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 CO₂ 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

<table>
<thead>
<tr>
<th></th>
<th>2018</th>
<th>2019</th>
<th>2020F</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHEV</td>
<td>361</td>
<td>327</td>
<td>426</td>
</tr>
<tr>
<td>BEV</td>
<td>122</td>
<td>85</td>
<td>53</td>
</tr>
<tr>
<td></td>
<td>239</td>
<td>242</td>
<td>332</td>
</tr>
</tbody>
</table>

**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)

<table>
<thead>
<tr>
<th></th>
<th>2018</th>
<th>2019</th>
<th>2020F</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHEV</td>
<td>324</td>
<td>518</td>
<td>1,024</td>
</tr>
<tr>
<td>BEV</td>
<td>152</td>
<td>207</td>
<td>445</td>
</tr>
<tr>
<td></td>
<td>242</td>
<td>310</td>
<td>579</td>
</tr>
</tbody>
</table>

**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)

<table>
<thead>
<tr>
<th></th>
<th>2018</th>
<th>2019</th>
<th>2020F</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHEV</td>
<td>1,165</td>
<td>1,200</td>
<td>1,097</td>
</tr>
<tr>
<td>BEV</td>
<td>282</td>
<td>219</td>
<td>860</td>
</tr>
<tr>
<td></td>
<td>883</td>
<td>981</td>
<td>687</td>
</tr>
</tbody>
</table>

\(^1\) 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 emissions

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. 3600 € ... 10000 € vs. an ICE

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

<table>
<thead>
<tr>
<th>Powertrain product costs (€ thousand)</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(_{\text{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(_{\text{peak}}) (electric)</td>
</tr>
<tr>
<td></td>
<td>• Range ca. 300 km (60 kWh battery)</td>
</tr>
<tr>
<td>FCEV</td>
<td>• 100 kW(_{\text{peak}}) (electric)</td>
</tr>
<tr>
<td></td>
<td>• Range ca. 400 km (thereof ca. 75 km battery-electric)</td>
</tr>
</tbody>
</table>

Product costs only based material and assembly costs, excluding research & development (R&D), sales, general & administrative (SG&A) cost.
Due to increased product costs with limited price potential, contribution margins are decreasing and profitability is under threat.

**Electrified vehicle profitability**

### The old world

**ICE as-is**

- Reference price as-is
  - Contribution margin
  - Powertrain costs
  - Vehicle costs without powertrain

- Fleet targets not achievable
- Margin satisfying

### Electrified vehicle traits

#### A The premium solution
- **Critical** (limited sales)
- Increase sales price
- Maintain contribution margin ratio

#### B The spartan niche
- **Critical** (limited sales)
- Maintain price
- Reduce vehicle costs and specs

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

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**Strategy&**

7
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**

<table>
<thead>
<tr>
<th>Component</th>
<th>Cost Share</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>eAxle</strong></td>
<td>9%</td>
</tr>
<tr>
<td>Inverter</td>
<td></td>
</tr>
<tr>
<td>Electric motor</td>
<td></td>
</tr>
<tr>
<td>Gearbox</td>
<td></td>
</tr>
<tr>
<td><strong>HV system and auxiliaries</strong></td>
<td>11%</td>
</tr>
<tr>
<td>HV wiring</td>
<td></td>
</tr>
<tr>
<td>LV-DCDC converter</td>
<td></td>
</tr>
<tr>
<td>On-board charger</td>
<td></td>
</tr>
<tr>
<td>HV heater</td>
<td></td>
</tr>
<tr>
<td><strong>Battery system</strong></td>
<td>80%</td>
</tr>
<tr>
<td>Cells</td>
<td></td>
</tr>
<tr>
<td>Wiring</td>
<td></td>
</tr>
<tr>
<td>Fuses and contactors</td>
<td></td>
</tr>
<tr>
<td>Cooling</td>
<td></td>
</tr>
<tr>
<td>Housing</td>
<td></td>
</tr>
<tr>
<td><strong>OEM</strong></td>
<td>8.5 – 10.5</td>
</tr>
</tbody>
</table>

