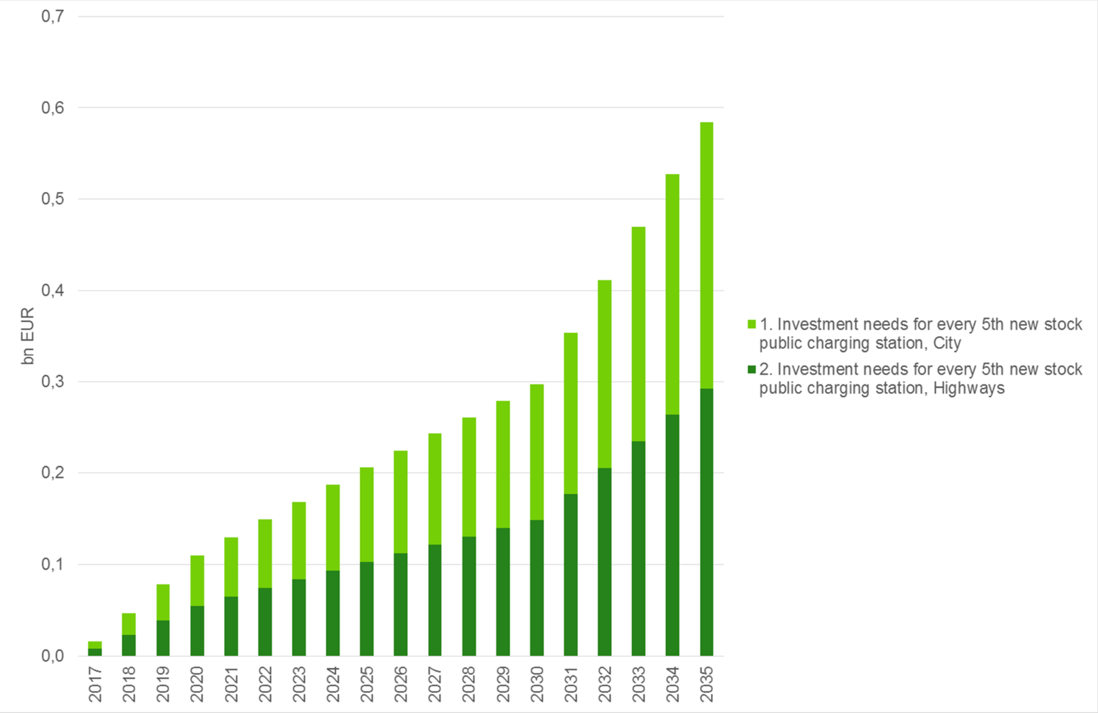
In the following years, investments related to combustion engines will decline in line with the proportionate decline in new registrations. This applies both to research and development activities and to investments in equipment. On the other hand, the investments required for the production of electric cars will continue to rise. In line with the assumed increase in productivity (see chapter Productivity Effect), we assume that investments per electric car will increase faster than investments per combustion engine in the QuBe basic projection. Figure 8 shows that the investment trend will approach the level of the QuBe baseline projection in the long term.

3.3 Infrastructure 1 – charging station

A nationwide charging infrastructure is a prerequisite for the market penetration of electric cars. Accordingly, an assumption must be made about the expansion of the publicly accessible charging stations - normal and fast charging stations.

Currently, the number of publicly accessible charging stations is 11,371, of which about 12 percent are fast-charging columns. With an electric car fleet of 53,861 at present, this results in a ratio of 4.7 - i.e. one charging station for every fifth electric car in the fleet. If there were no additional infrastructure expansion, by 2035 almost 524 electric cars would share a charging station.

Figure 9: Investment needs of charging stations in the electromobility scenario



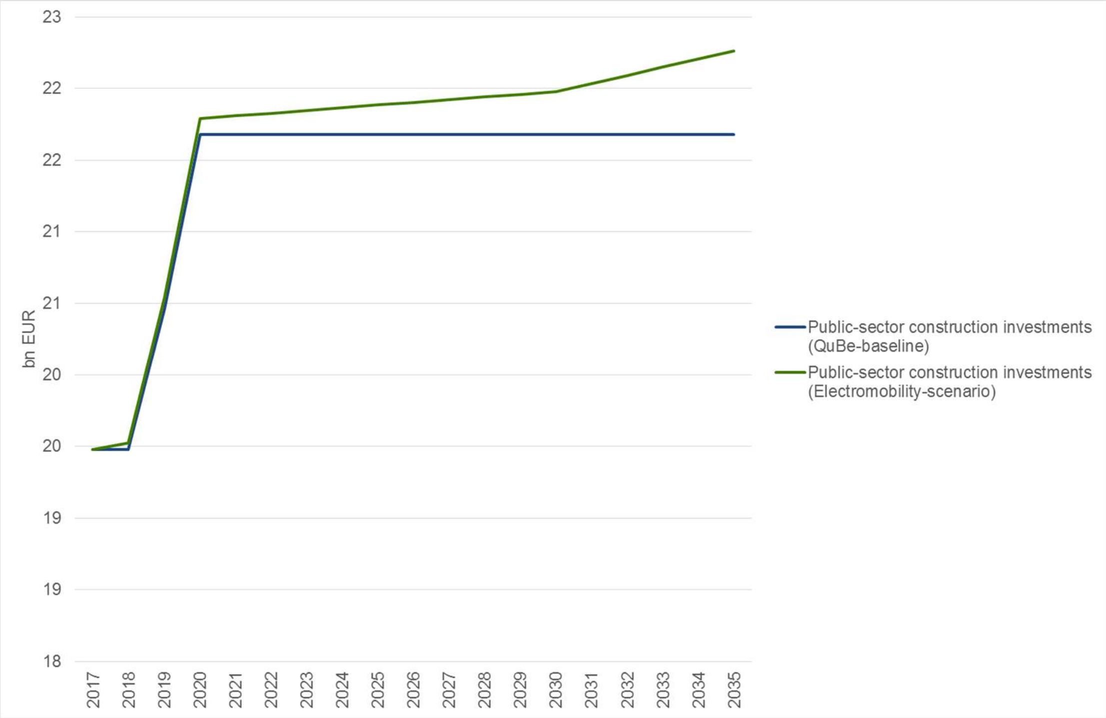
Source: QuBe-project

In order to maintain the ratio of electric car to charging station at 5:1 (ECF 2017: 2016), additional investment is required in the charging infrastructure. The investment requirement arises both in the city to avoid undersupply and on motorways and federal highways to ensure continuous e-mobility. (NPE 2015). Figure 9 shows the estimated investment requirements according to the assumed development of the electric car fleet.

For construction and maintenance, an average of EUR 2,000 per charging station is estimated. The necessary construction investments are borne by the state, since the construction of fast-charging infrastructure is predominantly carried out within the framework of subsidy programmes (NPE 2015).

Figure 10 shows the development of construction investments in the QuBe baseline projection and in the electromobility scenario. This results in cumulative additional investments of just under EUR 5 billion up to 2035. Possibly declining replacement investments at fuel filling stations are not considered.

Figure 10: Public-sector construction investments in the electromobility scenario and in the QuBe basic projection



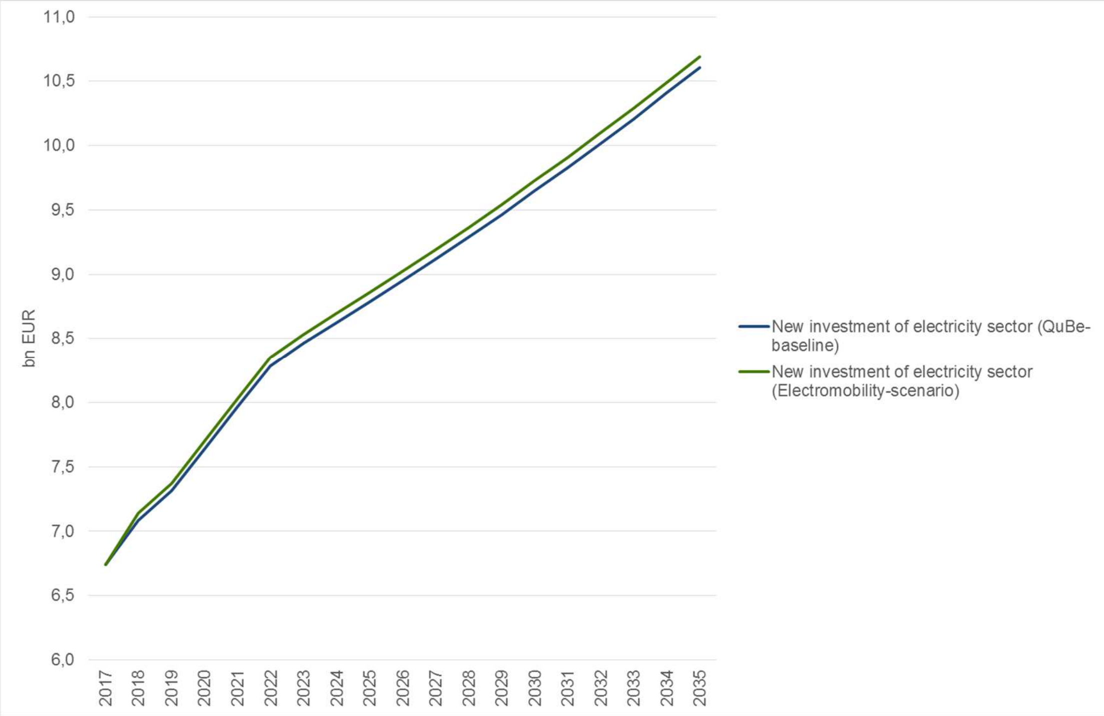
Source: QuBe-project

3.4 Infrastructure 2 – Power system

The market penetration of electric cars requires not only the development of a nationwide charging infrastructure but also the modernisation of the electricity grid. The system load, which would be caused by an (uncoordinated) charging of more and more electric cars, is likely to result in electricity peaks (especially in the evening) and thus "lead to increased capacity requirements on the grid and electricity generation and to high electricity production costs" (ECF 2017: 14). Intelligent charging systems could prevent negative effects on electricity distribution and generation.

In the electromobility scenario, it is therefore assumed that electricity companies are interested in expanding an intelligent charging system. The investment requirement is covered by ECF (2017: 18), which covers a cumulative amount of EUR 1.350 billion until 2035 (cf. Figure 11).

Figure 11: Investment requirements for power system in the electromobility scenario and in the QuBe basic projection



Source: QuBe-project

3.5 Import demand electric cars

The import demand of electric cars is not published by any known database. The imported electric cars are derived from Table 3. From Wietschel et al. (2017: 10) it is known that approx. 98,000 electric vehicles are produced in Germany. Domestic sales amount to around 24,000 cars and are the result of the subtraction of domestic production from the export of electric cars: the additional demand for electric cars must be met - if not satisfied from domestic production - by imports. The Federal Motor Transport Authority (KBA) has published new registration figures by fuel type. In 2017 25,056 new electric cars were registered. The demand for imports is the balance between new registrations and domestic sales. As a proportion of new registrations, the import quota is estimated at 4 percent.

