strategy&

Staying profitable in the new era of electrification

Powertrain study 2020

pwc

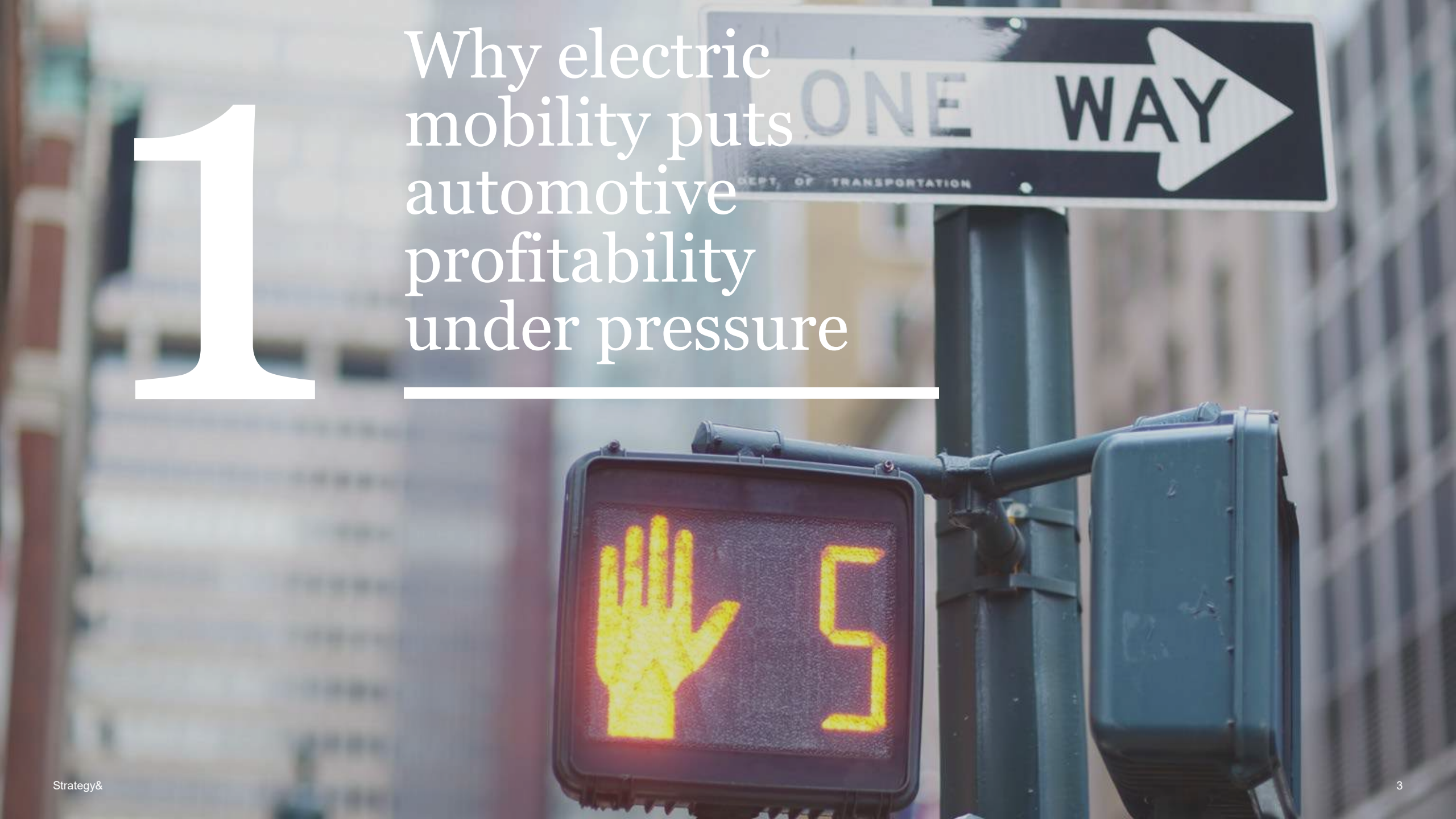
Staying profitable in the new powertrain age

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

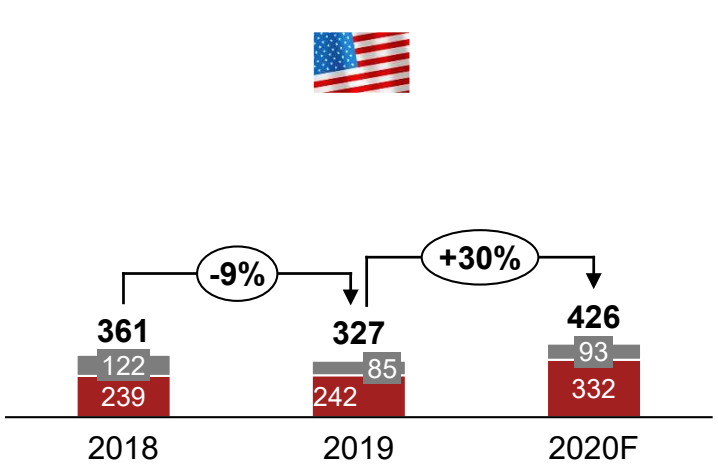
1

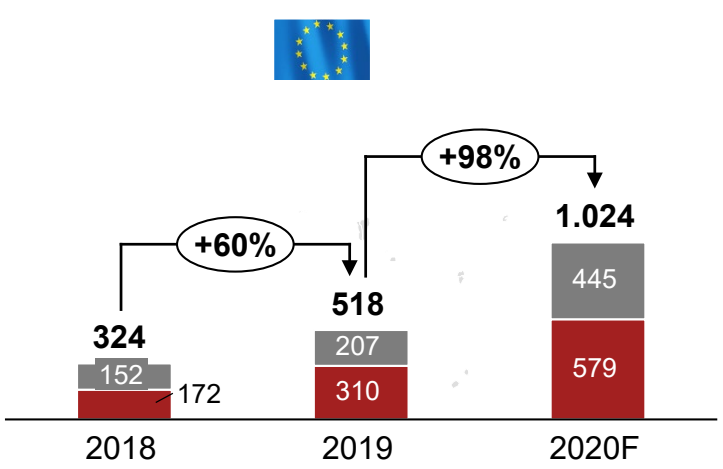
Why electric mobility puts automotive profitability under pressure

