Staying profitable in the new era of electrification

Powertrain study 2020

Dr. Jörn Neuhausen, Felix Andre, Jörg Assmann, Christoph Stürmer
Staying profitable in the new powertrain age

Management summary

1. The electrification trend is accelerating and is unstoppable, driven by legislation and popular sentiment. To achieve European CO\(_2\) fleet targets, an electrified vehicle (“xEV”) share 35% to 45% will be required in 2030.

2. As OEMs struggle with on-costs for xEVs, profitability and contributions margins are under threat. This is due to the new roll-out of xEVs to the volume segment, and the economic downturn caused by COVID-19.

3. For the next decade electric powertrain technology will maintain its pace of development.

4. Batteries are the largest cost driver of electric powertrains – costs will fall further, yet this fundamental point will still apply.

5. The often discussed turning point when BEVs become more economic than ICEs is not a discrete point in time. It depends largely on vehicle segment, power, and range (battery size). BEVs will become economic for several segments, but extended ranges (600 km+) will not be viable with BEVs.

6. Based on the customer value proposition for powertrains, variants should be reduced to enabled focused development capacities, while core competencies need to be revised.

7. Given that profitability is precarious (due to COVID-19) but xEV sales are growing, OEMs need to focus on cost-optimized powertrain platforms and a customer-oriented powertrain portfolio to improve margins and profitability.
Why electric mobility puts automotive profitability under pressure

The threat of transformation
xEV sales in China has slowed down – Europe has become the main growth market

Current sales figures and trends for BEV and PHEV (thousand units per year)

USA
- Nation is divided by states following CARB\(^1\) regulation (e.g. CA, MA, OR, ME) and others
- Government support measures for BEV (e.g. tax credit) limited by total sales per OEM
- No governmental charging infrastructure support package; efforts mostly driven by OEMs
- City bans are not relevant and are not expected to become so until 2030

EU-28
- Stricter CO\(_2\) fleet targets recently enacted
- BEVs and PHEVs are necessary to comply with target and avoid penalties
- COVID-19: Government support measures with strong focus on BEVs and PHEVs
- First city bans for combustion engines announced for 2030 (e.g. Amsterdam)

China
- As response to COVID-19, financial subsidies for NEV\(^2\) extended until the end of 2022
- In the next 3 years, gradually increase of the mandated production quota for NEV. Fines for non-compliance for manufacturers
- Quotas on license plate removed for NEV and somewhat relaxed for ICE (e.g. in Hangzhou)

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\(^{1}\) CARB – Californian air resource board
\(^{2}\) NEV – New Energy Vehicle
Source: Autofacts analysis, IHS Markit
In order to achieve the 2030 fleet targets, an electrified vehicle share of ca. 35% to 45% xEV (BEV, PHEV) is required.

Legislative trends – CO₂ fleet targets and xEV effect

International CO₂ fleet targets

Effect of xEV on fleet emissions¹,²)

1) As for volume manufacturers (>300 thousand units p.a.)  
2) Super credits not shown, due to discontinuation after 2022  
3) Additional weight of BEV taken into account  
4) Based on WLTP utility factor

Sources: https://theicct.org/chart-library-passenger-vehicle-fuel-economy, Strategy& analysis
## Electrified vehicles (xEV) come with higher product costs – ca. 3500 € ... 10000 € vs. an ICE

### On-costs of alternative powertrains (€ thousand, 2020)

### Main specifications

<table>
<thead>
<tr>
<th>Powertrain</th>
<th>Main Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICE</td>
<td>• 100 kW (gasoline)</td>
</tr>
<tr>
<td></td>
<td>• Automatic transmission (double clutch)</td>
</tr>
<tr>
<td></td>
<td>• Range ca. 700 km</td>
</tr>
<tr>
<td>PHEV</td>
<td>• 85 kW (gasoline)/75 kW_{peak} (electric)</td>
</tr>
<tr>
<td></td>
<td>• Range ca. 800 km, thereof ca. 100 km electric (20 kWh)</td>
</tr>
<tr>
<td>BEV</td>
<td>• 100 kW_{peak} (electric)</td>
</tr>
<tr>
<td></td>
<td>• Range ca. 300 km (60 kWh battery)</td>
</tr>
<tr>
<td>FCEV</td>
<td>• 100 kW_{peak} (electric)</td>
</tr>
<tr>
<td></td>
<td>• Range ca. 400 km (thereof ca. 75 km battery-electric)</td>
</tr>
</tbody>
</table>