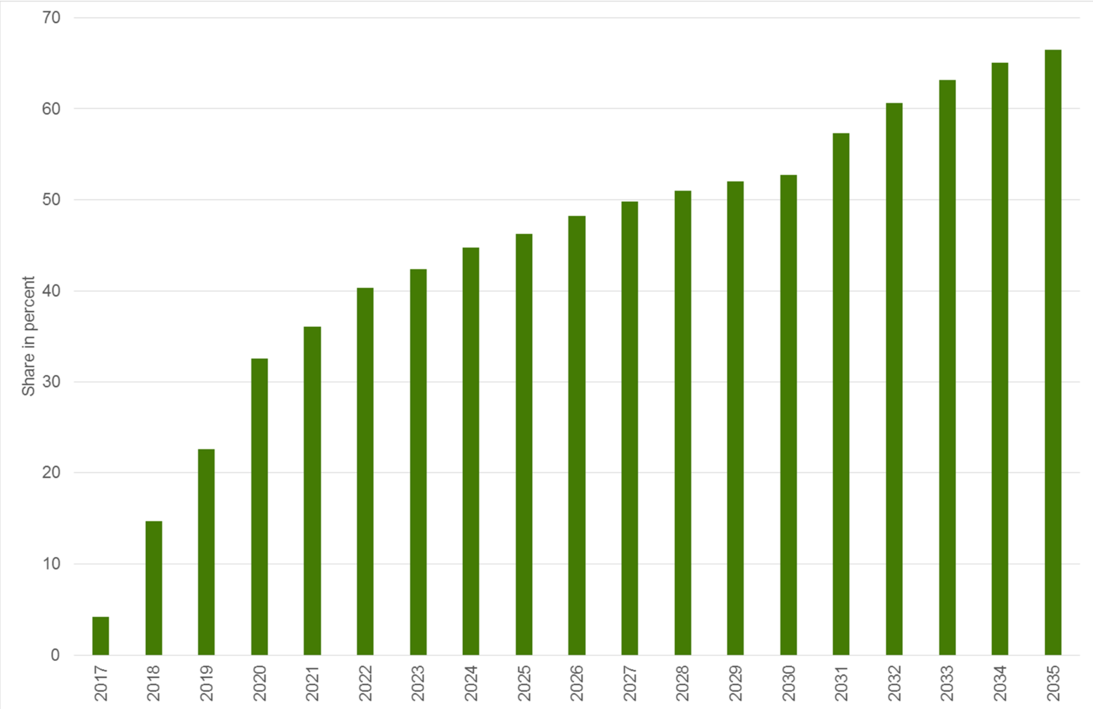
Table 3: Derivation of the import demand and the import quota of electric passenger cars in the electromobility scenario

	2017
E-car production in DE	98.000
Sales of e-car in DE	24.010
Export of e-car in DE	73.990
New registration of e-carin DE	25.056
Import need of e-car	1.046

E-car import share (import/new registration)	4,2 %

Source: QuBe-project

Figure 12: Import quota of electric cars for all new registrations of electric cars in the electromobility scenario



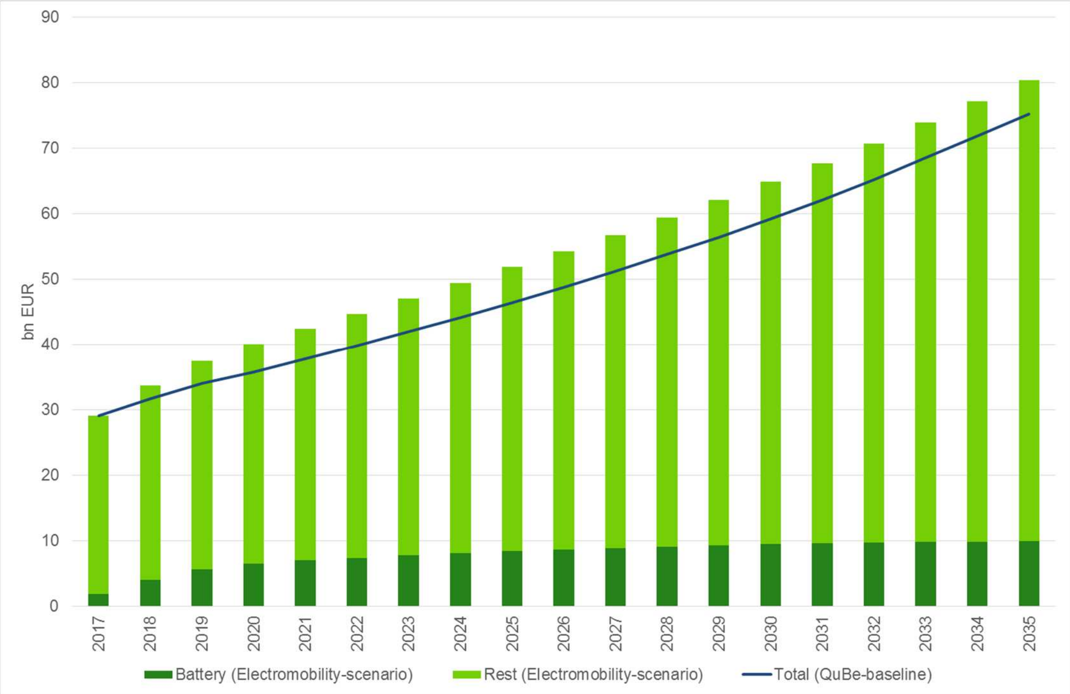
Source: QuBe-project

In the electric mobility scenario, it is assumed that import demand will increase because (as with combustion engines) domestic production minus exports will not be sufficient to cover the rising demand. It is assumed that the import ratio will increase in line with the development of the e-share of new registrations overall. Figure 12shows the import quota for electric cars. The import quota will rise to 66 percent by 2035. This will be roughly at the same level as the import quota for internal combustion engines (2017: 64 %). The share of electric cars in the imports of all motor vehicles will then rise to 31 percent - in 2017 the share was still 0.05 percent.

3.6 Imported intermediate demand of batteries

While the previous assumption related to the import demand of whole electric cars, the following assumption is made regarding the import demand of the battery necessary for the propulsion of electric cars. Traction batteries are needed for the operation of electric cars. Since 2015, there has been no factory in Germany that can produce sufficient numbers of battery cells required for traction batteries (NPE 2016b: 5). Since the traction battery cell accounts for 60-70 percent of the value added of the entire battery pack (NPE 2016b: 5), it has a high system relevance. Domestic production of electric cars will therefore require an increased advance demand for traction battery cells. However, German manufacturers have so far concentrated on the composition of the battery packs. The battery cells must be imported from abroad. Japan, Korea and China are the dominant suppliers.

Figure 13: Preliminary imports of electronic equipment in the electromobility scenario and in the QuBe basic projection



Source: QuBe-project

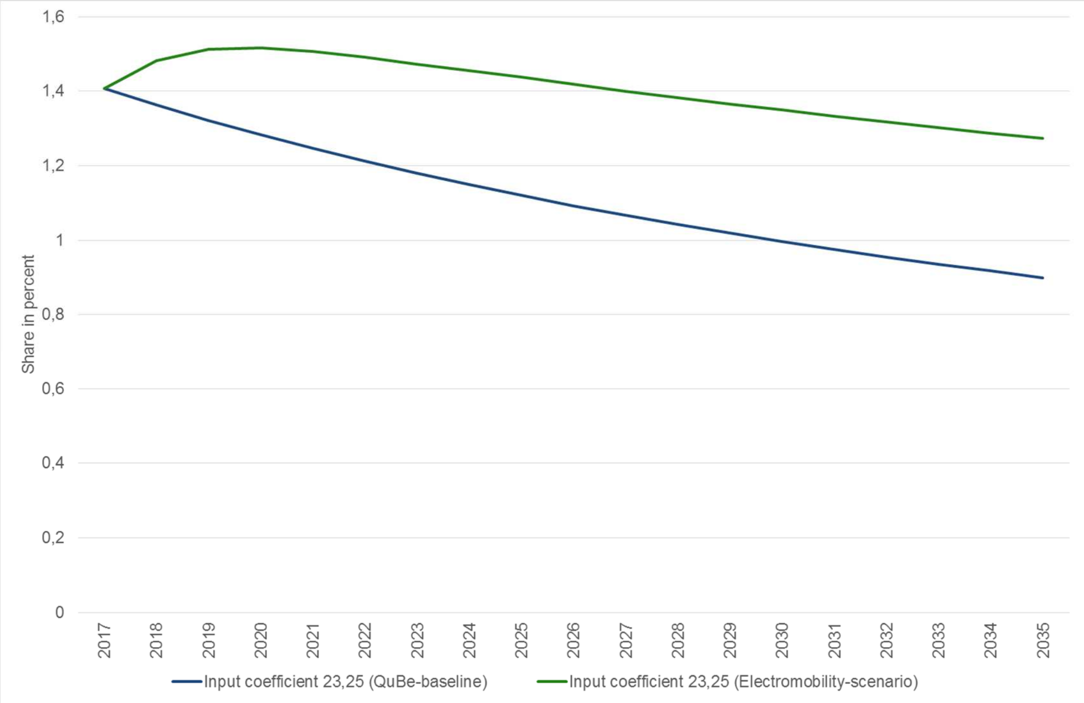
In the classification of economic activities, batteries are classified as electronic equipment (WZ-27). The import share of batteries in total electronic equipment is about 6.7 percent. However, this includes all batteries (and accumulators) and not only traction batteries relevant for electric cars. The import share of electronic equipment is therefore overestimated at 6.7 percent. The import demand for batteries will continue with the domestic production of electric cars. Accordingly, the wholesale imports of electronic equipment are increasing more strongly than in the QuBe baseline projection (Figure 13).

3.7 Cost effect 1 – Battery

Batteries and accumulators belong to the wholesale input of electrical equipment (WZ-27). The automotive industry demands around EUR 5 billion in intermediate consumption from electrical equipment suppliers, which is 1.4 percent of the production value. The entire battery accounts for almost 40 percent of the value added of electric cars

(Wietschel et al. 2017: 11, NPE 2016b: 5). The domestic production share of electric cars in total cars produced in Germany is 1.7 percent.

