Global Powertrain Model Forecast

Edward Anculle

BCG Automotive and Mobility Introduction

Boston Consulting Group

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Global consulting firm that partners with leaders in business and society to tackle their most important challenges and capture their greatest opportunities
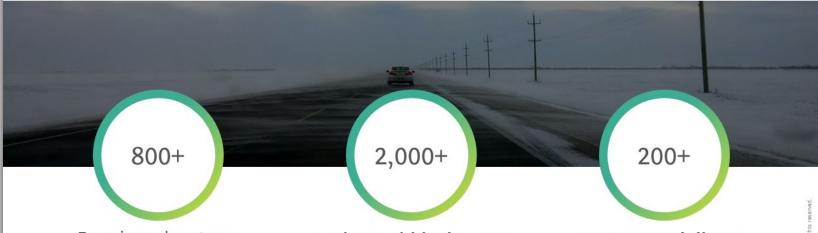
- **25,000** employees including management consultants, economists, engineers, physicists, mathematicians, data scientists, and more
- **$11Bn** global revenues
- Offices in **90+** cities in **50+** countries
- Founded by Bruce Henderson in **1963**

Unlocking the Potential of Those Who Advance the World

BCG Automotive and Mobility

800+

Experienced partners, principals, project leaders, analysts, and researchers' **members of BCG's A&M core team**

2,000+

Projects within the past 5 years across Automotive and Mobility sector globally

200+

BCG xEV and climate change experts with >30 dedicated battery experts, with deep knowledge on battery technologies and market dynamics

Note: Status December 2021

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BCG Automotive and Mobility

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Digital in Automotive
- 350+ experts in digital transformation
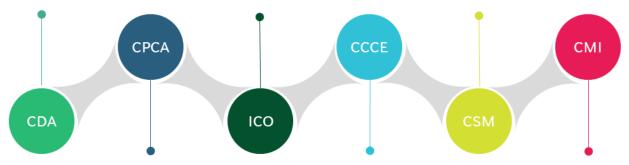- Proven framework of "digital house" how to assess digitalization

CENTER FOR
Innovation Center *for* Operations
- 10 ICOs operated across the world for tangible I4.0 experience
- 85 technical providers across regions

CENTER FOR
Sales and Marketing in Automotive
- Key areas of activity are digital marketing, future of retail network, pricing and analytics, omnichannel customer experience

CPCA

CCCE

CMI

CDA

ICO

CSM

CENTER FOR
Product Creation in Automotive
- Leading thinking on product development
- Cross-functional approach with adjacent functions like purchasing and manufacturing

CENTER FOR
Climate Change & Electrification
- Expertise and tools in an electrified and low-carbon future
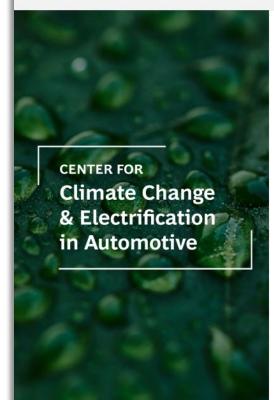- 20+ publications, 200+ experts globally and 20+ integrated models

CENTER FOR
Mobility Innovation
- "Future mobility" offerings for companies, authorities, and cities
- Value propositions based on scenarios, urban mobility accelerator, collaboration platforms, and city engagement strategies

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BCG's Center for Climate Change and Electrification

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CENTER FOR
**Climate Change
& Electrification
in Automotive**

Develops leading expertise and products in support of our private and public sector clients as they seek to build winning strategies, operations, and organizations in an electrified and low-carbon future

Our insights have served as the basis for the automotive industry since our first forecast was shared in 2009

The BCG powertrain model projects new vehicle sales by powertrain, vehicle segment, and country. It is key input to other BCG Automotive & Mobility models

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Synchronized to maximize client's value

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Powertrain model feeds other key BCG mobility tools

Profit Pool Model
- Integrated BCG view on A&M profit pools, and shift over the next 15 years
- Covers the entire value chain, from component manufacturing via vehicle sales and after sales to mobility services