### Automotive battery value chain and value share

<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>
<tbody>
<tr>
<td>Main materials</td>
<td>Main materials</td>
<td>Main processes</td>
<td>Main processes</td>
<td>Main processes</td>
</tr>
<tr>
<td>- Cobalt</td>
<td>- Active materials (e.g. NCM,</td>
<td>- Mixing and electrode</td>
<td>- Housing assembly</td>
<td>- Housing assembly</td>
</tr>
<tr>
<td>- Nickel</td>
<td>graphite)</td>
<td>coating</td>
<td>- Electrical connection</td>
<td>- Electrical connection</td>
</tr>
<tr>
<td>- Lithium</td>
<td>- Electrolyte</td>
<td>- Winding/stapling</td>
<td>(power/signal)</td>
<td>- Main sub-assemblies</td>
</tr>
<tr>
<td>- Graphite</td>
<td>- Separator foil</td>
<td>- Electrolyte filling</td>
<td>- HV contactors</td>
<td>- Module controller</td>
</tr>
<tr>
<td>- Solvents</td>
<td>- Cell housings</td>
<td>- Sealing</td>
<td>- BMS</td>
<td>- Cell connectors</td>
</tr>
<tr>
<td>Tier-1/OEM</td>
<td>26%</td>
<td>8%</td>
<td>21%</td>
<td>7%</td>
</tr>
<tr>
<td>Tier-3</td>
<td>16%</td>
<td>29%</td>
<td>Tier-1/OEM</td>
<td>Tier-2</td>
</tr>
<tr>
<td>Tier-2</td>
<td>11%</td>
<td>26%</td>
<td>Tier-1</td>
<td>Tier-3</td>
</tr>
<tr>
<td>OEM</td>
<td>9%</td>
<td>29%</td>
<td>Tier-2</td>
<td>Tier-1</td>
</tr>
</tbody>
</table>

- Raw materials
  - Cobalt
  - Nickel
  - Lithium
  - Graphite
  - Solvents

- Processing of battery materials
  - Main materials
    - Active materials (e.g. NCM, graphite)
    - Electrolyte
    - Separator foil
    - Cell housings

- Production of single cells
  - Main processes
    - Mixing and electrode coating
    - Winding/stapling
    - Electrolyte filling
    - Sealing
    - Formation and ageing

- Production of cell modules
  - Main processes
    - Stapling
    - Electrical connection (power/signal)
    - Main sub-assemblies
      - Module controller
      - Cell connectors

- Assembly of battery system
  - Main processes
    - Housing assembly
    - Electrical connection
  - Main sub- assemblies
    - HV contactors
    - BMS
    - Module connectors
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)
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)

<table>
<thead>
<tr>
<th>Main specifications</th>
<th>ICE</th>
<th>PHEV</th>
<th>BEV</th>
<th>FCEV</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 kW (gasoline)</td>
<td></td>
<td></td>
<td>85 kW (gasoline)/75 kW_{peak} (electric)</td>
<td>100 kW_{peak} (electric)</td>
</tr>
<tr>
<td>Automatic transmission (double clutch)</td>
<td></td>
<td></td>
<td></td>
<td>100 kW_{peak} (electric)</td>
</tr>
<tr>
<td>Range ca. 700 km</td>
<td></td>
<td></td>
<td></td>
<td>Range ca. 400 km (thereof ca. 75 km battery-electric)</td>
</tr>
</tbody>
</table>

**Powertrain product costs (€ thousand)**

ICE

- 2020: 4.5 – 5.5
- 2025: 4.5 – 5.5
- 2030: 5 – 6

PHEV

- 2020: 7.5 – 9.5
- 2025: 7 – 8.5
- 2030: 7 – 8.5

BEV

- 2020: 8.5 – 10.5
- 2025: 7 – 8.5
- 2030: 6 – 7.5

FCEV

- 2020: 40
- 2025: 20
- 2030: 7.5 – 9.5

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Strategy&

Product costs only based material and assembly costs, excluding research & development (R&D), sales, general & administrative (SG&A) cost.
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></th>
<th>Most economical solution</th>
<th>Key findings</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vehicle segment</strong></td>
<td><strong>Range</strong></td>
<td><strong>Viable powertrains</strong></td>
<td><strong>Evolution of TCO leader</strong></td>
</tr>
<tr>
<td>A/B</td>
<td>Budget 70 kW</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>150 km</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mid</td>
<td>300 km</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Long</td>
<td>600 km</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C/D</td>
<td>Volume 100 kW</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mid</td>
<td>300 km</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Long</td>
<td>600 km</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extra-long</td>
<td>800 km</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E/F</td>
<td>Premium 250 kW</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mid</td>
<td>300 km</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Long</td>
<td>600 km</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extra-long</td>
<td>800 km</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **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**