Figure 14: Input coefficient of electrical equipment on car in the electro-mobility scenario and in the QuBe basic projection



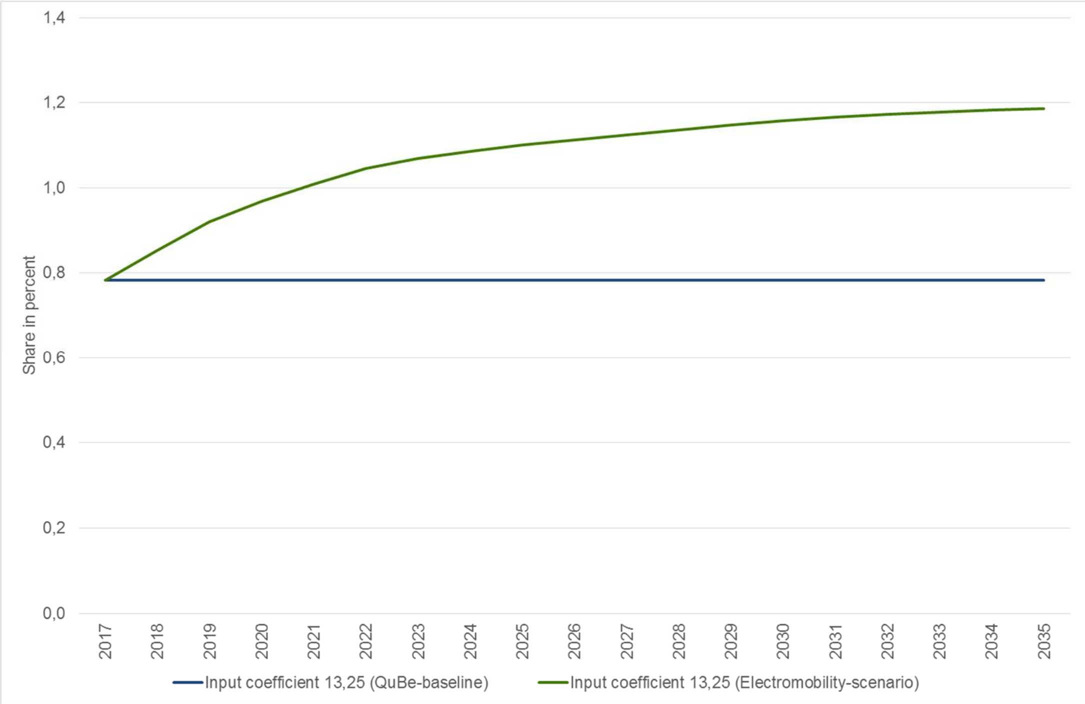
Source: QuBe-project

The future development of the input coefficient of the automotive industry for electrical equipment is based on the domestic production share of electric cars and the value-added share of the battery. As the production share of electric cars increases, the costs also rise with the increase in electric car production. The value-added share of the battery remains constant at 40 percent over the entire projection period. Figure 14 shows the input coefficient in the QuBe base projection and in the electromobility scenario.

3.8 Cost effect 2 – Chemistry

The shift to electromobility will lead not only to the battery but also to further changes in the components required to manufacture a vehicle (ELAB 2012, McKinsey 2011). The additional demand for chemical input is not only the result of the increased use of traction batteries. With the increasing use of an electrified drive train in vehicles, the electricity efficiency of a vehicle is also coming to the fore, to which chemistry can make valuable contributions (VCI 2011). For example, new, chemical-based products can reduce energy requirements for heating (e.g. insulating materials) or cooling (e.g. sun blockers for windscreens) (VCI 2011).

Figure 15: Input Coefficient Chemistry in Cars in the Electromobility Scenario and in the QuBe Base Projection



Source: QuBe-project

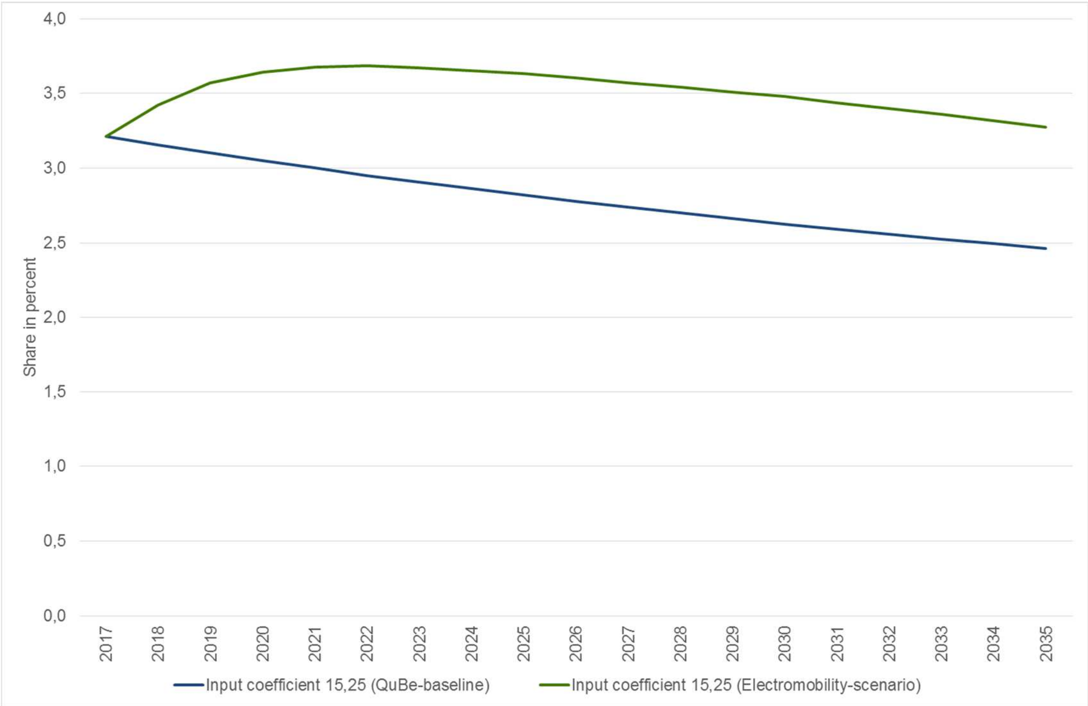
At present, chemical products (WZ-20) of EUR 2.3 billion are required as intermediate consumption by the automotive industry. The input-output table does not show which chemical products are needed by the automotive industry. However, it can be assumed that there will be demand for products such as paints and adhesives, but also for antifreeze agents or basic chemical substances for production. Relative to the production value, this accounts for 0.8 percent. In the electromobility scenario, the input coefficient for chemicals in cars is updated in accordance with the approach in chapter Cost Effect 1 - Battery. Figure 15 compares the course of the input coefficient for the QuBe base projection and for the electromobility scenario.

3.9 Cost effect 3 – Plastic

The production of electric cars will cause a change in the use of materials. In particular, more plastic will be needed in the production of every car (ELAB 2012, ECF 2017 b). On the one hand, this is necessary for the construction of a lighter car body. On the other hand, more plastics are needed to install the battery.

Plastics (WZ-22) are currently required by the automotive industry as intermediate consumption amounting to EUR 11 billion. Relative to the production value, this corresponds to a share of 3 percent. In the electromobility scenario, the input coefficient plastic for cars is extrapolated according to the approach in Chapter 3.7. Figure 16 compares the course of the input coefficient for the QuBe base projection and for the electromobility scenario.

Figure 16: Input coefficient plastic on car in the electromobility scenario and in the QuBe basic projection

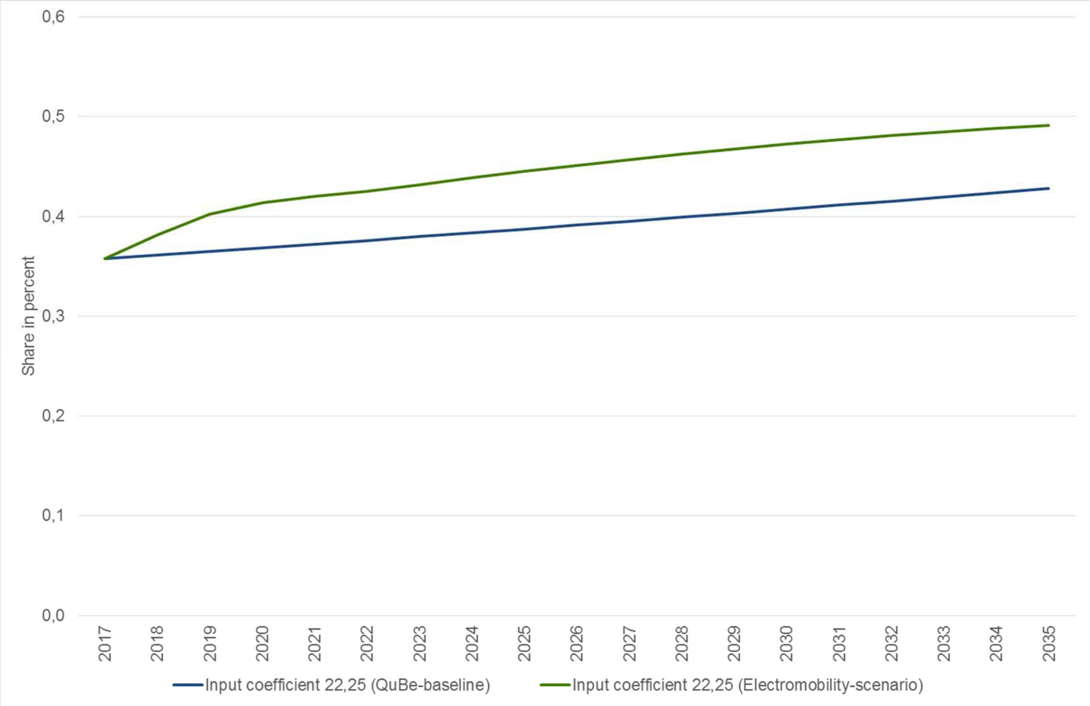


Source: QuBe-project

3.10 Cost effect 4 – Electronics

Compared to cars with a combustion engine, electric cars will contain more electronics and in particular power electronics (Wietschel et al. 2017: 23). Electronics (WZ-26) is required by the automotive industry in the amount of EUR 1 billion as intermediate consumption. This corresponds to 0.4 percent of the production value. In the electromobility scenario, the input coefficient electronics for cars is updated in accordance with the approach in Chapter 3.7. Figure 17 compares the course of the input coefficient for the QuBe base projection and for the electromobility scenario.

Figure 17: Input coefficient electronics on car in the electromobility scenario and in the QuBe basic projection



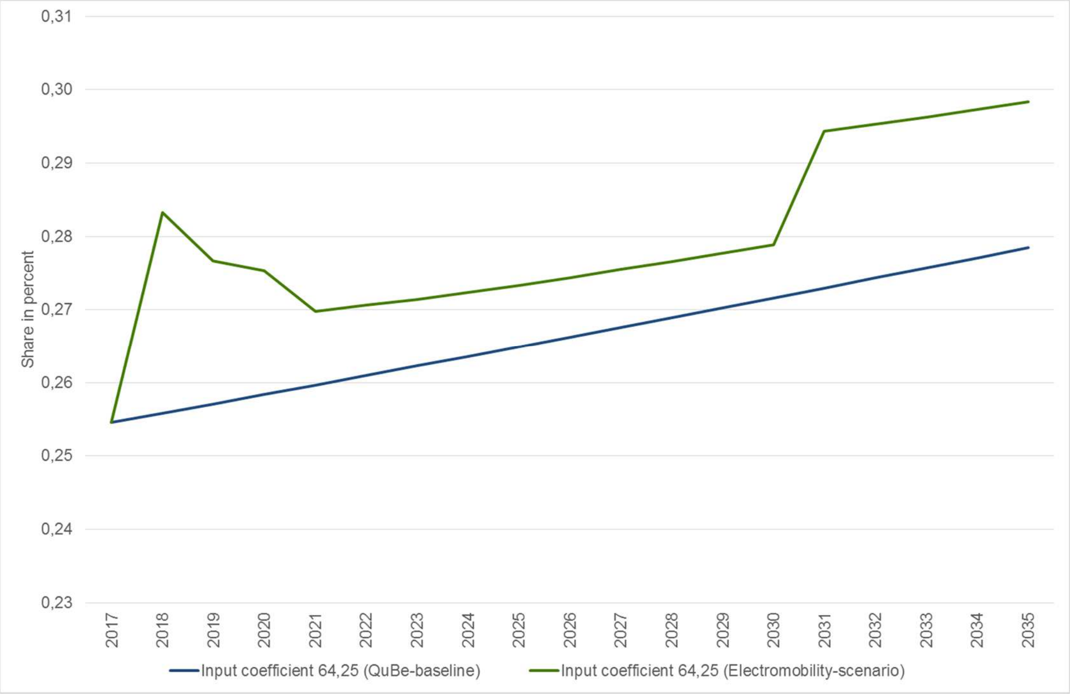
Source: QuBe-project

3.11 Cost effect 5 – Further education

For the production of electric cars, specific further training and education of the employees is necessary (ELAB 2012). A shift in qualification requirements is to be expected (McKinsey 2011), which cannot only be covered by the recruitment of new employees. This also means that existing employees will have to be trained in the new production processes. To date, the automotive industry has spent EUR 1 billion on training services (WZ-85). Relative to the production value, this corresponds to a share of 0.25 percent.

