COSTS OF ELECTRIFICATION

COST DEVELOPMENT OF ELECTRIC VEHICLES CONSIDERING FUTURE MARKET CONDITIONS

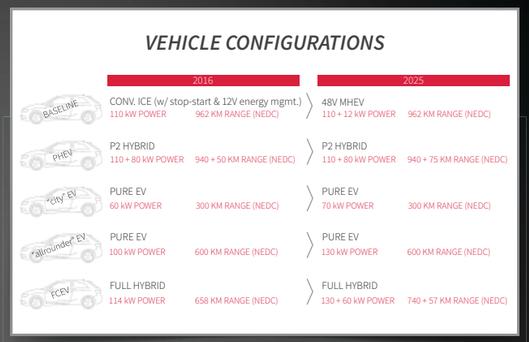
MARKET STUDY AND COST ANALYSIS OF ELECTRIC, HYBRID AND FUEL CELL VEHICLES

With a market share of only about 1% of new vehicles sold, battery driven electric vehicles and plug-in hybrid vehicles ("xEVs") stand, from a European market perspective, far below expectations. In Germany, the xEV share is 0.6%; corresponding to about 25,000 vehicles sold in 2016. Germany is below the EU average. It is clear that the purchase and tax subsidies from the German government have, so far, not had a significant impact: In the first 3 months, only 4,500 sales were realized. Despite the subdued market demand, the number of public charging stations for electric vehicles tripled between 2015 and 2016. Against this background, FEV Consulting conducted a market and cost study to answer the question of how electric vehicle costs will develop in the future under conditions of increased sales volumes, growing demand for raw materials, and developing production capacities. The main objective is to assess the extent to which xEV vehicles can be cost competitive with conventional vehicles and which powertrain type will dominate the market.

FEV's study answers the following core questions:

- What are the latest trends in electrification and hybridization?
- What are key market and technology trends regarding xEVs towards 2025/30?
- How high are costs for alternative powertrains today, and what will they be in 2025/30?
- What are the primary cost drivers and how will they develop?
- Will combustion engines still be the cost leaders in 2025/30?
- Which additional costs are expected in order to meet statutory and supervisory requirements?
- How cost competitive will fuel cell technology be in 2025/30?

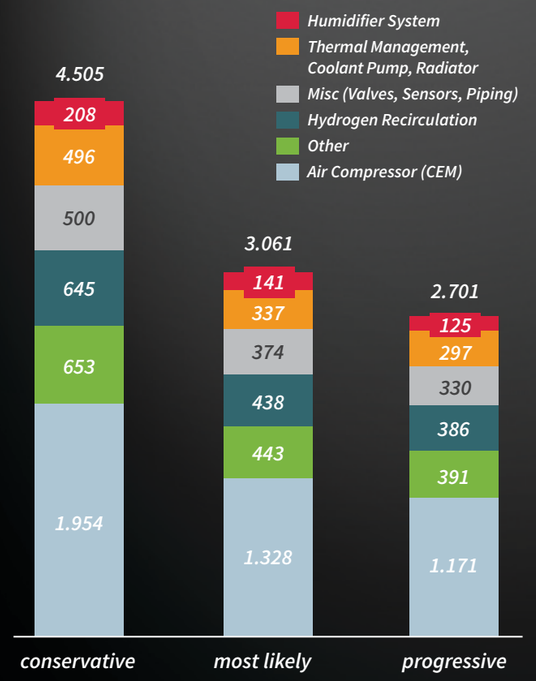
Driven by "diesel gate", statutory regulations, regulatory pressure and technological advances, alternative drives (or xEV vehicles) have developed into a key trend in the automotive sector. Many European OEMs are convinced that the tipping point for electric vehicles will soon be reached: OEMs and suppliers are currently investing heavily in the development of their EV fleet and EV component portfolios. Volkswagen just recently released the launch of its xEV platform (MEB) with a goal of achieving a 600 km electric driving range in its compact car concept, "ID." Daimler showcased an electric SUV Coupé called "Generation EQ," at the Paris Motor Show that is based on a dedicated EV architecture. Other manufacturers are planning similar concepts, including purely electric as well as hybrid, and fuel-cell electric vehicles with electric ranges exceeding 350 km. Aside from the regulatory and legislative motivation, the financial implications for OEMs over the next 10 years are still not clear. The question of whether xEVs will be able to attain a significant market share largely depends on future price competitiveness compared with their conventionally powered counterparts.



Selected vehicle concepts for cost comparison of future xEVs

Methodology and Assumptions

Several alternative powertrain vehicle concepts and a conventional compact vehicle were compared in a cost analysis study. The selected models included typical plug-in hybrids (PHEV), pure battery-electric vehicles (BEV) and fuel-cell electric vehicles (FCEV) in the compact car segment. In order to capture market and technology uncertainties, 3 scenarios were developed that reflect technology development costs and fluctuations in raw material prices. For all 3 scenarios, a set of boundary conditions were determined to allow a fair cost comparison between the different concepts.