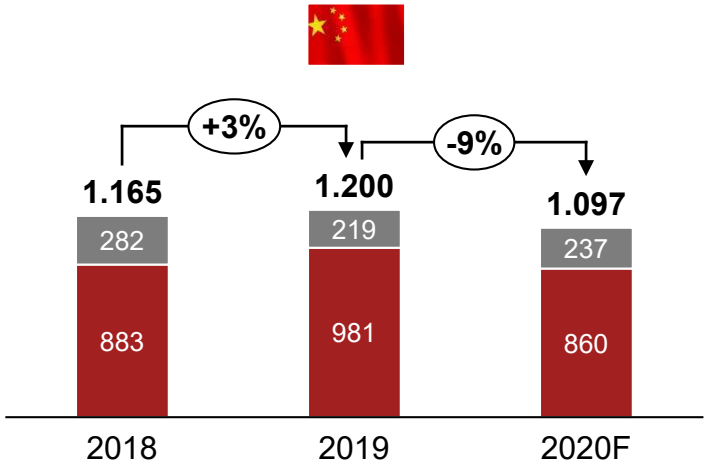


xEV sales in China has slowed down – Europe has become the main growth market

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

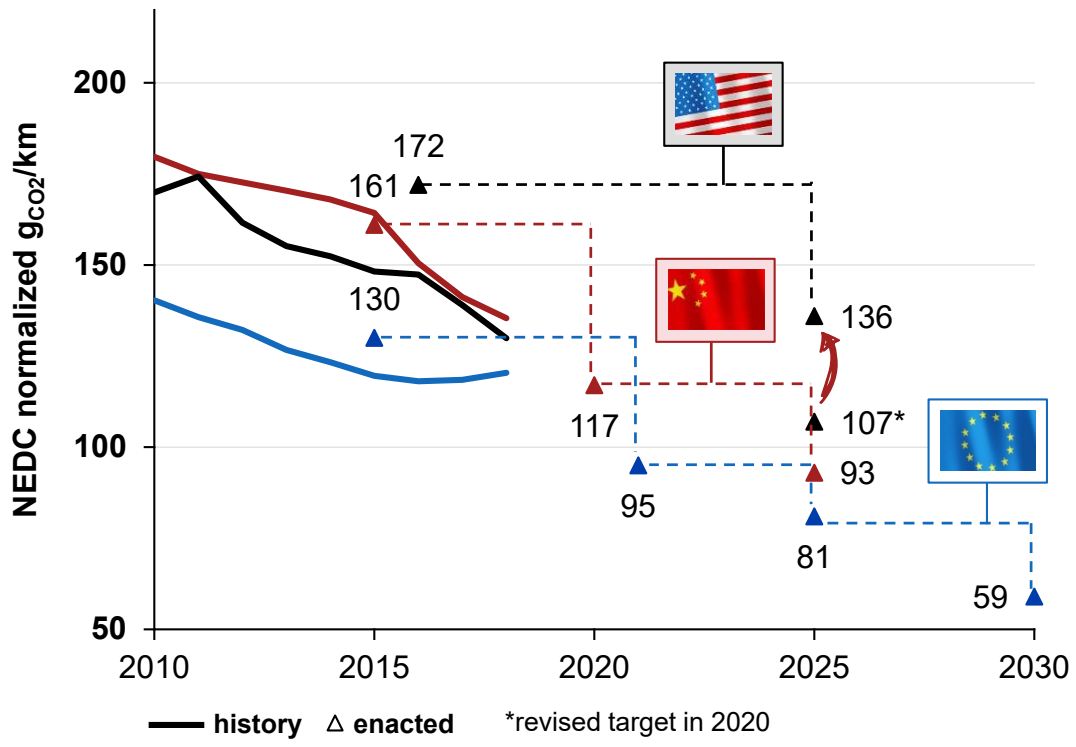
- As response to COVID-19, financial subsidies for NEV[2)] extended until the end of 2022
- In the next 3 years, gradually increase of the mandated production quota for NEV. Fines for non-compliance for manufacturers
- Quotas on license plate removed for NEV and somewhat relaxed for ICE (e.g. in Hangzhou)

1) CARB – Californian air resource board 2) NEV – New Energy Vehicle
Source: Autofacts analysis, IHS Markit

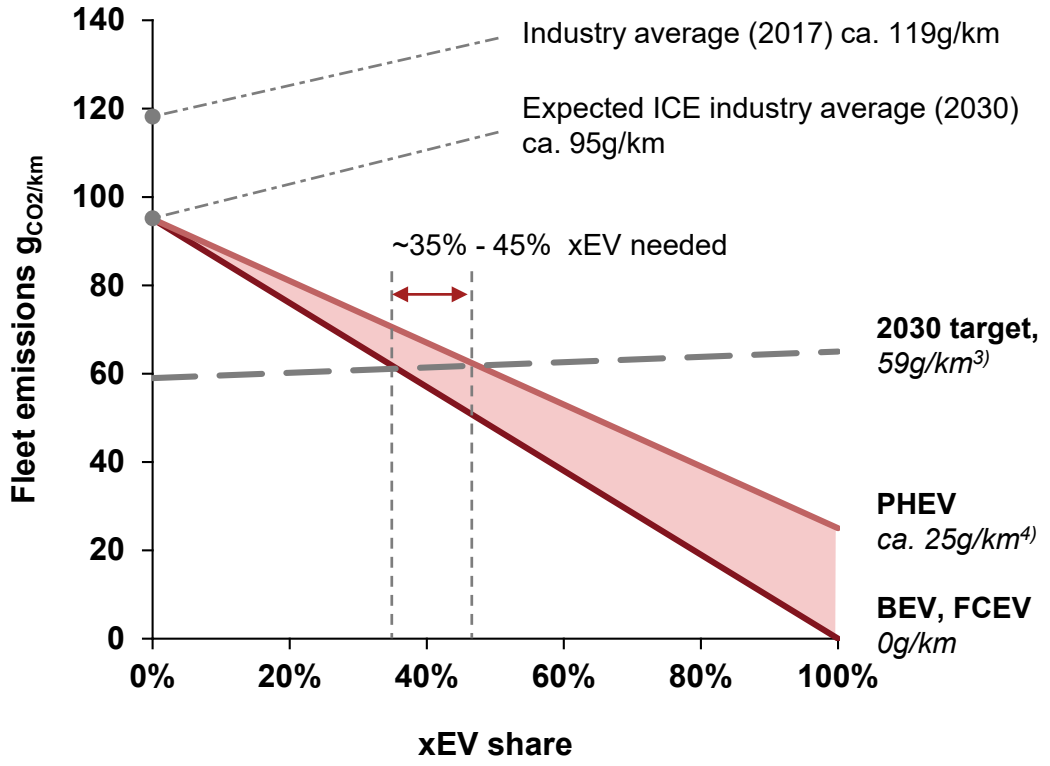
In order to achieve the 2030 fleet targets, an electrified vehicle share of ca. 35% to 45% xEV (BEV, PHEV) is required