Carparc (VIO) Model
- Calculates and forecasts powertrain distribution of vehicles in operation (VIO)
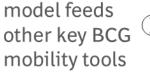- Global and key markets focus

Li-ion Battery Supply Chain Model
- Quantifies and forecasts demand of key li-ion battery mid-stream products and raw material
- Assess supply chain gap, and estimates TAM
- Global and key markets focus

Recycling Model
- Forecasts kilotons materials by region, including manufacturing scrap & end-of-life vehicles
- Matches up forecast vs regulatory requirements such as EU battery directive

O&G Oil Demand Model
- Forecasts oil and gas product demand
- Projections until 2050

Emissions Model
- Quantifies and forecasts CO_2 emissions impact of VIO
- Global and key markets focus

Charging Model
- Forecasts EV charging points, energy demand, revenues and value pools
- Covert home, workplace, destination and en-route chargers (slow, medium, fast and HPC)
- Regions and country level focus

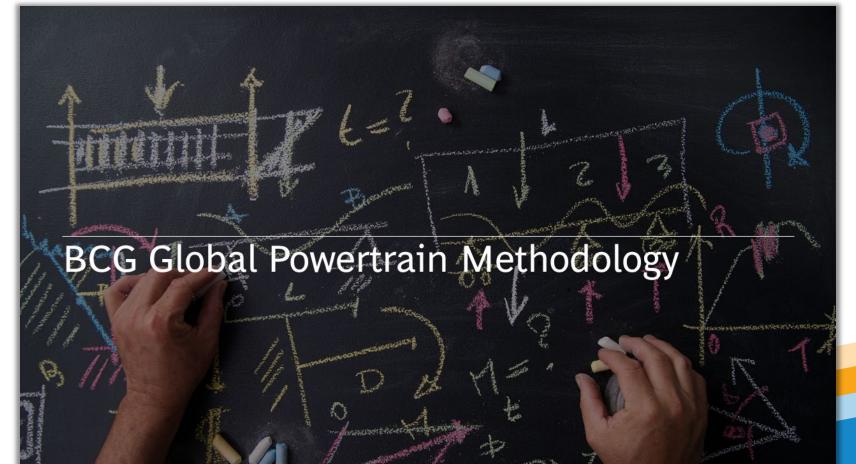**Aftermarket and Services Model**
- Evaluates TAM of key aftermarket products

BCG Global Powertrain Methodology

Process leverages BCG global footprint and multi-industry experience

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Committee and Requirements	Data Collection and Analysis	Modeling	Model Pressure Test	Publication and Client Discussions
• **Assemble team with a global footprint**	• **Collect, assess and triangulate data** from internal and external sources, including:	• **Leverage on internal algorithms and multi-industry BCG IP to estimate**:	• Identify key model drivers, and quantify impact by performing a **sensitivity analysis**	• Progressively disclose results to key clients to discuss clarifications, assumptions, and impact of results
• Set new forecast goals i.e. incentives granularity, countries scope, sensitivity analysis, etc.	– Global incentives and regulations	– Total Cost of Ownership (TCO)	• Highlight the "IF" scenarios that would enable alternative adoptions	• Summarize results and distribute models across global teams and other BCG models
• Highlight key past and forthcoming events, perform focused research	– Market actuals per region, production by powertrain, market segments, etc	– Adoption rate (S-Curves) by segment, powertrain, and region	• Discuss results with a broader group of BCG automotive experts	• **Publish main results to the industry**
• **Define timeline, strategies, and key venues of publication**	– BCG view of future battery prices and powertrain costs (xEV and ICE)	– Fleet emissions regulatory status and impact	• If necessary, adjust model by adjusting key drivers, or adjust boundary conditions	
	– Energy & fuel prices by region, miles driven & new mobility updates	• **Develop and implement new algorithm branches driven by new market developments** i.e. ICE bans, customer behavior, etc.	• **Achieve a unified BCG view**	

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Analyzes key markets by sub-segments to forecast powertrain adoption

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Model countries & regions

20% US

18% Europe

6% Japan

24% Rest of the world

4% India

29% China

% indicates global market share of new light duty vehicle sales

Segment by key attributes

- **Powertrain type**: ICE Gasoline, ICE Diesel, ICE NG, HEV, BEV, PHEV, FCEV
- **Vehicle Type**: Small Car, Medium Car, Large Car, Pick up, Small SUV, Medium SUV, Large SUV
- MDT/HDT included in a different BCG model