- 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)

- Real **long-range** capability of BEVs is technically limited, only PHEV and FCEV are alternatives for real-life long-range

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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
3 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**

The specific powertrain features should be shaped along the customer value proposition within the vehicle portfolio.

**Dominant powertrain types**

- **Premium city BEV**: Highly dynamic and green. Range up to technical maximum.
- **Distinctive green rocket BEV**: Highly dynamic and green. Range for use in urban area only.
- **Rational green BEV**: Low-cost and green. Orientated to actual required everyday range.
- **Pure-play ICE**: • Driving dynamics and comfort weaker than for electrified drives • Low-cost economic • Independent of weak infrastructure • Highly dynamic and green • Range for use in urban area only
- **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
- **Sustainable prime FCEV**: • Highly dynamic and green • Range up to technical maximum
- **Marathon runner ICE**: • Driving dynamics and comfort weaker than for electrified drives • Allrounder with long-range capability

**Operating costs**

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

**Sustainability**

- **Pure-play ICE**: • Low-cost and green • Orientated to actual required everyday range
- **Sustainable prime FCEV**: • Highly dynamic and green • Range up to technical maximum
- **Distinctive green rocket BEV**: • Highly dynamic and green • Range for use in urban area only
- **Marathon runner ICE**: • Driving dynamics and comfort weaker than for electrified drives • Allrounder with long-range capability

**Dynamics**

- **Pure-play ICE**: • Low-cost and green • Orientated to actual required everyday range
- **Sustainable prime FCEV**: • Highly dynamic and green • Range up to technical maximum
- **Distinctive green rocket BEV**: • Highly dynamic and green • Range for use in urban area only
- **Marathon runner ICE**: • Driving dynamics and comfort weaker than for electrified drives • Allrounder with long-range capability

**Flexibility**

- **Pure-play ICE**: • Low-cost and green • Orientated to actual required everyday range
- **Sustainable prime FCEV**: • Highly dynamic and green • Range up to technical maximum
- **Distinctive green rocket BEV**: • Highly dynamic and green • Range for use in urban area only
- **Marathon runner ICE**: • Driving dynamics and comfort weaker than for electrified drives • Allrounder with long-range capability
Development focus should be based on the future expectation of relevant powertrain features

**Powertrain features and development focus**

**Mainstream powertrain configurations**

**ICE**
- **Pure-play ICE**
  - A/B segment
  - 3-4 cylinder gasoline
  - 40-60 kW
- **Marathon runner ICE**
  - C-E segment
  - 3-4 cylinder gasoline or diesel
  - 60-150 kW

**PHEV**
- **Dynamic yet zero-emission capable PHEV**
  - D/E segment
  - 4-cylinder gasoline, 80-200 kW
  - 100-200 km (20-40 kWh)
  - 40-150 kW_{el}

**BEV**
- **Rational green BEV**
  - A-C segment
  - 120-300 km (20-50 kWh)
  - 40-80 kW
- **Premium city BEV**
  - A/B segment
  - 150-250 km (20-30 kWh)
  - 60-100 kW
- **Distinctive green rocket**
  - C/D segment
  - 300-500 km (55-80 kWh)
  - 150-350 kW

**FCEV**
- **Sustainable prime FCEV**
  - E/F segment
  - 100-200 km (20-40 kWh), grid rechargeable (“plug-in”)
  - 500-800 km (6-8 kg H2)
  - 80-120 kW_{cell} FC stack, 150-350 kW_{peak} axle

**Implications on component strategy**

- **ICE**
  - 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

- **PHEV**
  - 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

- **BEV**
  - 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)

- **FCEV**
  - 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
- 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

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
We would be happy to discuss our study with you
Thank you