Legislative trends – CO_2 fleet targets and xEV effect

International CO_2 fleet targets



Effect of xEV on fleet emissions[1,2)]

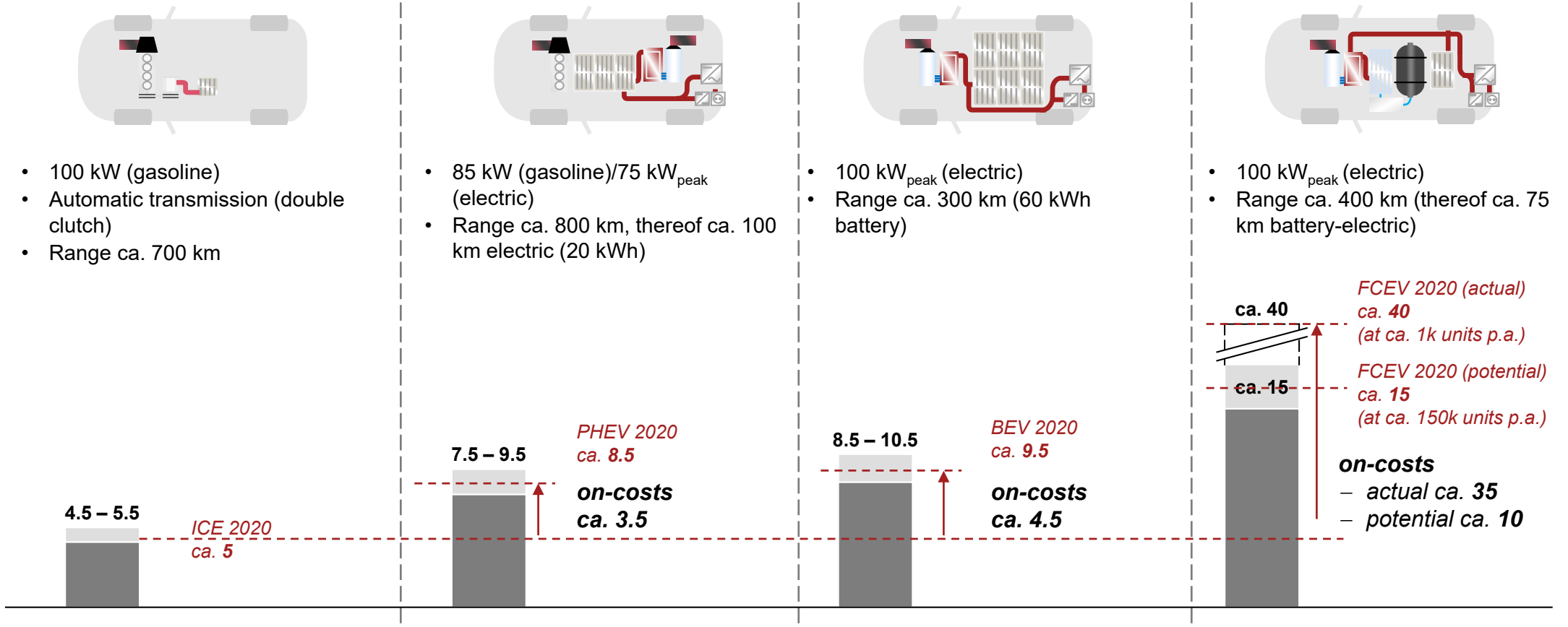


1) As for volume manufacturers (>300 thousand units p.a.) 2) Super credits not shown, due to discontinuation after 2022 3) Additional weight of BEV taken into account
4) Based on WLTP utility factor
Sources: https://theicct.org/chart-library-passenger-vehicle-fuel-economy, Strategy& analysis

Electrified vehicles (xEV) come with higher product costs – ca. 3500 € … 10000 € vs. an ICE

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

	ICE	PHEV	BEV	FCEV
Main specifications	• 100 kW (gasoline) • Automatic transmission (double clutch) • Range ca. 700 km	• 85 kW (gasoline)/75 kW_{peak} (electric) • Range ca. 800 km, thereof ca. 100 km electric (20 kWh)	• 100 kW_{peak} (electric) • Range ca. 300 km (60 kWh battery)	• 100 kW_{peak} (electric) • Range ca. 400 km (thereof ca. 75 km battery-electric)



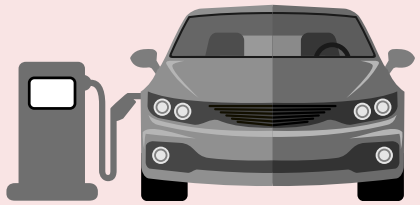
Product costs only based material and assembly costs, excluding research & development (R&D), sales, general & administrative (SG&A) cost

Due to increased product costs with limited price potential, contribution margins are decreasing and profitability is under threat

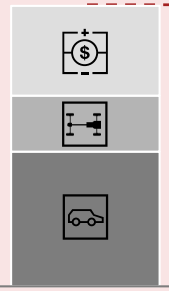
Electrified vehicle profitability

The old world

ICE as-is



Reference price as-is



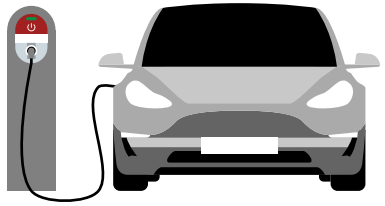
- Contribution margin
- Powertrain costs
- Vehicle costs without powertrain

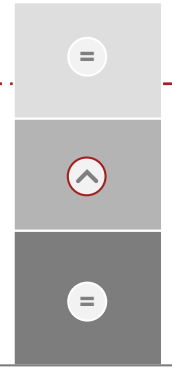
Fleet targets not achievable

Margin satisfying

Electrified vehicle traits

A The premium solution



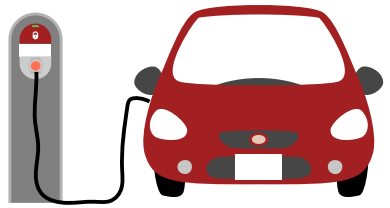


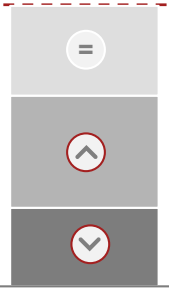
- **Increase** sales price
- **Maintain** contribution margin ratio

Critical (limited sales)