Model each sub-segment

Algorithm runs through each individual sub-segment of key global markets
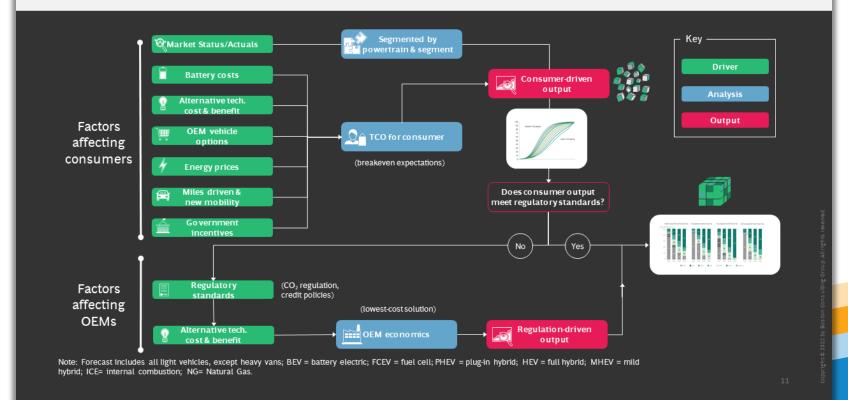
- **Model each individual sub-segment** in projected years and expected breakeven timeline
- Model with S-curve theory, sub-segment boundary conditions, and applicable regulation/incentives

Note: Forecast includes all light vehicles, except heavy vans; BEV = battery electric; FCEV = fuel cell; PHEV = plug-in hybrid; HEV = full hybrid; MHEV = mild hybrid; ICE= internal combustion; NG= Natural Gas; MDT/HDT = Medium Duty/Heavy Duty; SUV=Sports Utility Vehicle; Vehicle type follows internal BCG convention

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Each sub-segments goes through the following steps

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Factors affecting consumers:
- Market Status/Actuals
- Battery costs
- Alternative tech. cost & benefit
- OEM vehicle options
- Energy prices
- Miles driven & new mobility
- Government incentives

- Segmented by powertrain & segment
- TCO for consumer (breakeven expectations)
- Consumer-driven output

Does consumer output meet regulatory standards?
- No
- Yes

Factors affecting OEMs:
- Regulatory standards (CO_2 regulation, credit policies)
- Alternative tech. cost & benefit
- OEM economics (lowest-cost solution)
- Regulation-driven output

Key
- Driver
- Analysis
- Output

Note: Forecast includes all light vehicles, except heavy vans; BEV = battery electric; FCEV = fuel cell; PHEV = plug-in hybrid; HEV = full hybrid; MHEV = mild hybrid; ICE= internal combustion; NG= Natural Gas.

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Forecast follows a technology adoption curve driven by TCO parity

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xEV adoption in % of new LV sales

Illustrative

Later TCO parity

Earlier TCO parity

Sub-segment actuals

$$Market\ Penetration$$
$$= \frac{A}{(Q * e^{-t*\alpha} + 1)^{\wedge}(1/\upsilon)}$$

A – Steady-state penetration of cumulative market
μ - Mean year
Q – Scaling parameter
α – Scaling parameter
υ – Scaling parameter to move the tipping point in time

Years

Note: BCG Analysis

- Detailed Total Cost of Ownership (TCO) calculation for each sub-segment determines speed adoption

- Detailed assumptions feed TCO calculation
  - Vehicle prices and operating costs (taxes, insurance, maintenance, parking, etc.)
  - EV technology and development (battery cost and capacity, energy costs, maintenance savings, etc.)