In the projection for the estimation of future further training measures within the automotive industry, it is expected that 23 percent of employees will have received further training by 2035 - corresponding to the e-share of new registrations. The development corresponds to the change in the e-share of new registrations. Assuming an estimated further training cost of EUR 718 per person (FSO 2013), additional costs of EUR 7.5 billion will be incurred over the entire forecast horizon. Figure 18 compares the development of the input coefficient for the QuBe basic projection and for the electromobility scenario.

Figure 18: Input coefficient for continuing education on cars in the electromobility scenario and in the QuBe basic projection



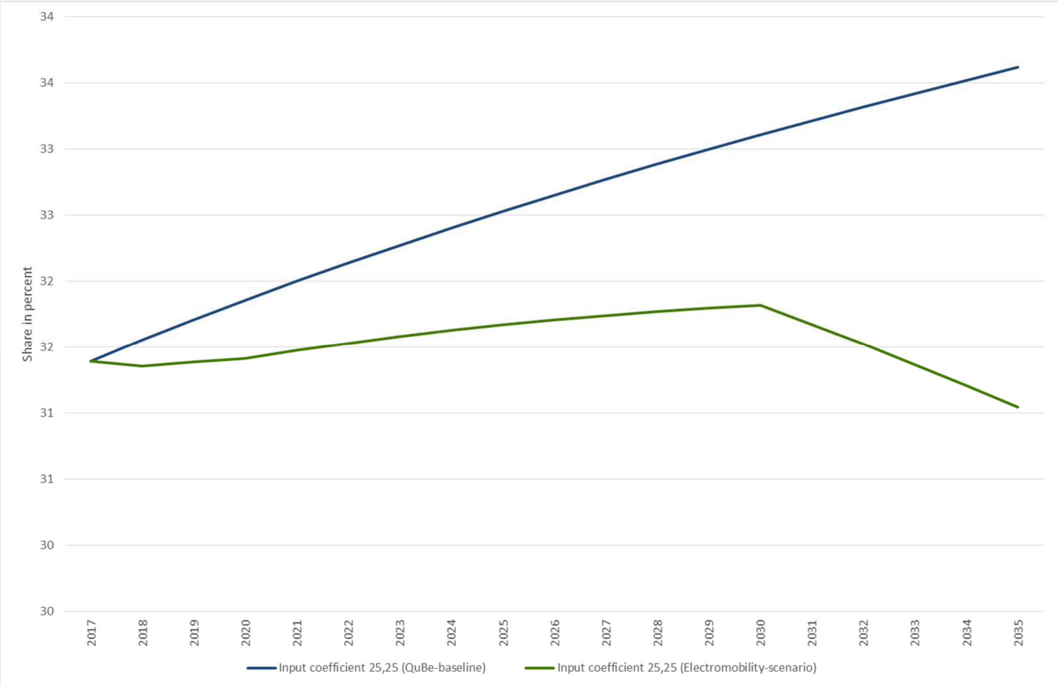
Source: QuBe-project

3.12 Cost effect 6 – Supply industry

The automotive industry not only has strong links with other sectors through intermeidate demand, it is also one of the sectors with the highest level of internal supply integration, at over 30 percent. The automotive industry is divided into original equipment manufacturers (OEMs) and suppliers.

The latter can be divided into Tier-1 and Tier-2/3 types, the difference being whether they are direct suppliers to OEMs (Tier-1) or not (Tier-2/3). According to the classification of economic activities (WZ-2008), car manufacturers are classified in branch 29.1 ("Manufacture of motor vehicles and their engines"). The basic characteristic for this classification is the ability to manufacture engines and (whole) motor vehicles. The automotive suppliers belong to WZ-29.3 ("Manufacture of parts and accessories for motor vehicles"), which manufactures essential parts and components for the automotive industry. These include components that are independent of the powertrain, such as alternators, window regulators, axles or airbags. However, suppliers in particular also supply drive-dependent parts and accessories (exhaust pipes and poppets, radiators, clutches or catalytic converters) that are no longer needed in electric drive trains.

Figure 19: Input coefficient car to car in the electromobility scenario and in the QuBe basic projection



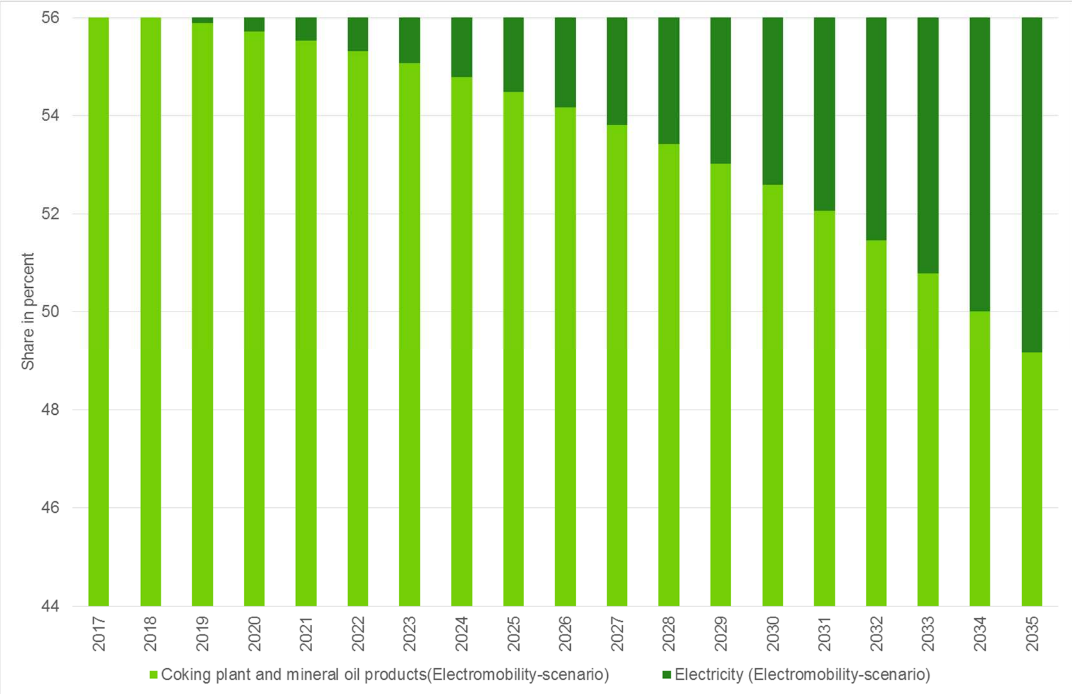
Source: QuBe-project

The input-output table does not distinguish between manufacturers and suppliers, which is why the interdependence between WZ-29.1 and WZ-29.3 is not known. Nevertheless, the change into the age of electromobility is also a change that will particularly change the interdependence within the sector: On the one hand, manufacturers are likely to have an intrinsic interest in maintaining a particularly high level of competence in the manufacture of electric cars. On the other hand, the proportion of valuable components in electric cars is significantly lower than in burners. This applies in particular to the gearbox, which is highly complex for combustion engines but very simple for electric motors (ELAB 2012: 24). But the number of components required for vehicles with combustion engines alone also exceeds the number of components required for vehicles with electric engines. Thus, it can be concluded that the internal interdependence of the industry will decrease with the electrification of the powertrain. Figure 19 shows the (price-adjusted) input coefficient of the QuBe base projection and the electromobility scenario. Taking into account the productivity gap and the shift in the share of new registrations between burners and electric cars, the proportion of intra-industry advance deliveries will decrease compared to the QuBe base projection.

3.13 Fuel demand 1 – private households

In the electric age, petrol and diesel are increasingly being replaced by electricity. So far, private households have spent 56 percent of their expenditure on "goods and services for the operation of private vehicles" on the purchase of "coking plant and mineral oil products". "Electricity" is not yet in demand for this purpose.

Figure 20: Distribution of use "operation of private vehicles" between mineral oil and electric current in the electro-mobility scenario



Source: QuBe-project

Since the electromobility scenario does not assume any change in the degree of motorization, the fuel requirement will also remain unchanged in principle. However, the composition of the fuel requirement will change: Electric power is also increasingly being used as an operating medium for private vehicles. This shift will take place by shifting the share of the consumption matrix between the groups of goods mineral oil and electricity while maintaining the same total share (56 %). Accordingly, private demand for coking plant and petroleum products will be lower and private demand for electricity stronger than in the QuBe baseline projection.

Figure 20 shows the share shift. According to this, the 56 percent share previously spent on coking plant and mineral oil products alone will fall by a good 7.5 percentage points to 48.5 percent by 2035. The share loss will be fully distributed among the proportionate demand for electricity.