Satisfying

B The spartan niche



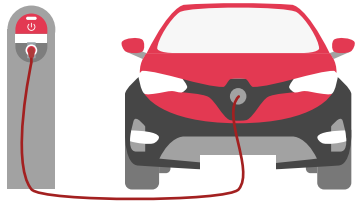


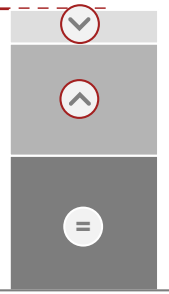
- **Maintain** price
- **Reduce** vehicle costs and specs

Under threat (limited sales)

Satisfying

C The volume challenge



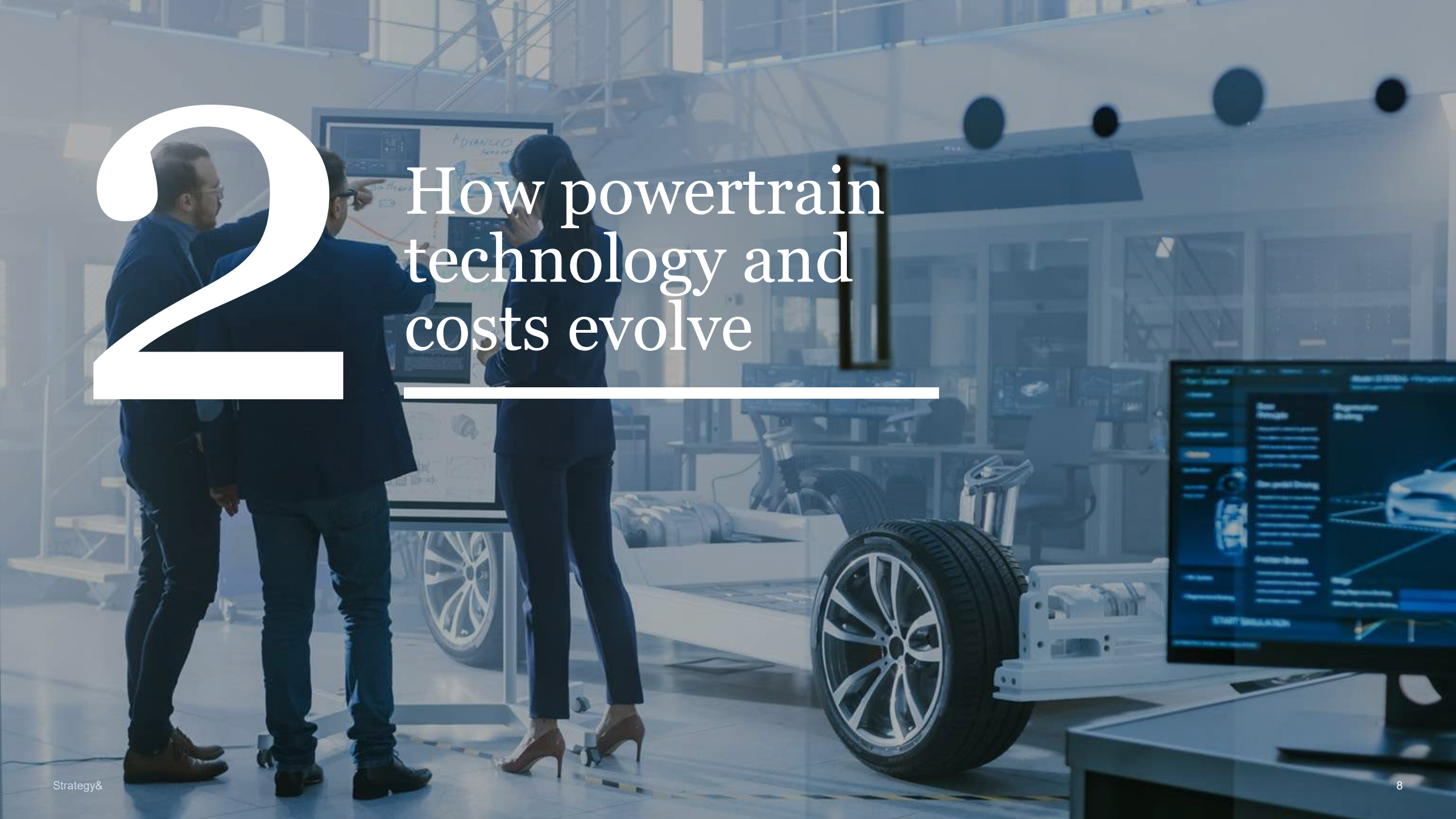


- **Maintain** price
- **Reduce** contribution margin ratio

Met

Under threat

Fleet targets | Margin | Uncritical | Critical



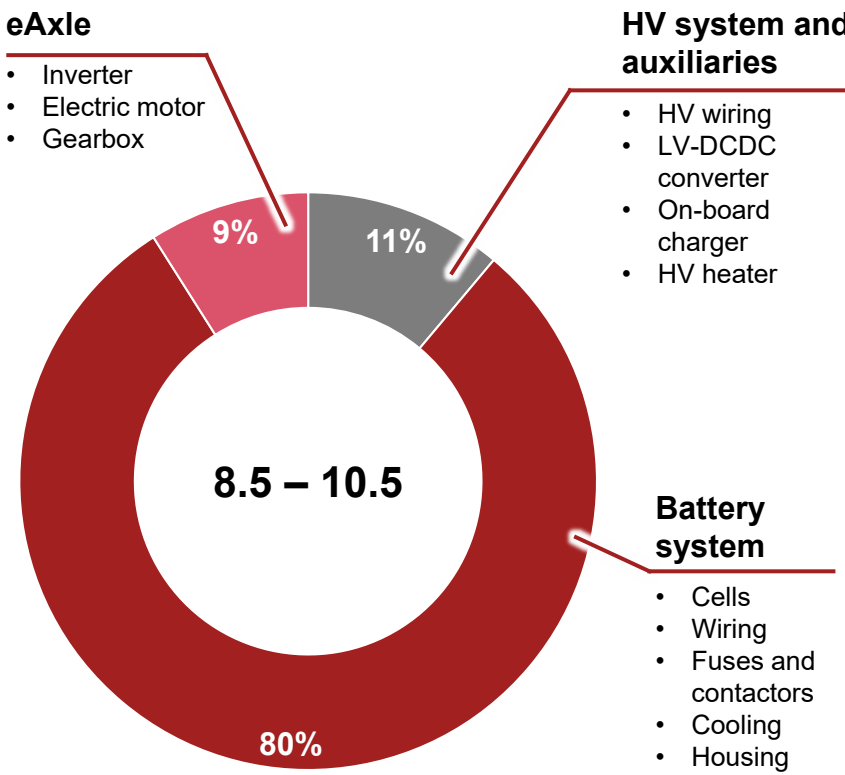
2 How powertrain technology and costs evolve

