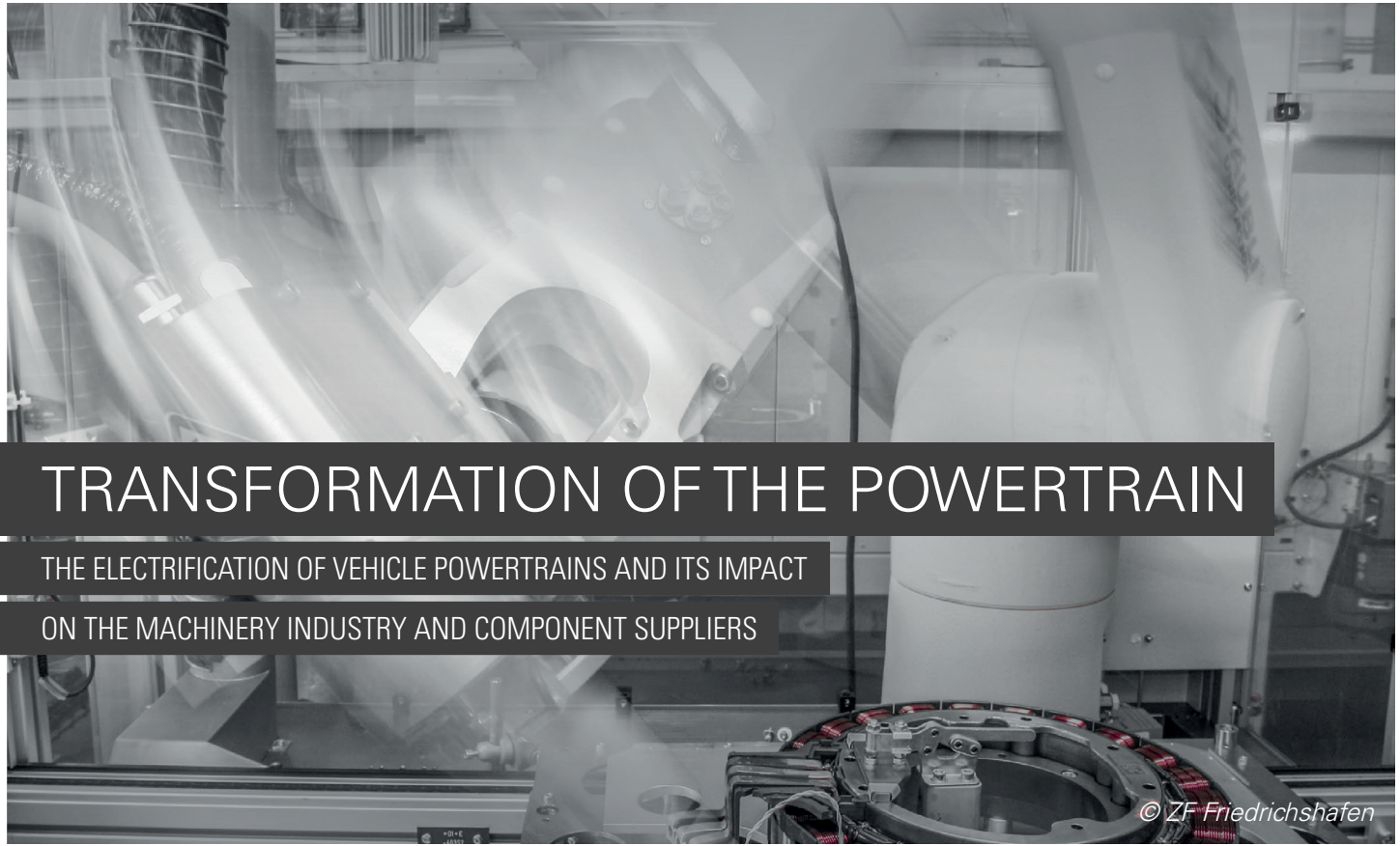


TRANSFORMATION OF THE POWERTRAIN

THE ELECTRIFICATION OF VEHICLE POWERTRAINS AND ITS IMPACT ON THE MACHINERY INDUSTRY AND COMPONENT SUPPLIERS

FEV CONSULTING

VDMA Forum Elektromobilität

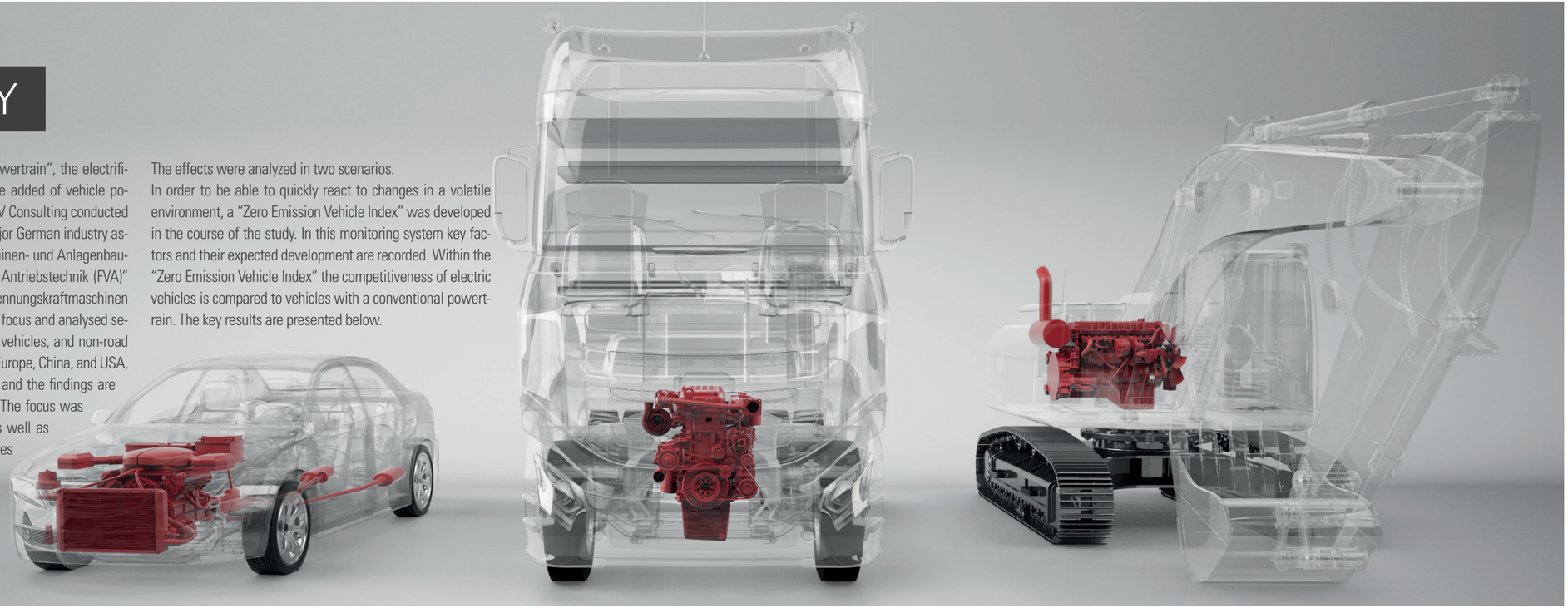
FVA Forschungsvereinigung Antriebstechnik e V

FVV

THE STUDY

In the study „Transformation of Powertrain“, the electrification and its impact on the value added of vehicle powertrains by 2030 is examined. FEV Consulting conducted the study in collaboration with the major German industry associations „Verband Deutscher Maschinen- und Anlagenbauer (VDMA)“, „Forschungsvereinigung Antriebstechnik (FVA)“ and „Forschungsvereinigung Verbrennungskraftmaschinen (FVV)“. Three vehicle categories are in focus and analysed separately: passenger cars, commercial vehicles, and non-road mobile machinery.The three markets, Europe, China, and USA, were considered as leading markets, and the findings are transferrable to subsequent markets. The focus was on the share of electrical vehicles as well as added value and production processes for different powertrain types. By linking these two factors a statement can be made about the change in production processes and their added value in the future powertrain.