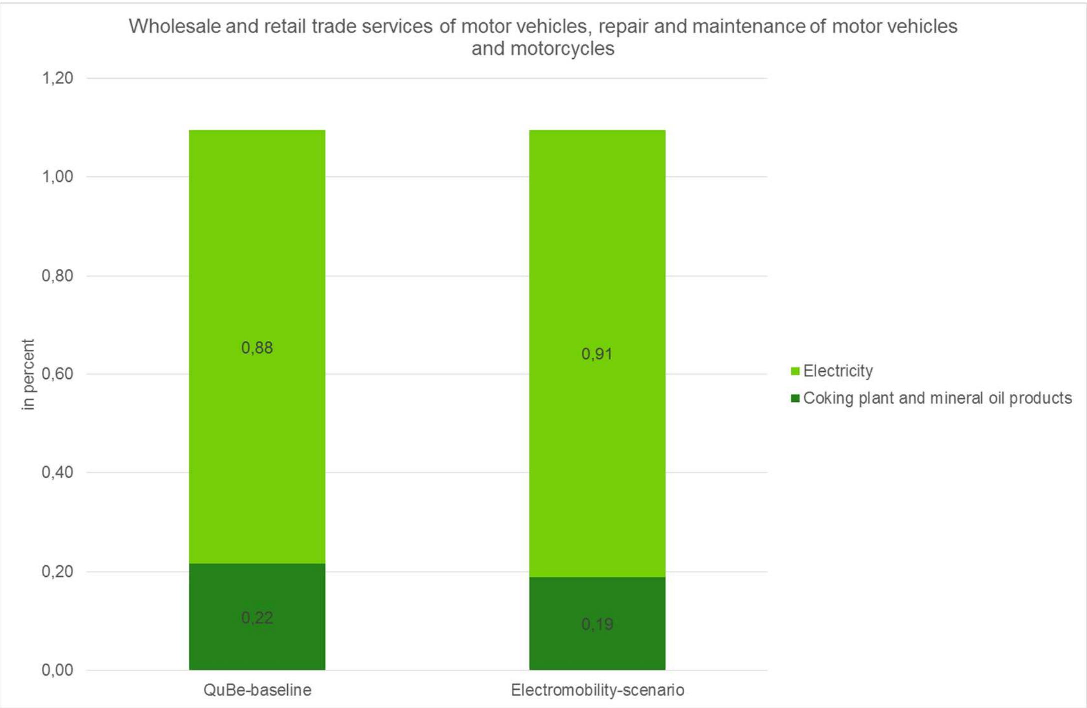
3.14 Fuel demand 2 – Commercial

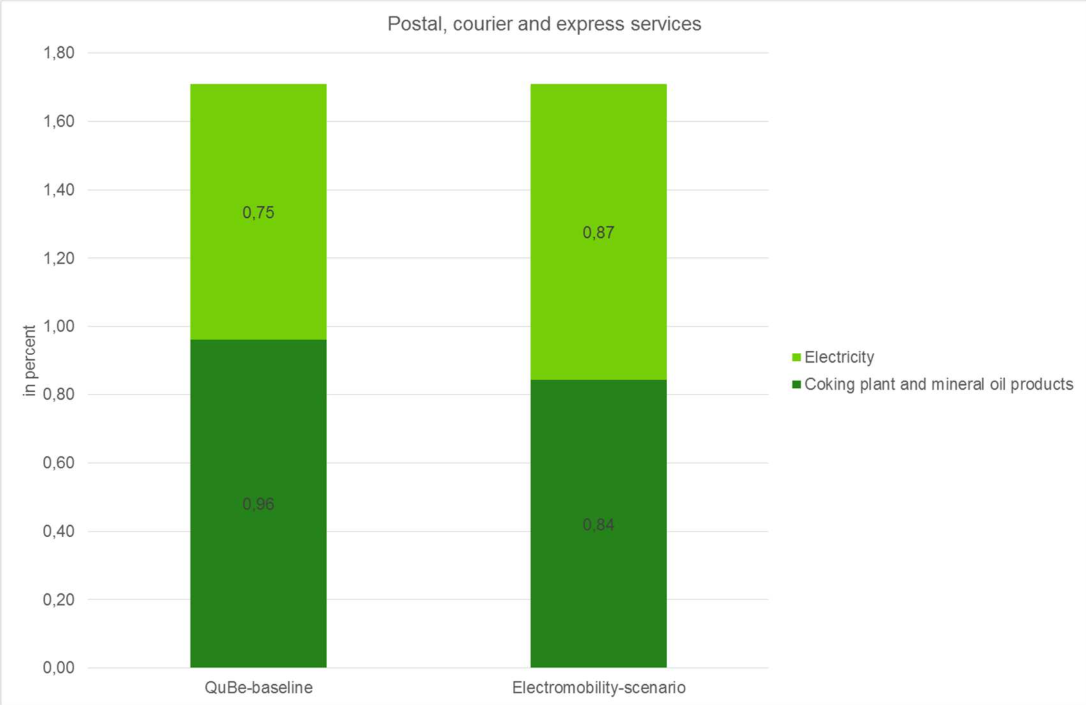
Similar to assumption fuel demand 1 - private households, the industry will also convert to electric cars and accordingly fill up with more electricity and less mineral oil. This will require an adjustment of the wholesale structure. The assumption is that only the service sector will be affected, as electric cars are the main type of vehicles used here. The manufacturing industry also needs mineral oil for its production processes and not only as fuel for transport.

The service sector begins with the trading sector. Aviation is excluded from this sub-scenario because it is assumed that it will not switch to electricity as fuel within the forecast horizon. For all other areas of the service sector, it is assumed that the real input coefficient - i.e. the ratio of input to production - of mineral oil will follow the decline in the share of new registrations of non-electric cars. The input coefficient for electricity increases accordingly by the declining share.

Figure 21 illustrates for two sectors how the input coefficients will differ in 2035. For the area of trade performance with motor vehicles, the QuBe base projection for 2035 shows a relative input of electricity of 0.88 percent and of 0.22 percent for mineral oil. In the electromobility scenario, the electricity input for the same sector will increase to 0.91 percent, while the use of mineral oil will fall to 0.19 percent relative to the production value. A similar development is foreseeable for the postal, courier and express services sector.

Figure 21: Shift of the real input coefficients coking plant and mineral oil and electricity according to two selected sectors in the electromobility scenario in 2035





Source: QuBe-project

3.15 Productivity effect

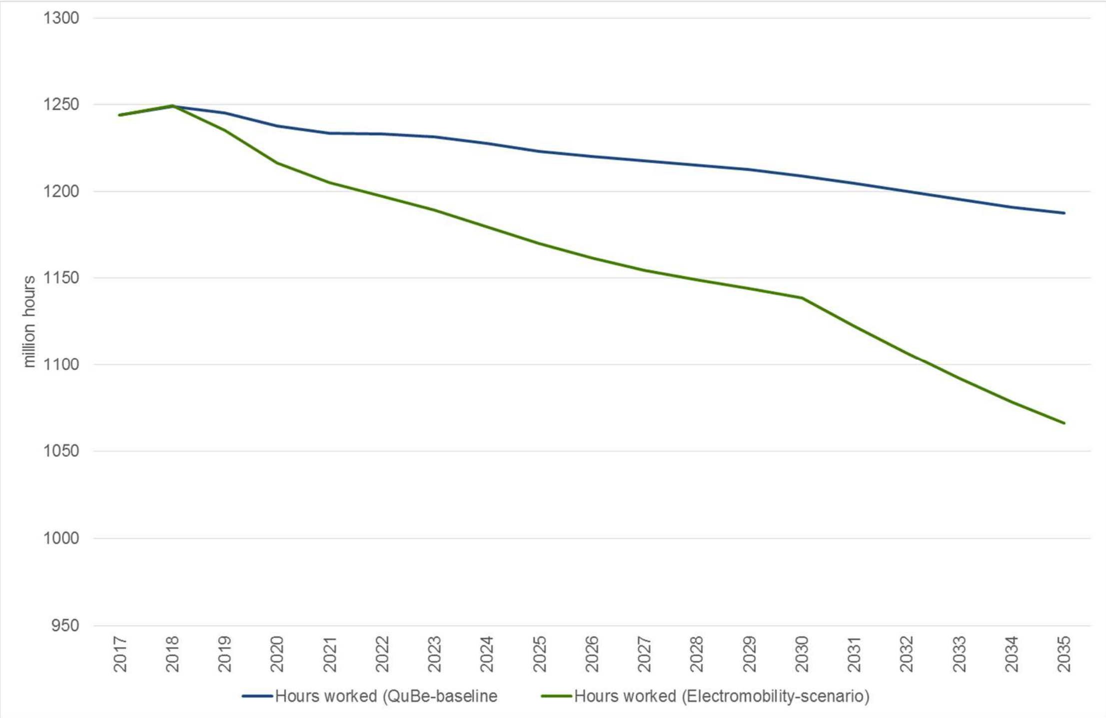
So far, the average annual increase in labour productivity in the automotive industry has been 4 percent. In the QuBe baseline projection, it weakens significantly to just over 1 percent p.a. The switch to the electric drive train can have an effect on productivity via two different channels. On the one hand, the production of electric cars is less labor-intensive than that of a car with a combustion engine alone, because significantly fewer components are installed and the complexity of the drive train is reduced. According to ELAB (2018), the assembly of a car running with a combustion engine requires 20 working hours. For an electric car, an average of 15 working hours is required. This makes the production of an electric car 25 percent or 5 working hours faster than the production of a combustion engine.

It can also be assumed that, in addition to the pure component effect, the efficiency of the production of electric cars can also be increased as time progresses. This productivity effect must also be considered. For this purpose, the assumptions of ELAB (2018) are used, which assume a 50 percent higher productivity increase for electric cars compared to burners.

Taking into account the two productivity effects and the shift in the share of new registrations in favour of electric cars, a lower volume of work for the vehicle industry than in the QuBe baseline projection is required, as shown in Figure 22. Due to productivity reasons, fewer working hours will be worked in the vehicle industry in the long term.

By 2035, 120 million working hours will be lost in this industry, which corresponds to around 10 percent of all hours worked.

Figure 22: Work volume of the vehicle industry in the electromobility scenario and in the QuBe basic projection



Source: QuBe-project

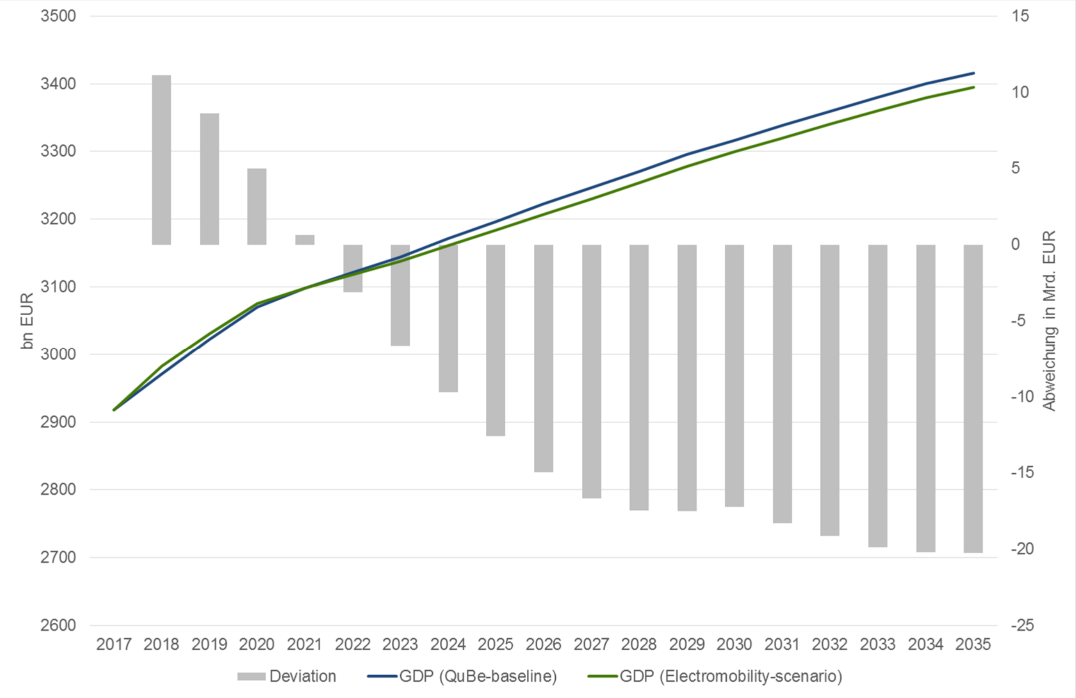
4 Results

The assumptions presented are implemented simultaneously in the QuBe model (Maier et al. 2016, Maier et al. 2018), so that the effects can be analysed. The results can be presented according to their partial results and in their overall effect on different sizes of the macroeconomic model. In the following, the effects on real GDP growth and its components, as well as on the total number of employed persons by economic sector, occupation and requirement level are described.