### Powertrain product costs (€ thousand)

<table>
<thead>
<tr>
<th>Powertrain</th>
<th>ICE 2020</th>
<th>PHEV 2020</th>
<th>BEV 2020</th>
<th>FCEV 2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICE</td>
<td>ca. 5</td>
<td>7.5 – 9.5</td>
<td>8.5 – 10.5</td>
<td>ca. 40</td>
</tr>
<tr>
<td>PHEV</td>
<td>ca. 8.5</td>
<td></td>
<td></td>
<td>ca. 15</td>
</tr>
<tr>
<td>BEV</td>
<td></td>
<td></td>
<td>ca. 9.5</td>
<td></td>
</tr>
<tr>
<td>FCEV</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

### On-costs

- Actual ca. 35
- Potential ca. 10
Due to increased product costs with limited price potential, contribution margins are decreasing and profitability is under threat.

**Electrified vehicle profitability**

<table>
<thead>
<tr>
<th>The old world</th>
<th>Electrified vehicle traits</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ICE as-is</strong></td>
<td><strong>A</strong> The premium solution</td>
</tr>
<tr>
<td><img src="image" alt="Car" /></td>
<td><strong>B</strong> The spartan niche</td>
</tr>
<tr>
<td><img src="image" alt="Car" /></td>
<td><strong>C</strong> The volume challenge</td>
</tr>
<tr>
<td><img src="image" alt="Car" /></td>
<td><img src="image" alt="Car" /></td>
</tr>
</tbody>
</table>

**Reference price as-is**

<table>
<thead>
<tr>
<th><strong>Contribution margin</strong></th>
<th><strong>Critical</strong> (limited sales)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Powertrain costs</strong></td>
<td><strong>Satisfying</strong></td>
</tr>
<tr>
<td><strong>Vehicle costs without powertrain</strong></td>
<td><strong>Satisfying</strong></td>
</tr>
<tr>
<td><strong>Fleet targets not achievable</strong></td>
<td><strong>Under threat</strong></td>
</tr>
<tr>
<td><strong>Margin satisfying</strong></td>
<td><strong>Under threat</strong></td>
</tr>
</tbody>
</table>

**Electrified vehicle traits**

- **A** The premium solution
  - **Increase** sales price
  - **Maintain** contribution margin ratio

- **B** The spartan niche
  - **Maintain** price
  - **Reduce** vehicle costs and specs

- **C** The volume challenge
  - **Maintain** price
  - **Reduce** contribution margin ratio

**Vehicle costs without powertrain**

- **Powertrain costs**
- **Contribution margin**
2 How powertrain technology and costs evolve
The battery cells comprise most of the BEV powertrain costs – a closer look at its value chain is imperative

Enable value chain optimization: Significance of battery and cell costs for BEV

Typical cost breakdown BEV powertrain

OEM production costs 2020, 60kWh/100kW, volume class € thousand

- **Battery system**
  - Cells
  - Wiring
  - Fuses and contactors
  - Cooling
  - Housing

- **eAxle**
  - Inverter
  - Electric motor
  - Gearbox

- **HV system and auxiliaries**
  - HV wiring
  - LV-DCDC converter
  - On-board charger
  - HV heater