The battery cells comprise most of the BEV powertrain costs – a closer look at its value chain is imperative

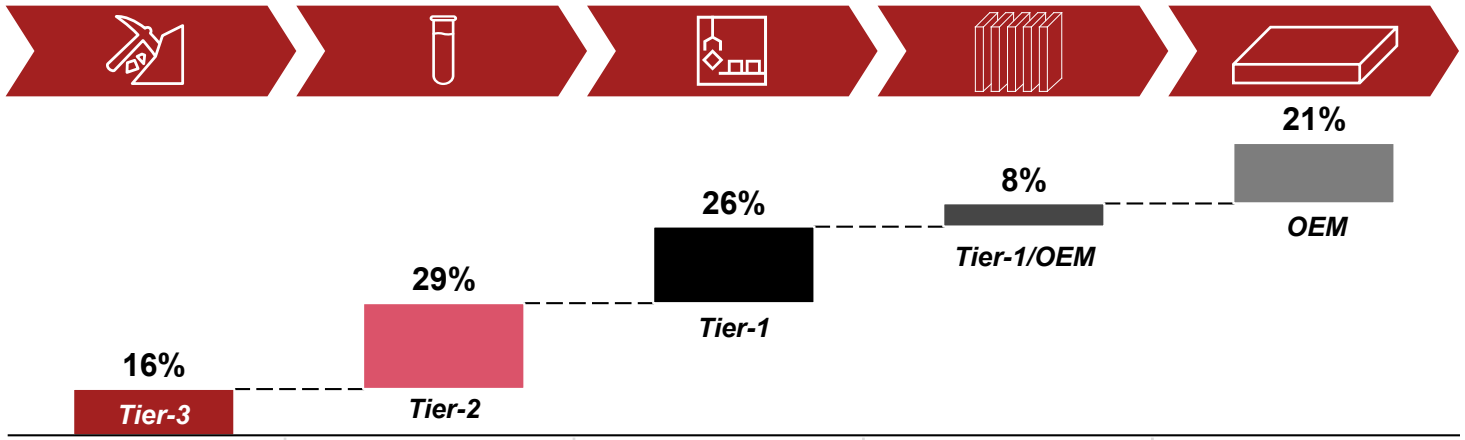
Enable value chain optimization: Significance of battery and cell costs for BEV

Typical cost breakdown BEV powertrain

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



Automotive battery value chain and value share

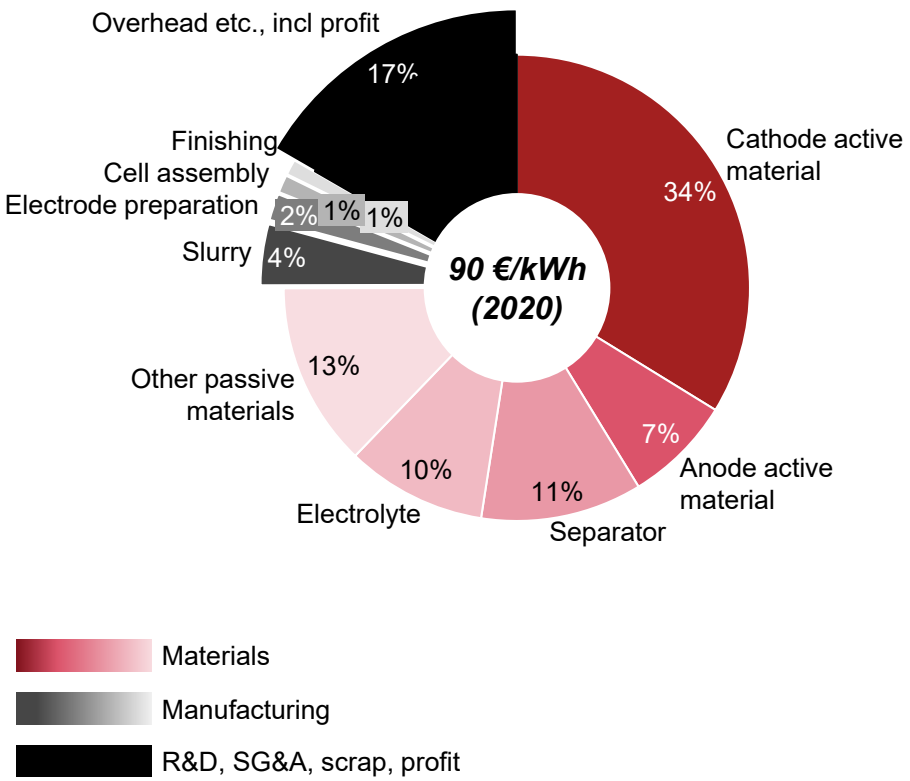


Raw materials and precursors	Processing of battery materials	Production of single cells	Production of cell modules	Assembly of battery system
• Main materials – Cobalt – Nickel – Lithium – Graphite – Solvents	• Main materials – Active materials (e.g. NCM, graphite) – Electrolyte – Separator foil – Cell housings	• 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