4.1 Growth effect

The assumptions made for an increasing electrification of the powertrain of passenger cars lead overall to a lower gross domestic (GDP) level and to an overall weaker growth path of the price-adjusted GDP development (cf. Figure 23). Over time, however, there are fluctuations that have a positive effect on growth, especially at the beginning. It also shows that, despite electrification up to a 23 percent share of new registrations of electric cars by 2035, the growth rates of price-adjusted GDPs will not become increasingly worse. On the contrary, the initially much lower growth rates in the electric mobility scenario will lead to an alignment of the dynamics with the QuBe basic projection. However, the absolute loss of economic power cannot be offset by this. In 2035, the gross domestic product of the economy as a whole will be EUR 20 billion below the level of the QuBe baseline projection. This corresponds to about 0.6 percent of the price-adjusted gross domestic product.

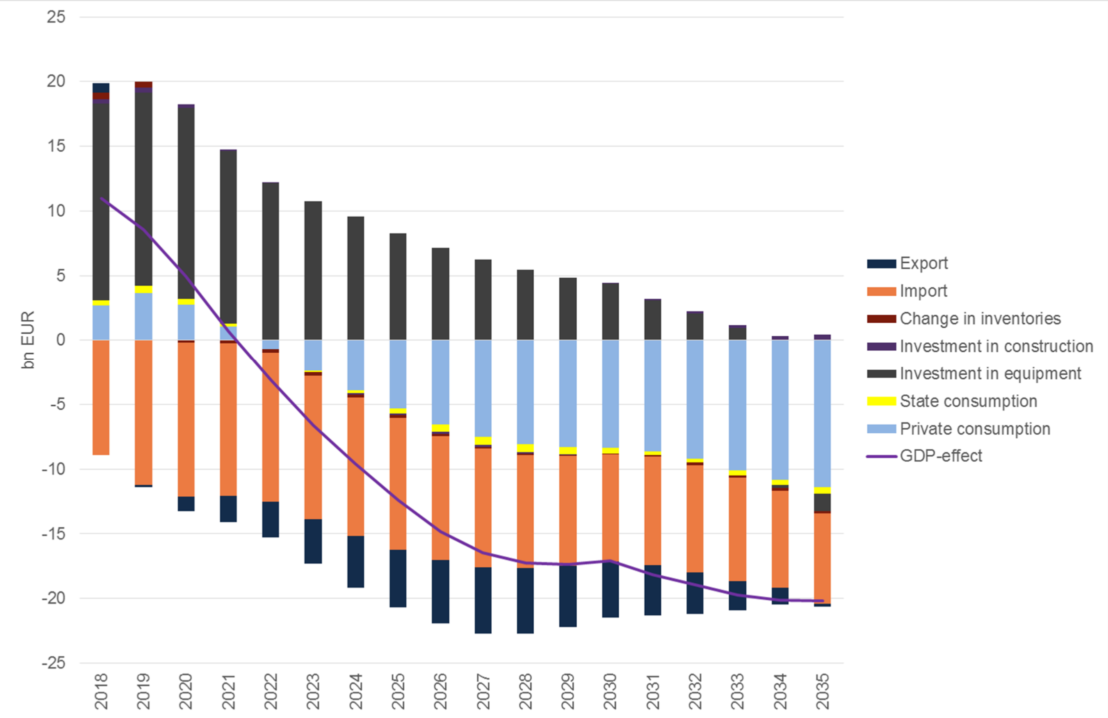
Figure 23: Real Gross Domestic Product in the Electric Mobility Scenario and in the QuBe Base Projection



Source: QuBe-project

Figure 24 shows which of the use-side GDP components is responsible for the macroeconomic growth trend. It is clear that the positive deviations of the GDP trend at the beginning are due to the additional investment needs of the automotive industry. To a much lesser extent, the additional construction investments are also supporting the development. Induced by the positive initial effects, private consumer spending will also make a positive contribution to growth in the early years of electrification via the interrelationship of the cycle.

Figure 24: Components of the real gross domestic product in the electromobility scenario compared to the QuBe baseline projection

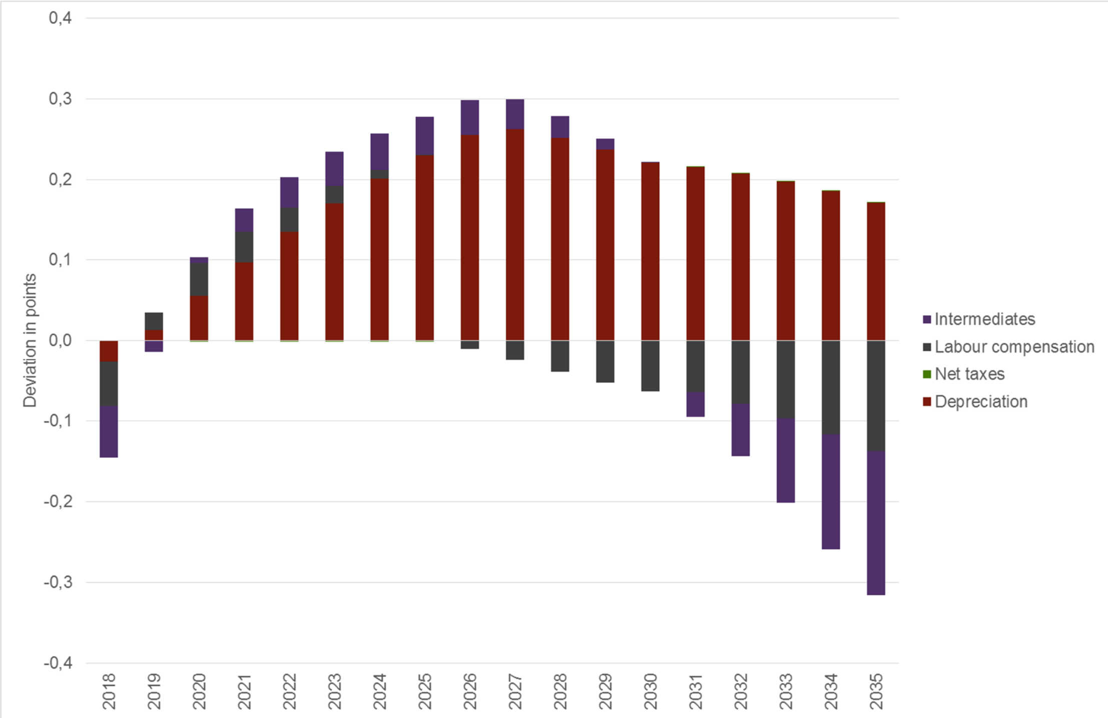


Source: QuBe-project

The predominantly negative effects on GDP result from the high import demand, which is fed both by the import of complete electric cars and the import of traction battery cells. Although no explicit assumptions (see above) have been made about exogenously inflowing nominal exports, price-adjusted exports change due to at least a temporary stronger rise in price levels than in the QuBe baseline projection.

The temporarily stronger rise in price levels is attributable to rising unit costs in the economy as a whole. As Figure 25 shows, it is depreciation and additional material expenses in particular that are driving the rise in costs. However, the adjusted additional expenditure for certain intermediate products is not as high as the increased costs for electronic equipment, chemicals, plastics or further training suggest. The significantly lower internal supply requirements in the industry due to the reduced need for components will have a significant long-term positive effect on the cost of materials. Unit labour costs have a positive effect on the economy as a whole. Although wage increases will also be felt in the first few years in particular as a result of the additional investments, the cost of materials will have a positive effect on the economy as a whole. However, this effect will level off later and, together with the loss of jobs, the overall wage bill will also fall below the level of the QuBe base projection.

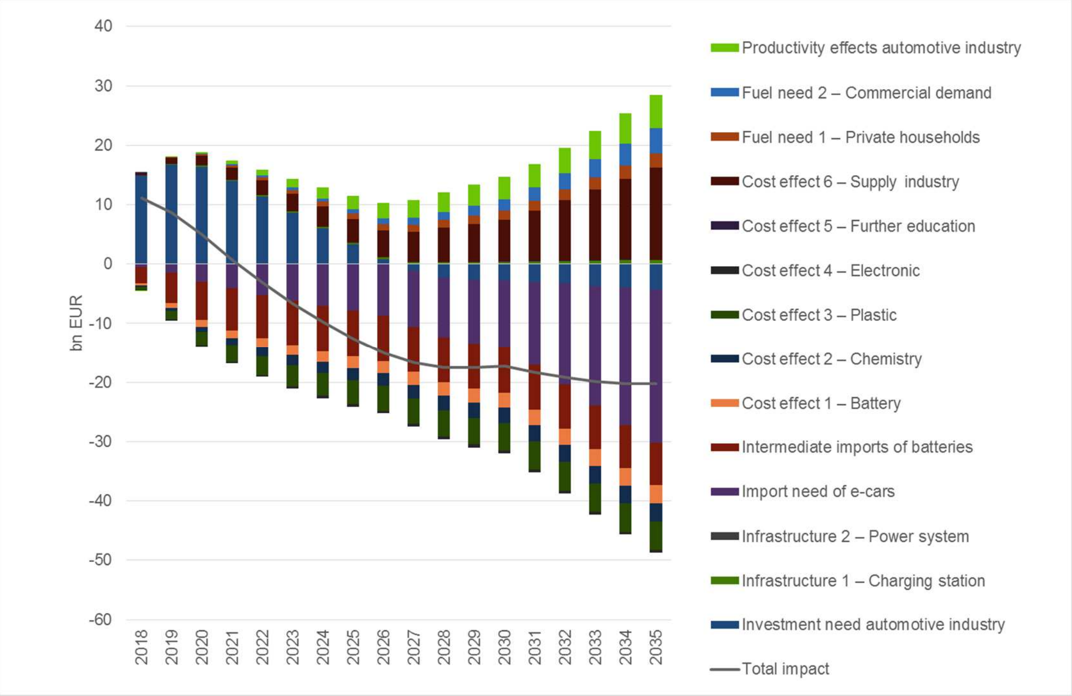
Figure 25: Macroeconomic unit cost components in the electromobility scenario compared to the QuBe base projection



Source: QuBe-project

The growth effect can be broken down into the individual sub-scenarios. Figure 26 shows the individual effects of the 14 quantitative sub-scenarios cumulatively for the price-adjusted GDP. The overall effect (grey line) corresponds to the grey bars in Figure 23.

Figure 26: Real gross domestic product in the respective sub-scenario compared to the QuBe baseline projection



Source: QuBe-project

As was to be expected, the greatest negative effects can be derived from the import assumptions. The negative effect will increase over time as the number of newly registered electric cars increases. With the exception of further training, the cost effects also have a negative impact on GDP. Although the increasing use of intermediate inputs represents additional costs for the vehicle industry, it also induces additional demand in the relevant supply sectors. If these sectors are employment-intensive - such as the education sector - this can have a positive effect on the economy as a whole due to downstream income effects.