The effects were analyzed in two scenarios.
In order to be able to quickly react to changes in a volatile environment, a “Zero Emission Vehicle Index” was developed in the course of the study. In this monitoring system key factors and their expected development are recorded. Within the “Zero Emission Vehicle Index” the competitiveness of electric vehicles is compared to vehicles with a conventional powertrain. The key results are presented below.



IN COLLABORATION

VDMA
Forum Elektromobilität

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TRENDS AND IMPLICATIONS FOR

PASSENGER CAR INDUSTRY

WORLDWIDE MARKET DEVELOPMENT

In 2017 90 million light-duty vehicles have been sold globally increasing to 118 million units by 2030. The three major automotive regions, Europe, USA and China, account for approximately 60 % of the global market. Between 2017 and 2030 vehicle sales are likely to stay constant in Europe and the US. For China and the rest of the world, an annual sales growth between 1.5 % and 4 % is forecasted. Sales of combustion engine based powertrains (including hybrid electric drivetrains) are expected to increase throughout 2025 reaching a maximum of approximately 100 million units, which represents a 12 % increase compared to 2017. In the base scenario sales of combustion engines are expected to reach a plateau between 2025 and 2030 before declining in the long-term. Sales of electric powertrains are expected to increase significantly reaching 20 million units by 2030. This includes almost exclusively battery electric vehicles, while large scale market penetration of fuel cell based drivetrains is only expected for the period after 2030.

GLOBAL LIGHT-DUTY VEHICLES SALES FORECAST IN MILLION UNITS

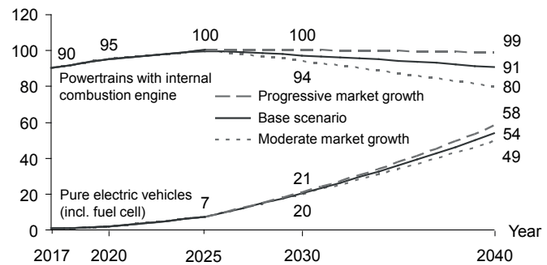
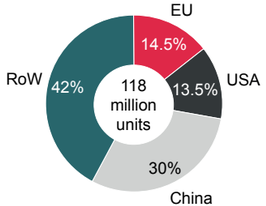


Figure 1: FEV global electrification forecast for light-duty vehicles

In Europe, USA, and China the transition from conventional to electrified powertrain systems will be happening significantly earlier than in less mature markets. As a result the number of internal combustion engines sold in these three markets in 2030 is expected to be approximately 10 % below the 2016 sales volume. Hybrid drivetrains (including mild hybridization with 48V technology) are expected to account for approximately 56 % of sales. The technological change also affects other components of the powertrain. The average number of cylinders decreases by 8 % from 4.3 to 4.0 due to an ongoing trend towards turbocharged three and four cylinder engines.

2030 light-duty* vehicles sales

BASE SCENARIO



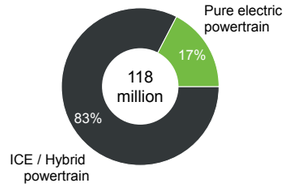
» IN 2030, 118 MILLION NEW VEHICLES SOLD IN TOTAL

Among the three key automotive regions the pace of the transition towards electrified powertrains varies. In Europe, a share of 21 % battery electric vehicles is forecasted for 2030. A main driver for this development is the regulation of CO2 emissions for newly registered vehicles, which every vehicle manufacturer has to abide by individually. In addition aversion against combustion engine based vehicles is increasing in some parts of society and acceptance of e-mobility is increasing. The expected investments into charging infrastructure and roll-out of electric vehicle portfolios by many manufacturers are likely to facilitate the transition. For the US market a lower sales share of electric vehicles (9 % in 2030) is expected for 2030. Compared to Europe, the US CO2 emission regulation is less stringent. In addition electric vehicles are less suitable for average US customers, which prefer larger vehicles and are driving longer distances compared to Europe. However, in some regions of the USA, especially the coastal areas, a higher market share of electric vehicle is expected. In China, a comparably high electric vehicle share of 29 % is expected for 2030. Main driver for the high market penetration is a variety of regulatory programs pushing electric vehicle sales, such as fuel economy targets, electric vehicle sales quotas („NEV credit targets“) and advantages for electric vehicles in license plate assignments.