Exemplary cost split for selected fuel cell component in 2025 [in €]

Selected boundary conditions for the 2016 cost baseline:

- Vehicle segment: Compact car
- Baseline vehicle for cost comparison is a conventional ICE with start-stop and 12V
- Low production volume for Fuel Cell Vehicles
- Battery specifications based on current market concepts

Selected boundary conditions for the 2025 cost forecast:

- Vehicle segment: Compact car
- Conventional baseline vehicle is MHEV (48V) with an additional 12 kW of electric power
- Production volume for FCEV has been increased to 50 thousand units
- Higher specific energy [Wh/kg]

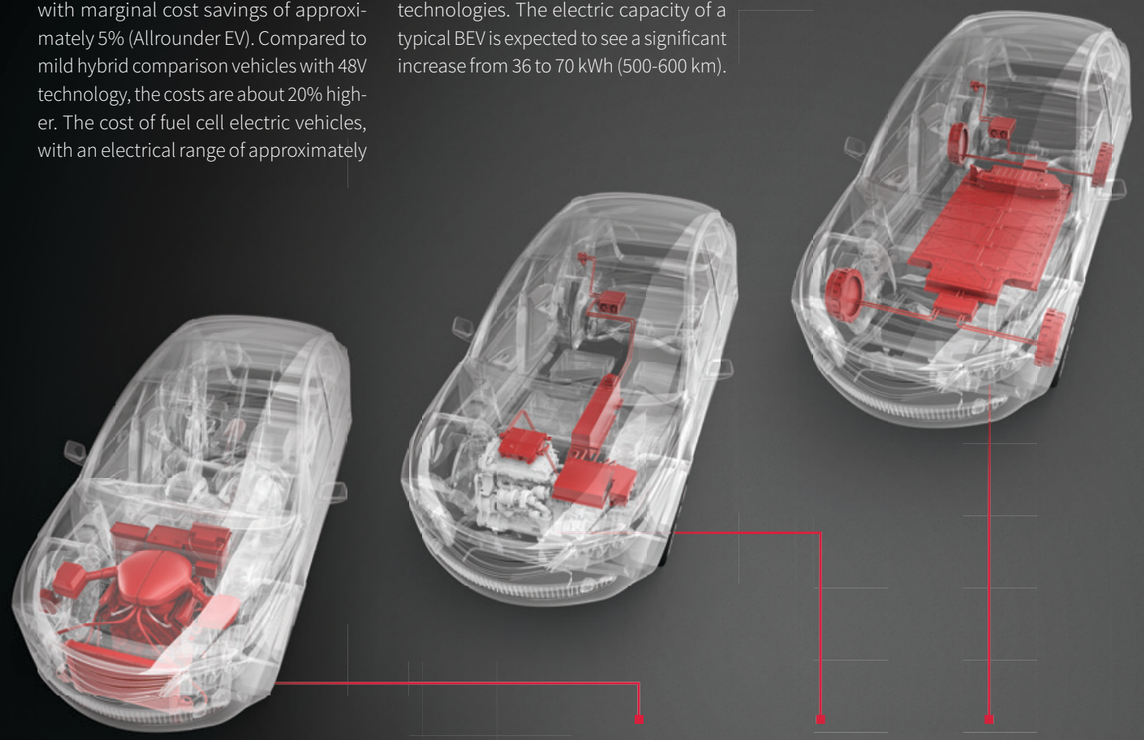
Selected Study Results

In 2016, the manufacturing costs of plug-in hybrids and battery electric vehicles (PHEVs & BEVs) were about one-third higher than a conventional ICE-powered vehicle with a Start/Stop automatic transmission. Fuel cell electric vehicles (VCEV) manufacturing costs are nearly 5 times as high as those for a conventional vehicle. The reasons for this are lower sales volumes and high development cost in 2016.

By 2025, it is expected that the electric range of xEV vehicles will nearly double, with marginal cost savings of approximately 5% (Allrounder EV). Compared to mild hybrid comparison vehicles with 48V technology, the costs are about 20% higher. The cost of fuel cell electric vehicles, with an electrical range of approximately 800 km, is expected to fall to one-fifth of today's price, leaving a remaining cost gap of 60% compared to the 2025 baseline vehicle (48V mild hybrid). Battery costs are expected to decrease by 50% for traditional OEMs due to economies of scale associated with increased production volumes and improvements in cell technologies. The electric capacity of a typical BEV is expected to see a significant increase from 36 to 70 kWh (500-600 km).