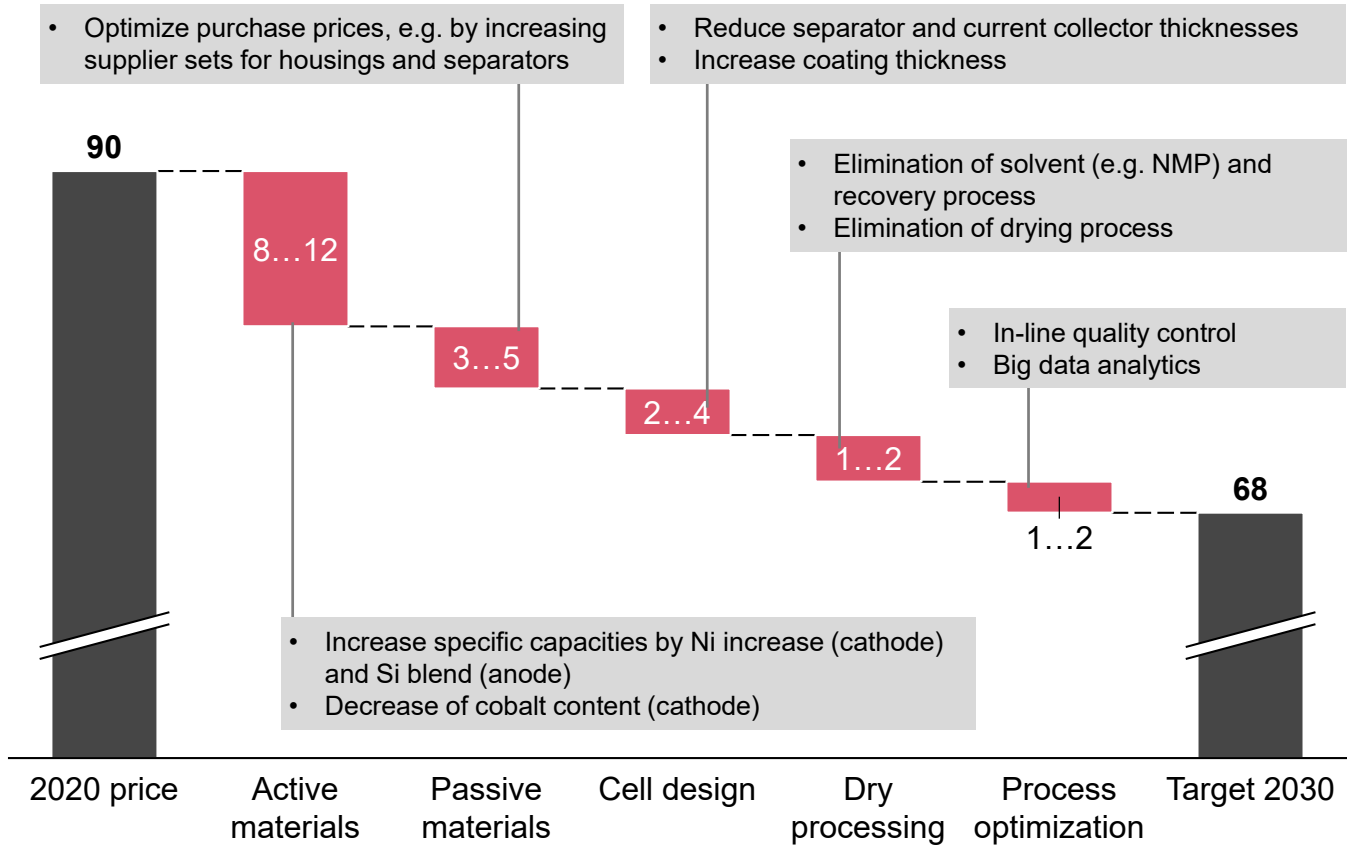
Depending on realization of optimization we see a decline from 90 to 68 €/kWh for large automotive battery cells

Battery cell prices and optimization

Cell price breakdown (2020)



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



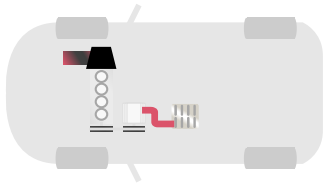
Large (>70 Ah) automotive cells in large quantities (>10 GWh/p.a.)
Source: Strategy& battery cost model

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)

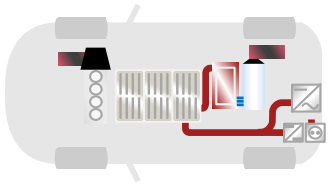
Main specifications

ICE



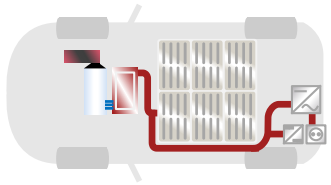
- 100 kW (gasoline)
- Automatic transmission (double clutch)
- Range ca. 700 km

PHEV



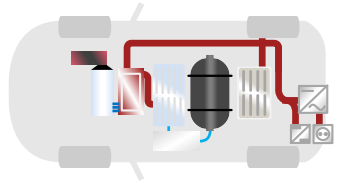
- 85 kW (gasoline)/75 kW_{peak} (electric)
- Range ca. 800 km, thereof ca. 100 km electric (20 kWh)

BEV



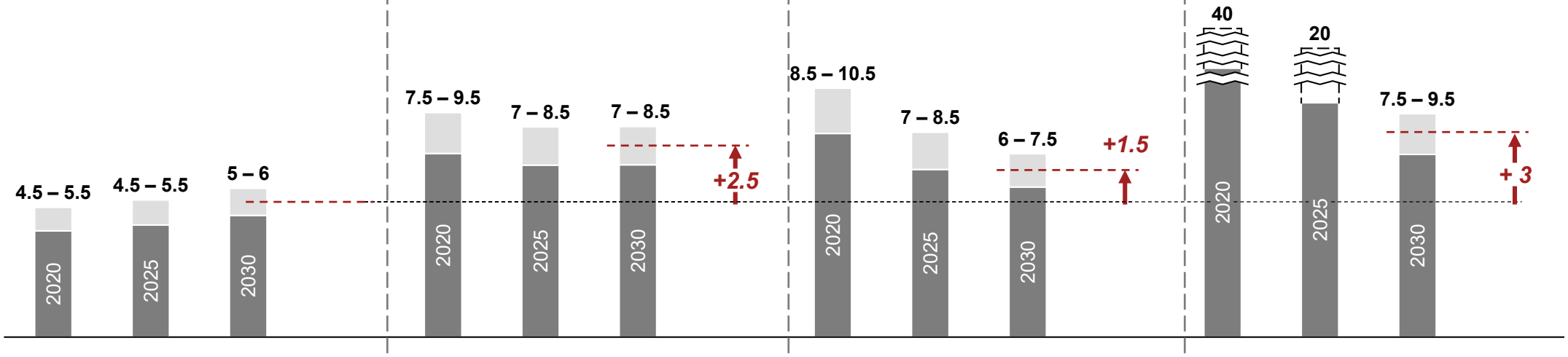
- 100 kW_{peak} (electric)
- Range ca. 300 km (60 kWh battery)

FCEV



- 100 kW_{peak} (electric)
- Range ca. 400 km (thereof ca. 75 km battery-electric)

Powertrain product costs (€ thousand)



Product costs only based material and assembly costs, excluding research & development (R&D), sales, general & administrative (SG&A) cost