» 17% ELECTRICALLY POWERED NEW VEHICLES IN 2030

Expected global sales volume[1] in 2030

BASE SCENARIO



Passenger car powertrain type forecast for 2030 in million units

BASE SCENARIO

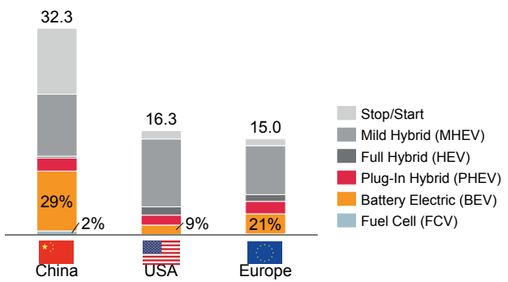


Figure 2: FEV electrification forecast for passenger cars in main automotive markets

1) Vehicle sales include passenger cars and light commercial vehicles up to 3.5 tons

CHANGE OF THE MANUFACTURING PROCESSES OF DRIVE SYSTEMS

64% LESS VALUE ADDED FOR ELECTRIC DRIVES – 24% HIGHER VALUE ADDED FOR HYBRID DRIVES

The manufacturing process effort required to produce a powertrain depends not only on the type of powertrain (e.g. conventional, hybrid or battery electric), but also on its technological complexity. Especially for conventional and hybrid powertrains the technological complexity is expected to increase towards 2030. This will be mainly driven by fuel efficiency improvements as well as pollutant emission reduction measures. In consequence the requirements for production technology also increase for these types of powertrains.

The results of a comprehensive cost analysis show substantial differences between conventional and electrified drivetrains. Compared to a combustion engine based powertrain, a battery electric powertrain has significantly higher material costs, mainly attributable to the traction battery. On the other hand, the manufacturing process effort for an electric drivetrain is significantly lower. Especially those manufacturing processes, which currently dominate the production of combustion engines, are reduced. Their overall value-add for a battery electric powertrain is 64 % lower compared to a mild hybrid powertrain (note: a mild hybrid powertrain is expected to be the „standard" powertrain in Europe by 2030). The extent of reduction varies between the individual manufacturing processes and ranges from approximately 50 % to 80 %. In contrast to that, the production of a plug-in hybrid powertrain requires 24 % more manufacturing process effort than a mild hybrid powertrain, because a powerful electric drive train is installed in addition to the combustion engine.

Manufacturing process costs in Euro

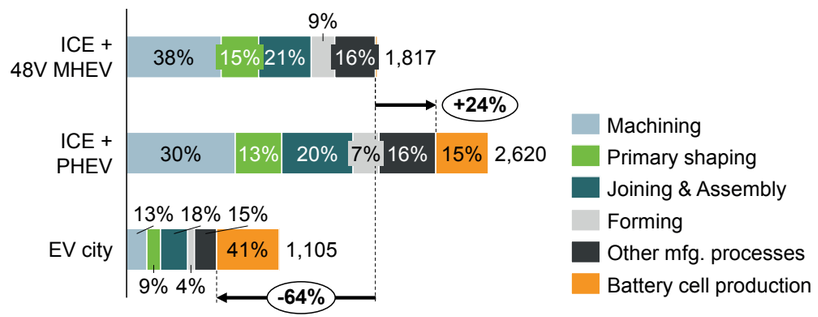


Figure 3: Manufacturing process costs for different powertrain types

The development of the overall manufacturing process related value creation can be estimated by combining the manufacturing process effort of individual powertrain types with their expected sales volume.