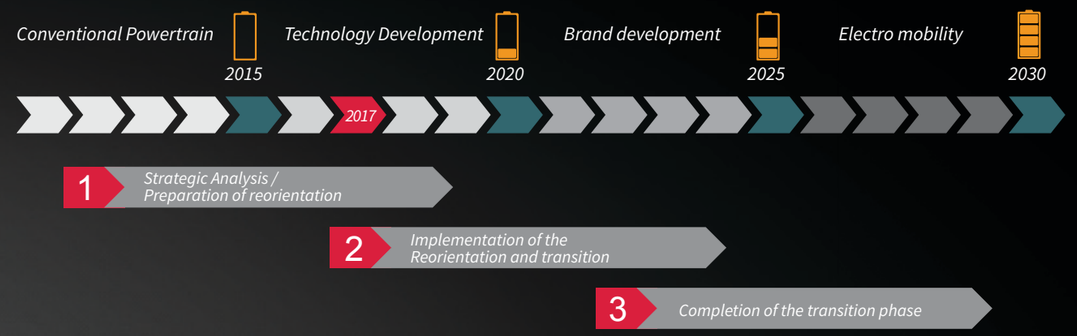
» BY 2025 BEVS WITH A 300 KM RANGE (NEDC) CAN BE REALIZED AT THE SAME COST LEVEL AS THEIR MILD HYBRIDIZED COUNTERPARTS

In addition to the comparison of the total cost and the delta analysis of the selected xEV vehicle configurations, detailed powertrain cost splits are provided in the study for key components like the electric motor, controller, battery, transmission, etc. Each key component has been further broken down into the main cost drivers, including material costs as well as overhead costs which were determined using the FEV "should cost" methodology. Uncertainties in future production volumes are considered in the "conservative," "most likely" and "progressive" scenarios.



	Conventional	Hybrid	Fully electric
Internal combustion engine *(crankcase, cylinder head, crankshaft, conrod, camshaft, valves etc.)*	Modified / Downsized	Modified / Downsized	Deleted
Fuel supply *(injectors, fuel pump, rails, tank, piping, filters)*	Modified	Modified	Deleted
Charging and exhaust gas *(turbocharger, manifold, catalysts, filter, sensors, exhaust system)*	Modified	Modified	Deleted
Starter and generator	Modified	Modified	Deleted
Transmission and clutch	Modified	Modified	Modified/Deleted
Cooler water pump, air conditioning etc.	Modified	Modified	Modified/Deleted
E-motor	-	New	New
Battery system	-	New	New
Power electronics	-	New	New

Modification / Change of powertrain configurations in a 15-year-timeframe



Impact on the Automotive Industry

Fully electric drivetrains are far less complex than their conventional counterparts with internal combustion engines, since many components of a conventional drivetrain are no longer necessary. The sales potential of injectors, fuel pumps, filter systems and turbochargers is adversely affected by increasing EV sales. Conversely, the strategic importance of new components, such as the electric motor, battery and power electronics increases. For the future, manufacturers need to decide what share of the added value they want to provide from within (vs outsourcing). This decision is strongly influenced by endogenous factors such as cost competitiveness, exogenous factors such as raw material prices, vehicle range and future development of charging infrastructures.

Suppliers – especially those with a product portfolio focusing on conventional powertrains – will have to undergo a fundamental transformation over the next 15 years, which can be subdivided into 3 steps:

1 Today: Strategic Analysis and Preparation of Realignment

Although the industry is in a state of upheaval, there is still partial restraint. On the one hand, the change to the development of alternative propulsion systems is already visible in the organizations of major manufacturers and large or specialized suppliers. On the other hand, traditional suppliers that are active in the internal combustion engine market are still in the preparatory phase.

2 2020: Implementation of the Realignment and Transition

As soon as market shares of xEVs have increased, product and service portfolios must be realigned and value chains have to be reorganized. The orchestration of an orderly ramp-down of the traditional business requires a solid strategic plan and dedicated implementation. It is very likely that the early inefficient suppliers will fall victim to the industry transition and exit the market. As a further consequence, the future R&D focus of the OEM's will shift even more clearly toward electrification and other value-added product offerings, such as automation and (digital) mobility services.

3 2025+: Completion of Transition Phase

Depending on the respective scenario, market shares for conventional powertrains (ICE-only) will shrink significantly. In one radical scenario, ICE vehicle sales are likely to drop to 75% of the 2016 level. On one hand, as a result of shrinking market volumes, further (and even stronger) consolidation of the remaining suppliers in the field of conventional powertrains is expected. On the other hand, market participants will be well-positioned with an early strategic focus on the realignment and transition toward the new boundary conditions for the future xEV market and technology competition.

If you are interested in the details of the study or would like to discuss implications and possible actions, please don't hesitate to contact us.

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