<table>
<thead>
<tr>
<th>Raw materials and precursors</th>
<th>Processing of battery materials</th>
<th>Production of single cells</th>
<th>Production of cell modules</th>
<th>Assembly of battery system</th>
</tr>
</thead>
</table>
| - Main materials
  - Cobalt
  - Nickel
  - Lithium
  - Graphite
  - Solvents | - Main materials
  - Active materials (e.g. NCM, graphite) | - Main processes
  - Mixing and electrode coating
  - Winding/stapling
  - Electrolyte filling
  - Sealing
  - Formation and ageing | - Main processes
  - Stapling
  - Electrical connection (power/signal)
  - Main sub-assemblies
  - Module controller
  - Cell connectors | - Main processes
  - Housing assembly
  - Electrical assembly
  - Main sub-assemblies
  - HV contactors
  - BMS
  - Module connectors |

8.5 – 10.5

80%

9%

11%

26%

29%

16%

21%

8%
Depending on realization of optimization we see a decline from 90 to 68 €/kWh for large automotive battery cells.

Battery cell prices and optimization

Cell price breakdown (2020)

Cell prices and selected optimization measures till 2030 (€/kWh)

- Optimize purchase prices, e.g. by increasing supplier sets for housings and separators
- Reduce separator and current collector thicknesses
- Increase coating thickness
- Elimination of solvent (e.g. NMP) and recovery process
- Elimination of drying process
- In-line quality control
- Big data analytics
- Increase specific capacities by Ni increase (cathode) and Si blend (anode)
- Decrease of cobalt content (cathode)

Source: Strategy& battery cost model
As a result of cost reductions for new technologies, we expect on-costs to reduce to ca. 1500 to 3000 € in 2030.

On-costs of alternative powertrains (€ thousand, 2020…2030)

**ICE**
- 100 kW (gasoline)
- Automatic transmission (double clutch)
- Range ca. 700 km

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- 85 kW (gasoline)/75 kW\textsubscript{peak} (electric)
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- 100 kW\textsubscript{peak} (electric)
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- Range ca. 400 km (thereof ca. 75 km battery-electric)
BEVs will become economic for several segments – but extended ranges (600 km+) will not be viable with BEVs

Economics of selected vehicle/powertrain combinations

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Most economical solution</th>
<th>Key findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle segment</td>
<td></td>
<td></td>
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<tr>
<td>A/B Budget</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>150 km</td>
<td></td>
</tr>
<tr>
<td>Mid</td>
<td>300 km</td>
<td></td>
</tr>
<tr>
<td>Long</td>
<td>600 km</td>
<td></td>
</tr>
<tr>
<td>C/D Volume</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mid</td>
<td>300 km</td>
<td></td>
</tr>
<tr>
<td>Long</td>
<td>600 km</td>
<td></td>
</tr>
<tr>
<td>Extra-long</td>
<td>800 km</td>
<td></td>
</tr>
<tr>
<td>E/F Premium</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mid</td>
<td>300 km</td>
<td></td>
</tr>
<tr>
<td>Long</td>
<td>600 km</td>
<td></td>
</tr>
<tr>
<td>Extra-long</td>
<td>800 km</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Evolution of TCO leader</td>
<td></td>
</tr>
<tr>
<td>2020</td>
<td>2025</td>
<td>2030</td>
</tr>
<tr>
<td>2019</td>
<td>2027</td>
<td>2040</td>
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<tr>
<td>2024</td>
<td>2035</td>
<td>2038</td>
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<tr>
<td>2018</td>
<td>2024</td>
<td>2028</td>
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<tr>
<td>Break-even</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2019</td>
<td>2027</td>
<td>2040</td>
</tr>
<tr>
<td>2024</td>
<td>2035</td>
<td>2038</td>
</tr>
<tr>
<td>2018</td>
<td>2024</td>
<td>2028</td>
</tr>
</tbody>
</table>

- The often described “turning point” when BEVs become more economic than ICEs is not a discrete point in time – it depends largely on vehicle segment, power, and range (battery size)
- Economics of BEV compared to ICE is promoted by two main parameters
  - Low range requirements and small batteries, explaining favorable BEV TCO for A/B low range segment
  - Moderate on-costs for high power electric drives, explaining favorable BEV TCO in premium segment
- Real long-range capability of BEVs is technically limited, only PHEV and FCEV are alternatives for real-life long-range

Main assumptions: electricity and fuel prices as for Germany 2020; H2 price 5€/kg; PHEV driving modes 40% EV mode / 60% ICE mode; FCEV driving modes 40% EV mode / 60% FC mode
One-time buying incentives not considered
How to reshape powertrain portfolio and core capabilities
The specific powertrain features should be shaped along the customer value proposition within the vehicle portfolio.