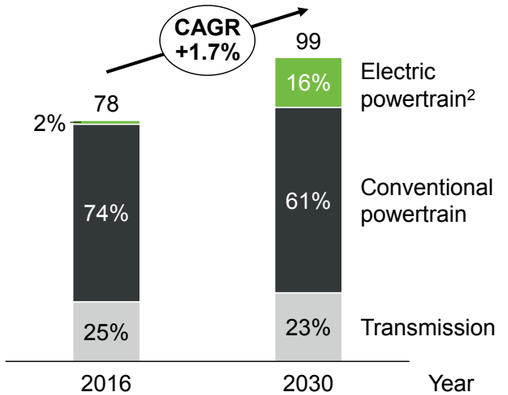
As a result it is expected that manufacturing process related value creation (excluding battery cell production) for the combined EU, US and Chinese markets will increase by 1.7 % annually between 2016 and 2030. The negative impact of the transition towards battery electric vehicles is expected to be overcompensated by three major positive impacts:

- Increase of hybrid powertrain market share, requiring high manufacturing process effort,
- Increase of complexity for remaining conventional powertrains,
- Increase of overall vehicle sales in China (23 million units in 2016; 32 million units in 2030)

However, the overall growth needs to be analyzed in detail. The development of value creation varies significantly between different powertrain components and sales markets: The value creation for internal combustion engines is expected to decline by -1.3 % per year for the European market and it is likely to stagnate for the US. Only for China an annual increase of 1.5 % is forecasted. For electric powertrain components, applied in hybrid and all-electric vehicles, a strong increase of value creation (approx. 20 % annually) is expected. Additionally battery cell production is expected to account for another 11 billion Euro of manufacturing process related value creation.

Value creation[1] of powertrain by system in billion Euro

BASE SCENARIO

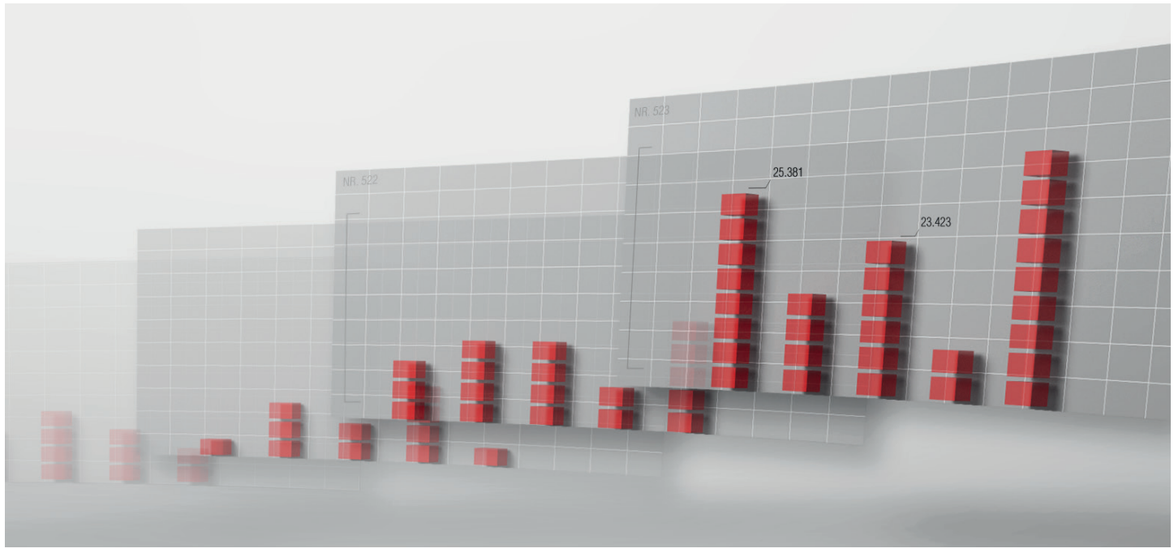


1) all manufacturing processes excluding battery cell production, values shown represent manufacturing process related value creation (excl. material costs, overhead and profit)
2) incl. components for electric propulsion of hybrid powertrains (e.g. e-motor of plug-in hybrid powertrain);
3) CAGR = compound annual growth rate