- Maximum adoption for each powertrain segment is determined by considering
  - Infrastructure and legislation
  - Regulation and driving bans
  - Use cases for each technology type

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ICE modeled as an exponential decrease based on historical CAGRS

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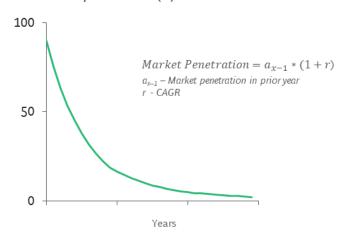
- Near-term decrease is driven by increasing regulatory pressure

- Decay is fastest in the near years, but remains significant as more cities ban diesel

- Steady-state penetration in a given segment is determined by in-country consumer preferences, e.g., diesels likely to remain in near-term in the truck segment
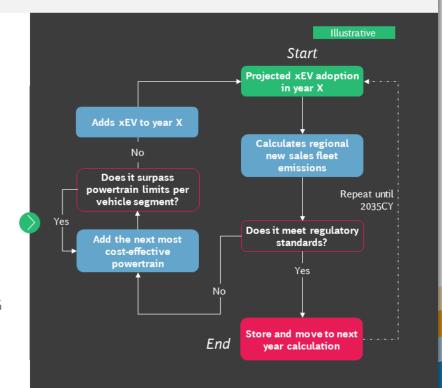
Note: BCG Analysis

ICE market penetration (%)

$$Market\ Penetration = a_{x-1} * (1 + r)$$

a_{x-1} – Market penetration in prior year
r - CAGR

Years

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Forecasts are adjusted by regulatory restrictions on year-by-year basis

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- Adjust upward the xEV powertrain mix based on the pure TCO-driven model results when the projected mix fails to meet country requirements

- Cost to OEMs is to be minimized at a market level, not for individual OEM fleets

- Added xEVs assumed to be the options with the lowest incremental cost per MPG or CO2
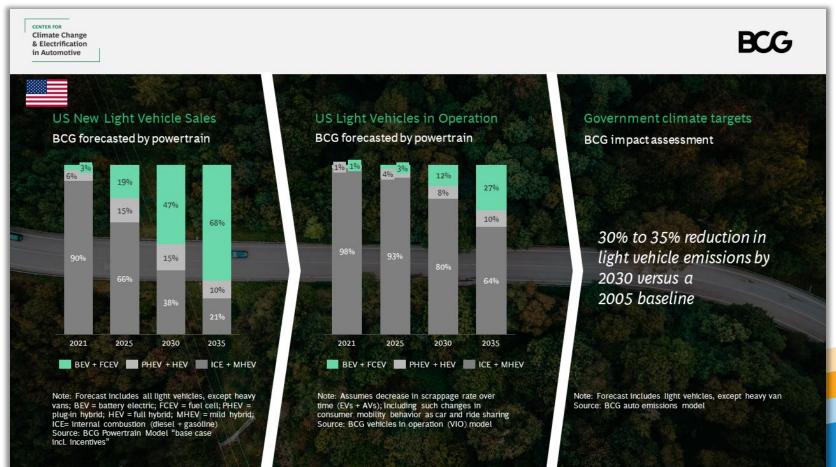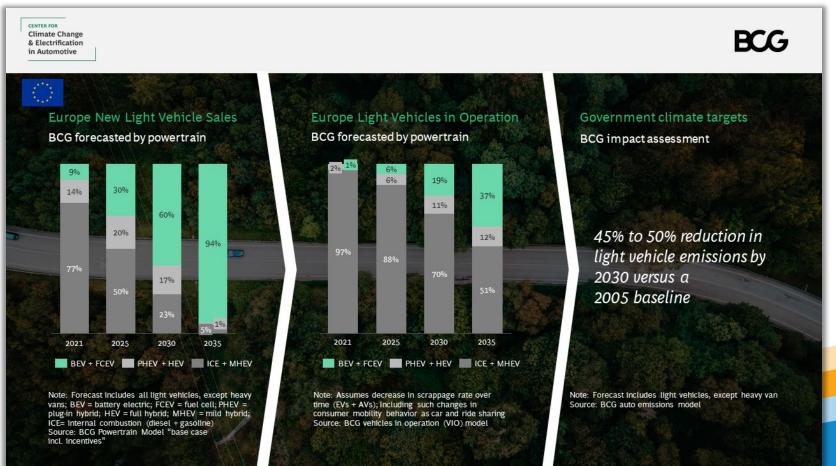
Note: BCG Analysis

Illustrative

Start

Projected xEV adoption in year X

Calculates regional new sales fleet emissions

Does it meet regulatory standards?