### Dominant powertrains and archetypes 2030

#### Dominant powertrain types

- **Premium city BEV**
- **Distinctive green rocket BEV**
- **Premium city BEV**
- **Rational green BEV**
- **Dynamic yet zero-emission capable PHEV**
- **Marathon runner ICE**
- **Pure-play ICE**
- **Sustainable prime FCEV**
- **Distinctive green rocket BEV**

#### Powertrain archetypes

- **Pure-play ICE**
  - Driving dynamics and comfort weaker than for electrified drives
  - Low-cost economic
  - Independent of weak infrastructure

- **Marathon runner ICE**
  - Driving dynamics and comfort weaker than for electrified drives
  - Allrounder with long-range capability

- **Dynamic yet zero-emission capable PHEV**
  - High driving dynamics through high torque electric motor without clutch and gear shifts
  - Urban distances via electric motor/battery green and silent
  - Highly flexible with long-range capable ICE

- **Rational green BEV**
  - Low-cost and green
  - Orientated to actual required everyday range

- **Premium city BEV**
  - Highly dynamic and green
  - Range for use in urban area only

- **Distinctive green rocket BEV**
  - Highly dynamic and green
  - Range up to technical maximum

- **Sustainable prime FCEV**
  - Highly dynamic and green
  - Grid rechargeable battery for short distance use and easy daily slow refill
  - Long-range and fast refill capability with fuel cell
  - High price but "zero constraints" and maximal flexibility
Development focus should be based on the future expectation of relevant powertrain features

### Powertrain features and development focus

#### Mainstream powertrain configurations

<table>
<thead>
<tr>
<th>ICE</th>
<th>Marathon runner ICE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pure-play ICE</td>
<td>• A/B segment</td>
</tr>
<tr>
<td></td>
<td>• 3-4 cylinder gasoline</td>
</tr>
<tr>
<td></td>
<td>• 40-60 kW</td>
</tr>
<tr>
<td></td>
<td>• C-E segment</td>
</tr>
<tr>
<td></td>
<td>• 3-4 cylinder gasoline or diesel</td>
</tr>
<tr>
<td></td>
<td>• 60-150 kW</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PHEV</th>
<th>Dynamic yet zero-emission capable PHEV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rational green BEV</td>
<td>• A-C segment</td>
</tr>
<tr>
<td></td>
<td>• 120-300 km (20-50 kWh)</td>
</tr>
<tr>
<td></td>
<td>• 40-80 kW</td>
</tr>
<tr>
<td></td>
<td>Premium city BEV</td>
</tr>
<tr>
<td></td>
<td>• A/B segment</td>
</tr>
<tr>
<td></td>
<td>• 150-250 km (20-30 kWh)</td>
</tr>
<tr>
<td></td>
<td>• 60-100 kW</td>
</tr>
<tr>
<td></td>
<td>Distinctive green rocket</td>
</tr>
<tr>
<td></td>
<td>• C/D segment</td>
</tr>
<tr>
<td></td>
<td>• 300-500 km (55-80 kWh)</td>
</tr>
<tr>
<td></td>
<td>• 150-350 kW</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>BEV</th>
<th>Sustainable prime FCEV</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• E/F segment</td>
</tr>
<tr>
<td></td>
<td>• 100-200 km (20-40 kWh), grid rechargeable (&quot;plug-in&quot;)</td>
</tr>
<tr>
<td></td>
<td>• 500-800 km (6-8 kg H₂)</td>
</tr>
<tr>
<td></td>
<td>• 80-120 km, net FC stack, 150-350 kW peak axle</td>
</tr>
</tbody>
</table>