Figure 4: Development of manufacturing process related value creation for passenger car powertrains

3 FEV'S ZERO EMISSION VEHICLE INDEX:

A NEW MONITORING SYSTEM



The results outlined in the previous chapters are based on FEV's baseline scenario for market penetration of electrified vehicles. However, the success of e-mobility is uncertain and depends variety of influencing factors ranging from regulatory boundaries to social acceptance. The development of these influencing factors are decisive for the pace and the extent of electric vehicle adoption in different markets.

As a consequence the most relevant factors should be identified, understood and carefully monitored. For this purpose FEV developed a new framework, the "Zero Emission Vehicle Index" (ZEV-Index). 40 different influencing factors (i.e. parameters) are included in the ZEV-Index covering the following dimensions: regulation, technology availability, infrastructure, behavior of industry, economic aspects and social acceptance. For each factor the status quo is recorded individually for different markets (e.g. number of charging points in EU, USA and China).

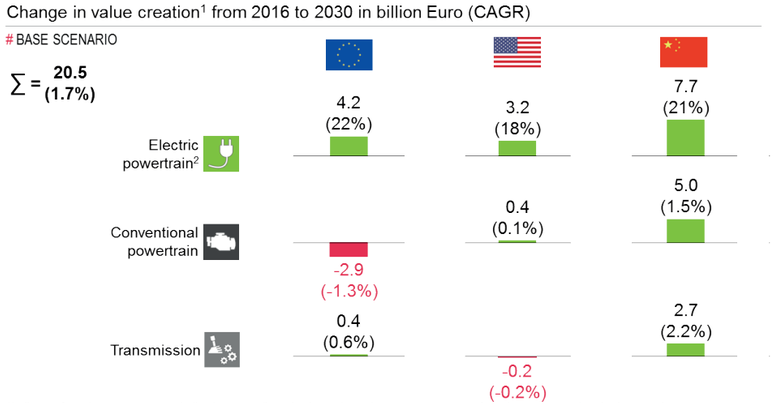
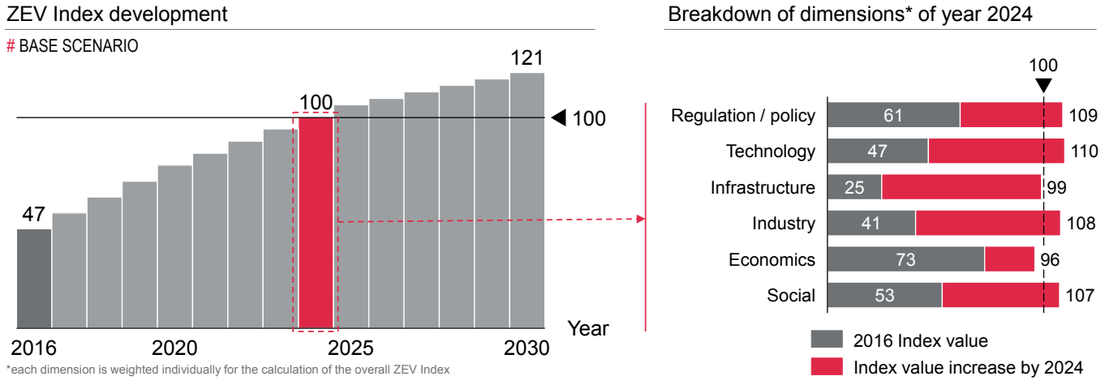


Figure 5: Change of manufacturing process related value creation for passenger car powertrains between 2016 and 2030

Additionally the development of the parameters until 2030 is forecasted. Based on technological and economic assessments the different parameters are normalized in order to integrate different dimensions into one single index value. As a result a forecast of the ZEV-Index value is generated specific for each analyzed market. An index value of 100 represents market boundary conditions, in which the attractiveness of an electric vehicle is equivalent to a conventional vehicle. Thereby the ZEV-Index can be used as an instrument for development of market scenarios regarding adoption of electric vehicles. Additionally the constant monitoring of key indicators allows for quick identification of changes in the e-mobility ecosystem in order to derive individual needs for action.