Repeat until 2035CY

Adds xEV to year X

No

Does it surpass powertrain limits per vehicle segment?

Yes

Add the next most cost-effective powertrain

No

Yes

End

Store and move to next year calculation

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BCG Global Powertrain Results

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US New Light Vehicle Sales
BCG forecasted by powertrain

Year	BEV + FCEV	PHEV + HEV	ICE + MHEV
2021	3%	6%	90%
2025	19%	15%	66%
2030	47%	15%	38%
2035	68%	10%	21%

■ BEV + FCEV   ■ PHEV + HEV   ■ ICE + MHEV

Note: Forecast includes all light vehicles, except heavy vans; BEV = battery electric; FCEV = fuel cell; PHEV = plug-in hybrid; HEV = full hybrid; MHEV = mild hybrid; ICE= internal combustion (diesel + gasoline)
Source: BCG Powertrain Model "base case incl. incentives"

US Light Vehicles in Operation
BCG forecasted by powertrain

Year	BEV + FCEV	PHEV + HEV	ICE + MHEV
2021	1%	1%	98%
2025	3%	4%	93%
2030	12%	8%	80%
2035	27%	10%	64%

■ BEV + FCEV   ■ PHEV + HEV   ■ ICE + MHEV

Note: Assumes decrease in scrappage rate over time (EVs + AVs); Including such changes in consumer mobility behavior as car and ride sharing
Source: BCG vehicles in operation (VIO) model

Government climate targets
BCG impact assessment

30% to 35% reduction in light vehicle emissions by 2030 versus a 2005 baseline

Note: Forecast includes light vehicles, except heavy van
Source: BCG auto emissions model

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Europe New Light Vehicle Sales
BCG forecasted by powertrain

Europe Light Vehicles in Operation
BCG forecasted by powertrain

Government climate targets
BCG impact assessment

45% to 50% reduction in light vehicle emissions by 2030 versus a 2005 baseline

Europe New Light Vehicle Sales (BEV + FCEV / PHEV + HEV / ICE + MHEV):
- 2021: 9%, 14%, 77%
- 2025: 30%, 20%, 50%
- 2030: 60%, 17%, 23%
- 2035: 94%, 5%, 1%

Europe Light Vehicles in Operation (BEV + FCEV / PHEV + HEV / ICE + MHEV):
- 2021: 1%, 2%, 97%
- 2025: 6%, 6%, 88%
- 2030: 19%, 11%, 70%
- 2035: 37%, 12%, 51%

Legend: ■ BEV + FCEV ■ PHEV + HEV ■ ICE + MHEV

Note: Forecast includes all light vehicles, except heavy vans; BEV = battery electric; FCEV = fuel cell; PHEV = plug-in hybrid; HEV = full hybrid; MHEV = mild hybrid; ICE = internal combustion (diesel + gasoline)
Source: BCG Powertrain Model "base case incl. incentives"

Note: Assumes decrease in scrappage rate over time (EVs + AVs); Including such changes in consumer mobility behavior as car and ride sharing
Source: BCG vehicles in operation (VIO) model

Note: Forecast includes light vehicles, except heavy van
Source: BCG auto emissions model

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China New Light Vehicle Sales — BCG forecasted by powertrain

China Light Vehicles in Operation — BCG forecasted by powertrain

Government climate targets — BCG impact assessment

35% to 40% increase in light vehicle emissions by 2030 versus a 2005 baseline

Note: Forecast includes all light vehicles, except heavy vans; BEV = battery electric; FCEV = fuel cell; PHEV = plug-in hybrid; HEV = full hybrid; MHEV = mild hybrid; ICE = internal combustion (diesel + gasoline)
Source: BCG Powertrain Model "base case incl. incentives"

Note: Assumes decrease in scrappage rate over time (EVs + AVs); Including such changes in consumer mobility behavior as car and ride sharing
Source: BCG vehicles in operation (VIO) model

Note: Forecast includes light vehicles, except heavy van
Source: BCG auto emissions model

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