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 Anlagenbau-er (VDMA)", "Forschungsvereinigung Antriebstechnik (FVA)", and "Forschungsvereinigung Verbrennungskraftmaschinen (FVV)". Three vehicle categories are in focus and analyzed 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.
Passenger car powertrain type forecast for 2030 in million units

In 2030, 118 million new vehicles sold in total

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. Among the three key automotive regions the pace of the transition towards electrified powertrains varies. In Europe, a share of 24 % 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 market share of electric vehicles (29 % in 2030) 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.

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 the three regions in 2030 is expected to be approximately 10 % below 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.

Since 2017, many manufacturers have introduced new powertrain systems and the average number of cylinders decreases from 4.4 to 4.0 due to an ongoing trend towards turbocharged three and four-cylinder engines. 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.

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CHANCE OF THE MANUFACTURING PROCESSES OF DRIVE SYSTEMS

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 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.

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 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.

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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 on various 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).

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.

Change in value creation $^*$ from 2016 to 2030 in billion Euro (CAGR)

<table>
<thead>
<tr>
<th>Base Scenario</th>
<th>Electric Powertrain</th>
<th>Conventional Powertrain</th>
<th>Transmission</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4.2 (22%)</td>
<td>3.2 (10%)</td>
<td>7.7 (21%)</td>
</tr>
<tr>
<td></td>
<td>(1.3%)</td>
<td>(0.6%)</td>
<td>(2.7)</td>
</tr>
</tbody>
</table>

The change in value creation is calculated for electric powertrains and conventional powertrains, as well as the transmission. The value creation includes material costs, overhead and profit

$^*$: Change in manufacturing process-related value creation for passenger car powertrains between 2016 and 2030.

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

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 compensated 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. The largest market for internal combustion engines is expected to be China, followed by Europe and then the USA. The main reason is the distinct regulatory framework pushing e-mobility. For the USA, the equivalent attractiveness is expected only in 2028.

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