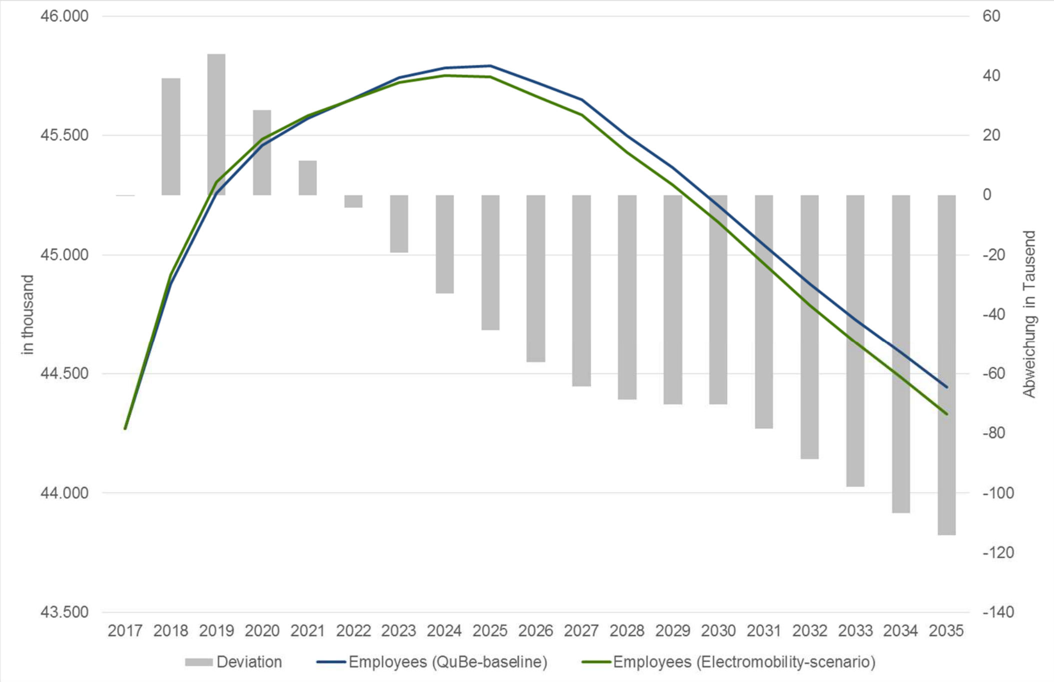
The investments made by the automotive industry, the product assumption made for the industry and the cost reductions for internal deliveries also had a positive impact on the economy as a whole, as did the necessary infrastructure measures.

The change in fuel consumption - both on the part of private households and on the part of the service sector - has a positive effect on GDP. This can be explained by the reduced need to import coking plant and petroleum products.

4.2 Consequences for labour demand

The effects and consequences of the assumptions in the electromobility scenario are also evident in the labour market. Figure 27shows the employment trend compared to the baseline scenario.

Figure 27: Number of persons employed in the electric mobility scenario and in the QuBe basic projection

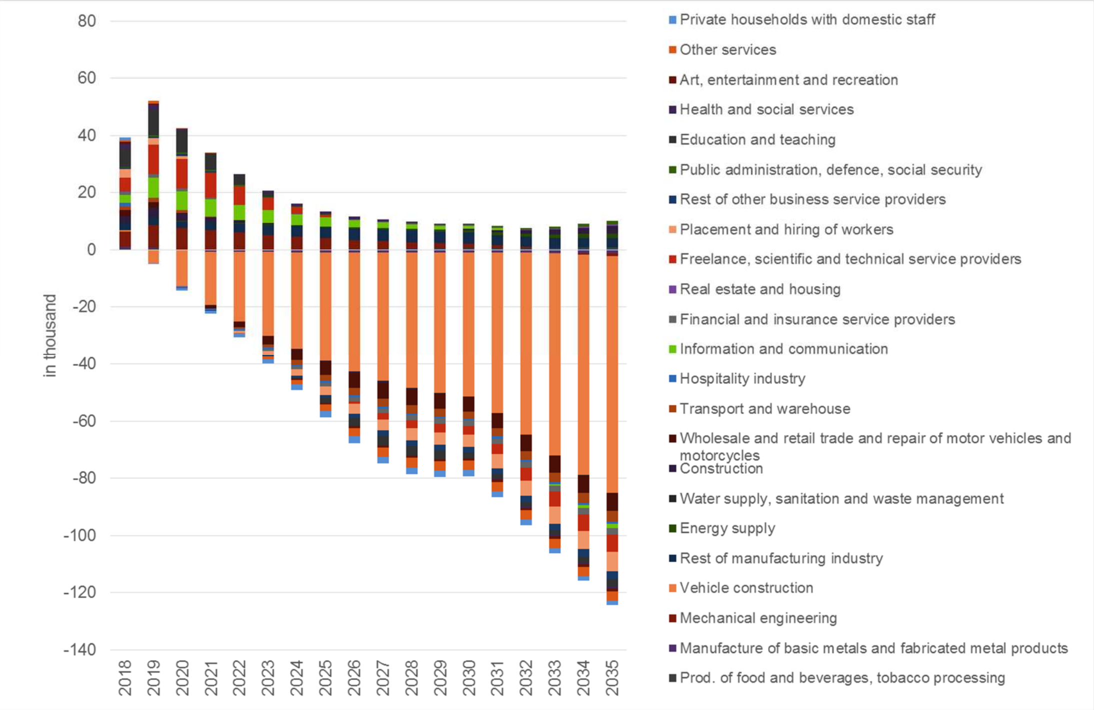


Source: QuBe-project

Accordingly, the employment effect changes its sign as of 2022. Until then, the assumptions made will still have a positive effect on the labour market and the overall employment situation. In 2035, almost 114,000 additional jobs will have been lost due to the electrification of the powertrain. Although this corresponds to only about 0.3 percent of the working population, 10 percent of the unemployed will become unemployed.

The relatively strong employment effect in the economy as a whole is being felt differently in the various sectors. A breakdown by 25, as shown in Figure 28, clearly shows the largest employment losses in the car industry. There alone, 83,000 jobs will be lost by 2035.

Figure 28: Number of employed persons in the electromobility scenario compared to the QuBe basic projection by economic sector

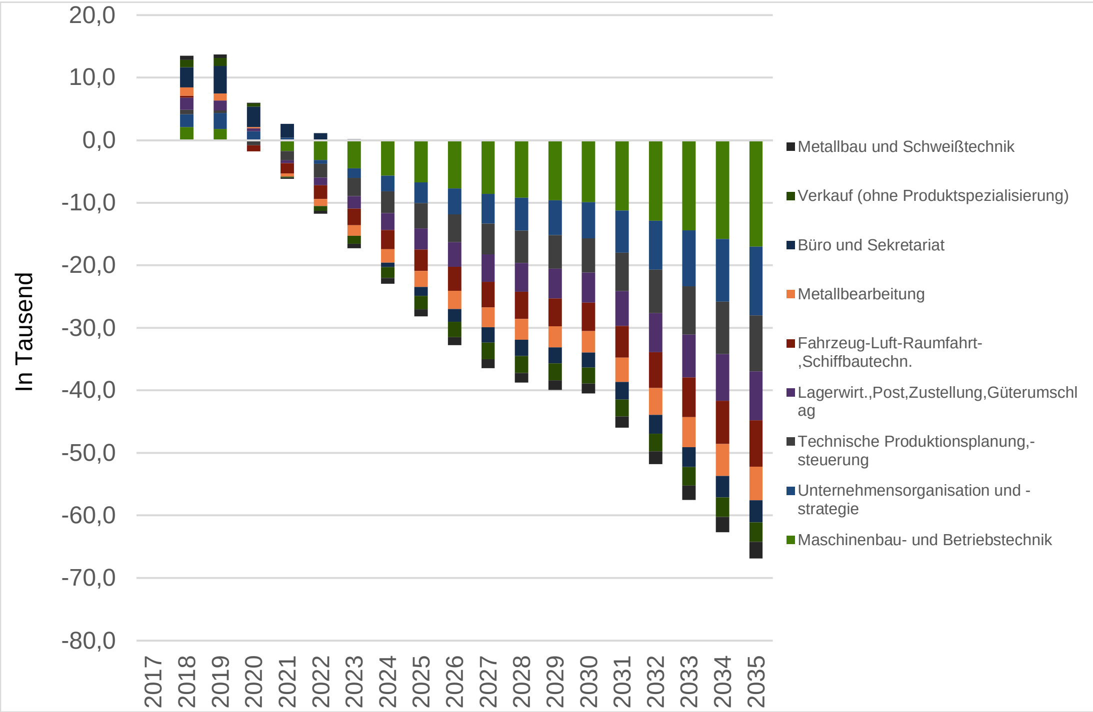


Source: QuBe-project

Slightly delayed due to the high need for investment and the associated higher demand for labour, job losses in this sector will be realised from 2019 due to the high increase in productivity. However, there will certainly be an increase in employment in other **sectors**. These are indirectly related to the investment needs of the automotive industry. Mechanical engineering, for example, will also benefit information and communications technology and other freelancers. Employment brokers, who often work for the automotive industry, will initially benefit from the investments made in the sector, but from 2022 jobs will also be lost for them. The continuing education sector will also provide new jobs in the medium term. Energy suppliers will benefit from the switch to electricity as a means of propulsion and will all be able to create new jobs. In view of the provision of the infrastructure, the construction industry will also see a temporary increase in hiring.

The long-term decline in labour demand is particularly at the expense of the mechanical and automotive engineering occupations and the occupations for technical development and construction of production controls (cf. Figure 29). However, **occupations** in metal production and metalworking are also less needed in the longer term. These are needed even more at the beginning of the scenario calculation than in the QuBe basic projection. However, after investment in new production facilities and processes, these occupations will be less necessary. The same applies to the occupations of company management and organisation, which initially create additional jobs but will significantly cut jobs in the long term.