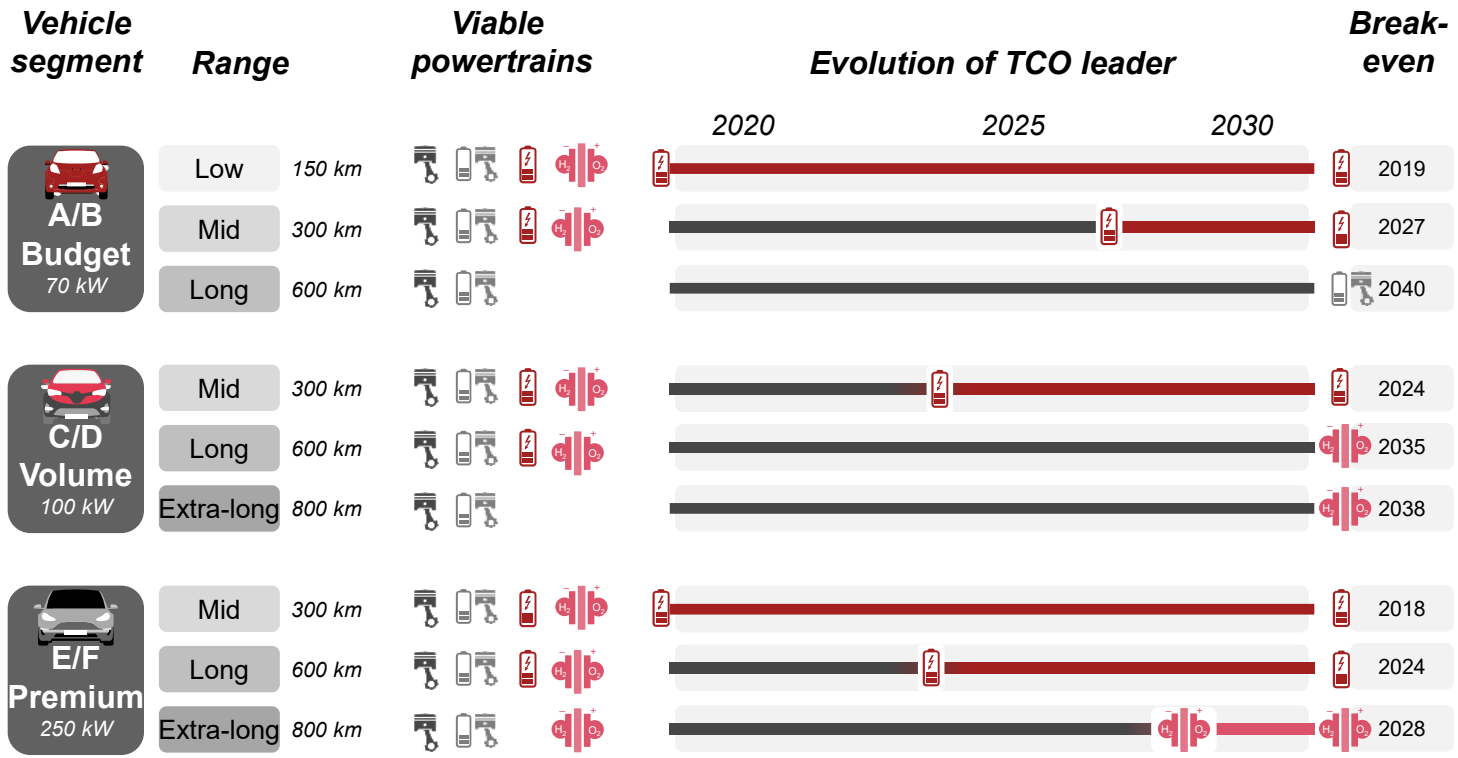
BEVs will become economic for several segments – but extended ranges (600 km+) will not be viable with BEVs

Economics of selected vehicle/powertrain combinations

Parameters

Most economical solution

Key findings



- 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

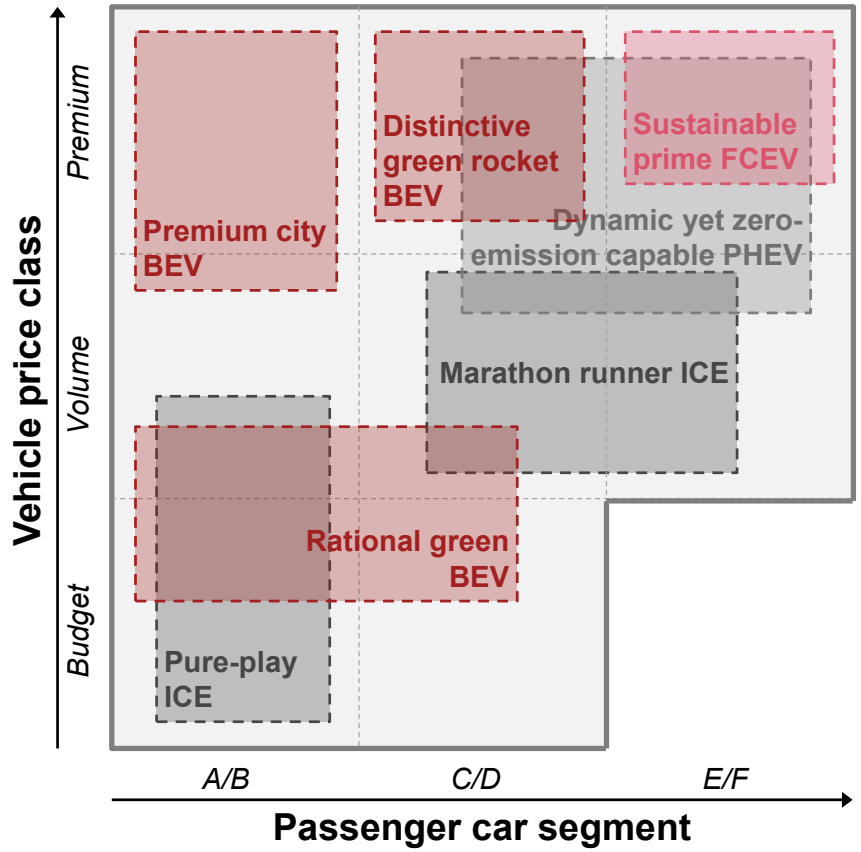
3

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

Dominant powertrain types



Powertrain archetypes

ICE

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

PHEV

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

BEV

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

FCEV

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

Pronounced powertrain features: Sustainability, Dynamics, Flexibility, Operating costs

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
- 3-4 cylinder gasoline, 80-200 kW
- 100-200 km_{el} (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_{el} (20-40 kWh), grid rechargeable ("plug-in")
- 500-800 km_{H2} (6-8 kg H2)
- 80-120 kW_{const} FC stack, 150-350 kW_{peak} axle

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 H_2**
- **"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***

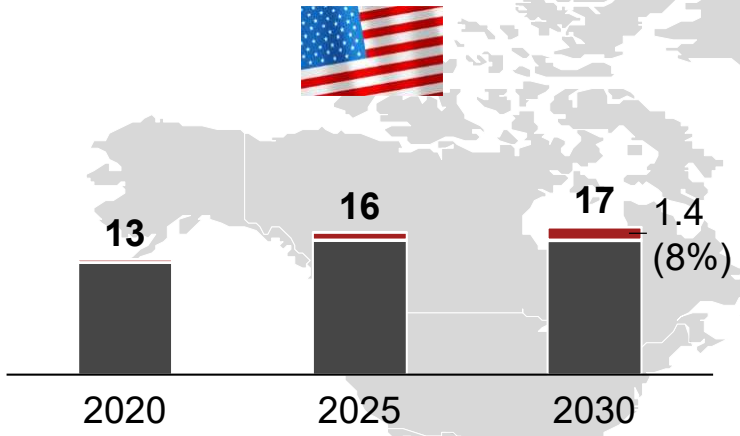
Pronounced powertrain features: Sustainability; Dynamics; Flexibility; Operating costs