#### Implications on component strategy

- **Top-dynamic powertrains offered mainly as BEV/PHEV**
- **Further ICE downsizing, >4 cylinders only for niches**
- **Diesel only in 4-cylinder 150...200 kW segment**
- **Increase of electric power, decrease of ICE power/dynamics, minim complex transmission**
- **3-4 cylinder engines, mainly gasoline**
- **Manifold injection and non-turbocharged engines at lower power end**
- **Scalable battery system architecture with high degree of commonality on cell/module level**
- **Power scaling up to ca. 150 kW...200 kW on single axle, above mainly via 2nd axle (4WD)**
- **Sustainable full product lifecycle (cradle-to-grave)**
- **Distinctive high range required, well above BEV, i.e. >5 kg H₂**
- **“Plug-in” with grid rechargeable battery for flexibility and low-cost home/workplace charging**
- **FC operated mainly as “range extender”**

#### Recommendation

Reduce variants and revise core competencies for powertrains and sub-components.
Implications and recommendations
Electric vehicle sales boosted by legislation in China and EU

**Market outlook to 2030**

**Electric vehicles** (total new vehicle sales – US, EU, CHINA; in millions)

<table>
<thead>
<tr>
<th>Year</th>
<th>USA</th>
<th>EU-28</th>
<th>China</th>
</tr>
</thead>
<tbody>
<tr>
<td>2020</td>
<td>13</td>
<td>14</td>
<td>22</td>
</tr>
<tr>
<td>2025</td>
<td>16</td>
<td>17</td>
<td>28</td>
</tr>
<tr>
<td>2030</td>
<td>17</td>
<td>17</td>
<td>31</td>
</tr>
</tbody>
</table>

- **USA**: About 1.4 million new electric car registrations in 2030
- **Penetration of electric lower than other regions due to relatively low cost of existing ICE alternatives**
- **Municipal and state-level privileges support local market dynamics**
- **Domestic charging infrastructure widespread only after 2030**

- **EU-28**: About 6 million new electric car registrations in 2030
- **Sufficient domestic/commercial/public charging infrastructure from 2025 onwards**
- **Strong legislative push from 2020 onwards**
- **Ongoing cost reductions and improved customer acceptance of BEVs expected to boost demand further after 2025**

- **China**: About 10 million new electric car registrations in 2030
- **Sufficient public charging infrastructure from 2022 in priority cities and main travel routes**
- **Strong legislative push from 2020 onwards**
- **Consumer demand for electric vehicles growing from sub-car segments to all segments**

Source: Autofacts analysis, IHS Markit
Cost increases induced by powertrain technology shift threaten margins and profitability in the next decade

**Next decade revenue and cost projection**

**OEM margin projection**

<table>
<thead>
<tr>
<th>Year</th>
<th>2020</th>
<th>2025</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>8%</td>
<td>10%</td>
<td>12%</td>
</tr>
<tr>
<td>Typical OEM target</td>
<td>6%</td>
<td>8%</td>
<td>10%</td>
</tr>
<tr>
<td>Optimized scenario</td>
<td>4%</td>
<td>6%</td>
<td>8%</td>
</tr>
</tbody>
</table>

**Implications**

**Baseline scenario:**
- **OEM costs** are increased by electrified vehicles, while **price increases are limited** and add-on costs aren’t fully covered.
- **Critical situation** for most traditional market players is expected after 2024/25, when xEV sales become more significant.

**Optimized scenario avoid critical situation** is:
- Reduce **product costs** for next powertrain platforms.
- Reshape **portfolio** to optimize customer perceived value and increase willingness to pay for alternative powertrains.

**COVID-19 margin impact**

Strategy&
We would be happy to discuss our study with you

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Thank you