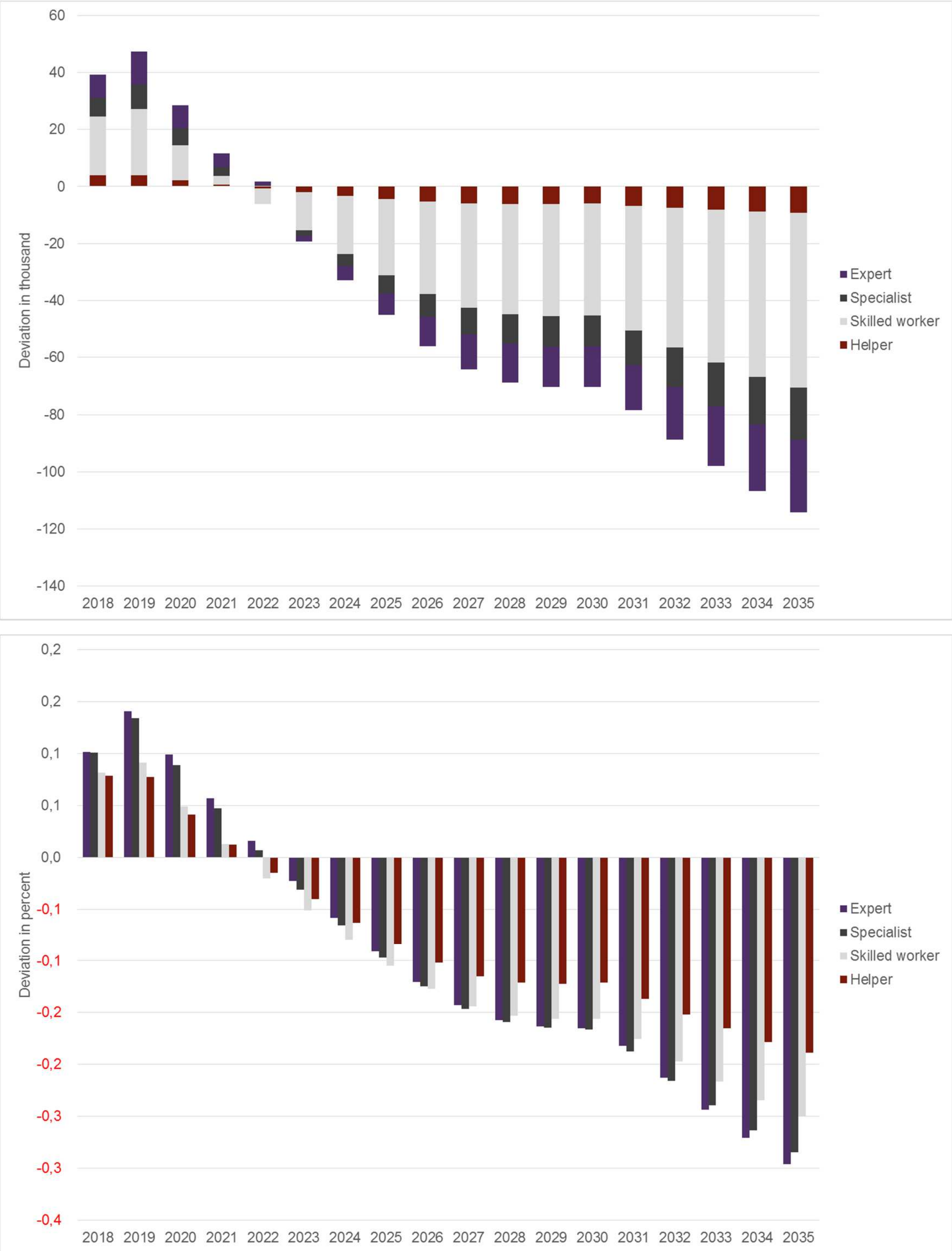
Figure 29: Number of employed persons in the electric mobility scenario compared to the QuBe basic projection by occupation



Source: QuBe-proejct

If employment effects are considered at the level of the **requirement** levels, it can be seen that all requirement levels up to and including 2021 are more in demand. In absolute terms, skilled workers in particular benefit, but a relative analysis shows that specialist and expert activities in particular will benefit in the medium term from the development and expansion phase of the electrification of the powertrain (cf. Figure 30). The turning point in the employment effect will first hit those in employment with a lower requirement level - i.e. helper and skilled workers. It is only one year later that the need for specialists and experts decreases. Then, however, there is an acceleration in the decline in the employment of experts and specialists, which will continue to be more dynamic from 2025 than for helper or skilled workers. One reason for this is the less complex structure of the electrified powertrain in motor vehicles.

Figure 30: Number of employed persons in the electromobility scenario compared to the QuBe basic projection according to requirement level

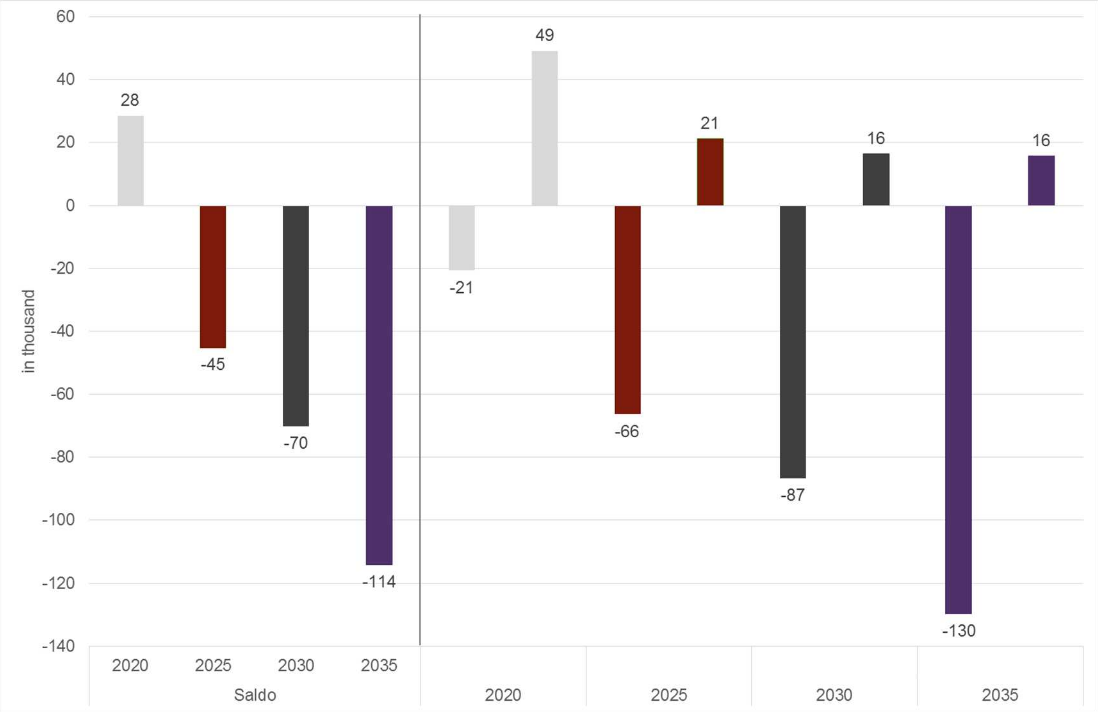


Source: QuBe-project

4.3 Total shift of employed persons

The impact of an electrified powertrain in passenger cars on the overall level of labour demand is relatively strong with a loss of 114,000 jobs in 2035.

Figure 31: Balance and number of jobs set up and dismantled in the electromobility scenario compared to the QuBe basic projection



Source: QuBe-project

This is based on job cuts of over 130,000 jobs, 83,000 of them in vehicle construction alone. At the same time, however, 16,000 new jobs are being created in other sectors (see Figure 31). The total turnover of employed persons resulting from the electrification of the powertrain of passenger cars was therefore almost 150,000 in 2035.

The employment shift is counted when jobs shift in the grid of 144 occupational groups and 63 economic sectors. In contrast to Wolter et al. (2016), the four requirement levels were not used to model the grid. In Wolter et al. (2016) the shift caused by economy 4.0 rises by 12 per cent by taking into account the requirement level, namely to the extent that there are shifts between requirement levels without changing the economic sector and the main occupational group. With a corresponding development, a shift of up to 170,000 jobs could be expected in the present study.

Overall, the job shift is lower compared to other disruptive changes such as economy 4.0 (cf. Wolter et al. 2016: 59ff), as the main loss of jobs is concentrated in vehicle construction and the compensating effects remain limited by job creation in other sectors. This is likely to turn out differently if other assumptions are made regarding the import demand for electric cars and battery cells.

5 Conclusions

The electrification of the powertrain in vehicle construction has already been examined in several studies for its growth and employment effects. The results of the studies vary depending on the chosen method and assumptions.

This contribution fits into the more complex previous studies by using a macroeconomic macroeconometric analysis tool and by performing a net analysis of the employment effects. Differences to the comparative studies result, among other things, from the following points:

- The model can map labour demand not only by sector, but also by occupation and requirement level.
- The bottom-up structure allows industry-specific assumptions to be made.

In order to quantify the electrification of the powertrain using the scenario technique, a number of assumptions had to be made. Possible assumptions were first collected from the literature and then checked for their implementation in the model.

The remaining assumptions were integrated into the overall system one after the other, building on each other, so that a sequential sequence of growth and employment effects was possible. Assumptions specifically relating to the supplier industry (diversification, substitution, competition) were only made in a simplistic way (see section Cost Effect 6 - Supplier Industry). In the current structure, the automotive industry as a whole (WZ-29) can be presented well, but no explicit distinction can be made between manufacturers (WZ-29.1) and suppliers (WZ-29.3).

Overall, the analysis has shown that while both positive growth and employment effects will emerge initially, lower GDP and employment levels must be expected in the long run. While at the beginning the necessary additional investments of the car industry, but also the construction investments in the charging infrastructure and the re-equipment of the power grids will provide positive effects, in the long run the increasing import demand for electric cars and traction battery cells will dominate. With the exception of training costs, the cost effects also have a negative impact on the economy as a whole, but are not dominant. The positive effect of the change in fuel demand - electricity instead of mineral oil - cushions the negative impulses. The productivity-induced growth and employment impulses, which will only take effect in the long term, cushion the largely import-induced decline in economic momentum on the one hand, but on the other hand contribute to the relatively large overall job loss.

Overall, the technology-driven job losses are relatively high. In 2035, around 114,000 jobs will have been lost as a result of the switch to electric drives in passenger cars. Although they make up only about 0.3 percent of the total workforce, they increase the number of unemployed by almost 10 percent. The economy as a whole will make a loss of EUR 20 billion by 2035. This corresponds to approx. 0.6 percent of the price-adjusted gross domestic product.

A sectoral analysis of the employment effects shows that with 83,000 jobs being lost, the largest job cuts in vehicle construction can be expected. Other sectors are also affected and will have to cut over 30,000 jobs. However, 16,000 new jobs will also be created, e.g. in the construction industry, power utilities or in parts of the service sector and manufacturing industry. In 2035, the total turnover of gainfully employed persons resulting from the electrification of the drive train of passenger cars was up to 150,000.

A differentiated picture emerges with regard to the requirement levels. While in the initial and build-up phase of the electrification of the powertrain, auxiliary and skilled workers will initially be negatively affected, specialist and expert activities will only be phased out with a time lag. In the long term, however, the demand for experts and specialists will decrease and the dynamics will exceed the reduction in auxiliary and skilled worker activities.

If one considers that the electromobility scenario "only" assumes an electric share of 23 percent by 2035, it can be assumed that stronger market penetration will lead to significantly higher growth and employment effects. However, the assumptions made here regarding market penetration appear realistic from today's perspective. Import demand is also a decisive factor in the scenario. If Germany were in a position to supply the market both more strongly with domestically produced cars and with domestically produced traction battery cells, a positive growth and employment effect could also be achieved in the long term.

Even though the number of assumptions made in the scenario presented here is already relatively large, there is still a need for further research. This applies in particular to the position of the supplier industry. As mentioned above, the calculation system does not know the difference between OEM (Original Equipment Manufacturer) and Tier-1 suppliers and Tier-2/3 suppliers. The literature expects a considerable shift in the value-added shares due to the electrification of the powertrain, especially in the relationship between manufacturers and suppliers. As a result, the supplier industry could change its customer portfolio and increasingly enter the energy or medical sector. There is also a high probability that competition will intensify, especially in the supplier sector. New players from other sectors (information and communications technology, battery manufacturers, electrical engineering companies) could become competitors. Such developments are currently not reflected in the electromobility scenario.

Moreover, in the current scenario only pure electric cars are considered. Other drive types such as hybrid or gas were not considered separately. If the transition to purely electric cars via hybrid drive were to take place, the job effects would be different in terms of time and absolute dimension. Since hybrid cars have both internal combustion engines and electric motors, a higher number of components are processed. The working time required to build hybrid powertrains is 9.7 hours (AlixPartners 2017). A deeper differentiation according to fuel type would be an even more plausible development, but would also increase the necessary data volume. In principle, the impact analysis expands if other forms of mobility are also included in the analyses (Mergener et al. 2018).

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