4 Implications and recommendations

Electric vehicle sales boosted by legislation in China and EU

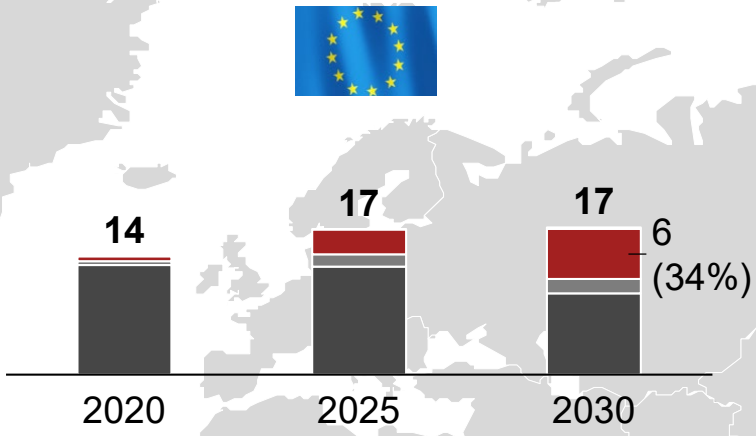
Market outlook to 2030

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



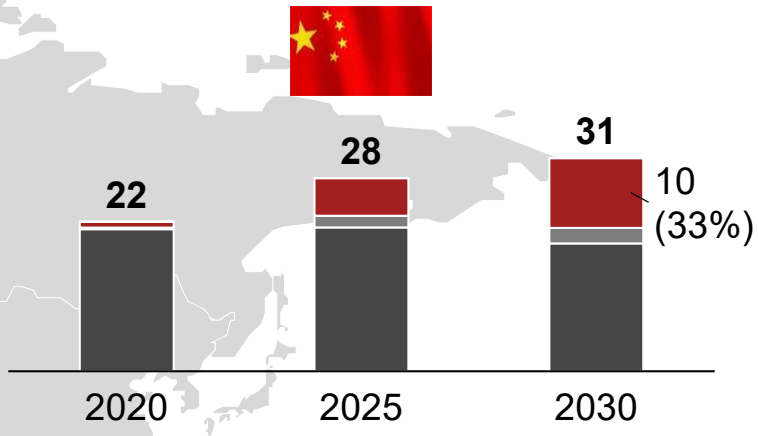
USA

- 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

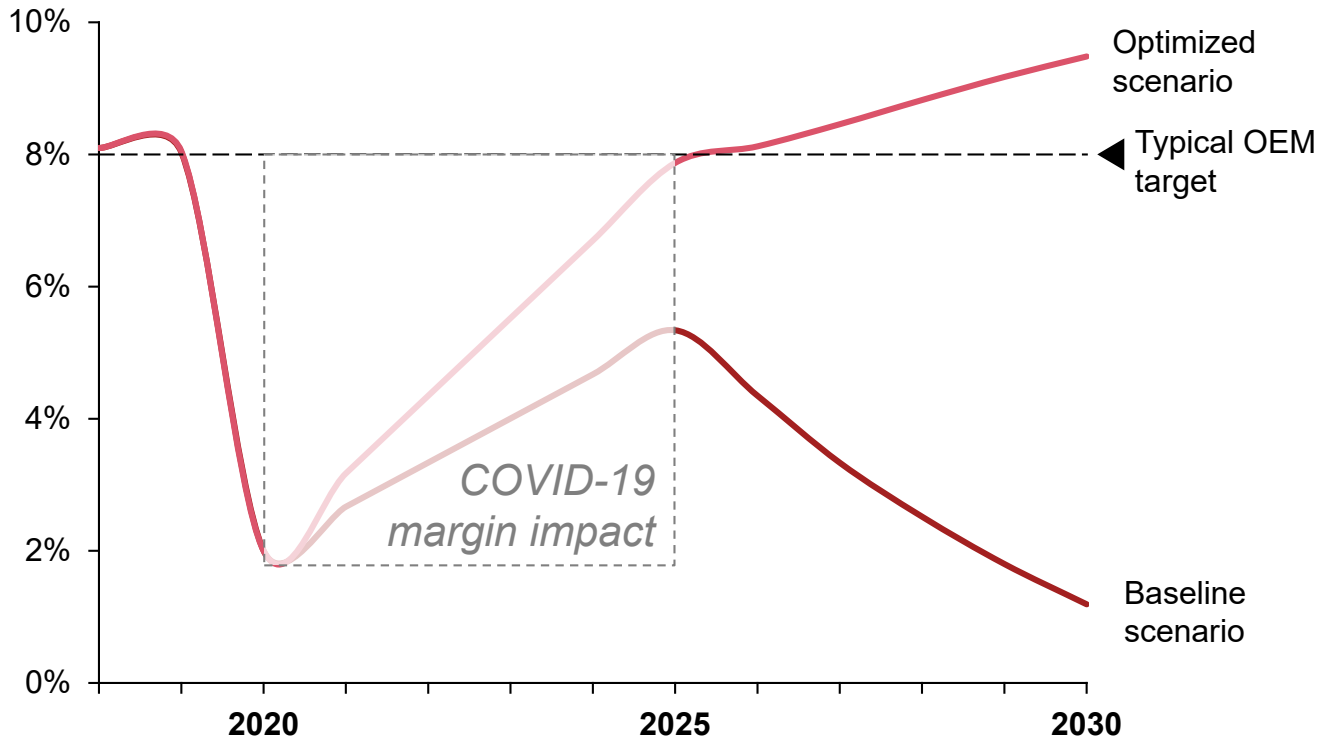
FCEV BEV PHEV Rest ICE

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

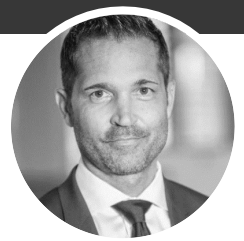
Baseline scenario:

- **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

We would be happy to discuss our study with you



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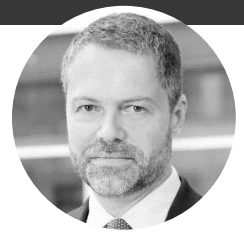

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