ZERO EMISSION VEHICLE (ZEV) INDEX FOR PASSENGER CAR IN EUROPE



For the European market electric vehicles are expected to be as attractive as conventional vehicles by 2024. In 2016 the ZEV-Index value was only 47. The main drivers for the steep increase towards 2024 are:

- Roll-out of a broad range of electric vehicles by all major vehicle manufacturers
- Significant expansion of occasional and fast charging infrastructure
- Battery technology improvements and cost reduction
- Broad social acceptance of e-mobility and increasing electric vehicle demand

In China parity of attractiveness between electric and conventional vehicles is expected to be reached two to three years earlier than in Europe. The main reason is the distinct regulatory framework pushing e-mobility. For the USA, the equivalent attractiveness is expected only in 2028.

Figure 6: Development of FEV's Zero Emission Vehicle Index for the European passenger car market

CONCLUSIONS AND RECOMMENDED ACTIONS FOR SUPPLIERS OF

MACHINERY AND COMPONENTS

Between 2016 and 2030, the manufacturing process related value creation combined for the three markets Europe, USA, and China, is expected to grow by 1.7 % annually. The reduction of value creation in the conventional powertrain area can be overcompensated by electrified powertrains, advanced technology application and increasing vehicle sales.

By 2030 the number of combustion engines sold in Europe, USA and China, is expected to decrease by 10 % compared to 2016. China continues to be the largest market for internal combustion engines.

For the machinery industry as well as component suppliers the field of internal combustion engines will remain a substantial business area. However, against the background of consolidating markets in Europe and US, individual market players should analyze and adjust their business models accordingly. In order to remain profitable, allocation of development and production resources should be reevaluated. The growing market in Asia will continue to gain importance, so market players should consider to intensify their Asian business by analyzing, if sales and production structures need to be expanded.

There are also opportunities for additional business in the conventional powertrain area. For the majority of combustion engines an increase of technological complexity is expected due to application of advanced engine technologies. In order to participate in the resulting value creation, market players have to gain or remain in technology leadership position by continuously improving their competencies and capabilities.

The market volume of electric powertrain components – applied in hybrid and battery electric vehicles – will grow significantly. In turn, new business opportunities will arise for market players across the entire automotive supply chain. Each company should identify its individual opportunities to participate in these markets. Existing core competencies and capabilities should be extended through dedicated build-up of additional know-how. Sustainable innovation networks combining industry and science can contribute to the development of new competencies.

In this study the timeline for the transition of powertrain systems is oriented on expected vehicle sales. However, the impact on the business of supplier of components and machines occurs much earlier, because investments into R&D and manufacturing require considerable lead time. As a consequence the business transformation process should already be ongoing or initiated immediately. Companies, which act fast and flexible, can foster their leadership position and exploit the potential of additional business. In the long run, participation in the market of electrified powertrains is imperative for the economic success of suppliers of components and machinery.

UNDERLYING STUDY AND
ACKNOWLEDGEMENTS

This article summarizes a part of the results of the study „Transformation of Powertrain - the electrification and its impact on the value added of vehicle powertrains by 2030". FEV Consulting conducted the study in collaboration with the German industry associations „Verband Deutscher Maschinen- und Anlagenbauer (VDMA)", „Forschungsvereinigung Antriebstechnik (FVA)" and „Forschungsvereinigung Verbrennungskraftmaschinen (FVV)". Three vehicle categories have been in focus and were analyzed separately: passenger cars, commercial vehicles, and non-road mobile machinery. The three major automotive markets Europe, China, and USA have been covered in detail, but the findings are transferrable to other markets as well. The results of the study include a forecast of the sales volume of conventional and electrified powertrains as well as an analysis of the required manufacturing processes for different powertrain types. By linking these two factors a forecast of the overall manufacturing process related value creation has been conducted.

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