



The decarbonization path for the Auto sector in Brazil

SEPTEMBER 2021

The decarbonization path for the automotive sector in Brazil



Context and local forces

Industry context in Brazil

Forces that influence the evolution of technological routes

- Regulation
- Cost and technology
- Infrastructure
- ...



Development scenarios

What are possible future scenarios of electrification and decarbonization in Brazil?

What are the implications and externalities in each scenario?



International trends and case studies

References and learnings from other markets



Global context and the Brazilian market



Demand for climate action is accelerating

Recent commitments by **the** government of the two largest economies, the U.S. and China, to the climate transition; more countries are expected to up to COP26

120 Countries aim net zero in the Climate Ambition Alliance

Customers are willing to pay higher prices or trade for eco-friendly products

~20% of customers willing to pay more or shape climate behaviour

Investors continue to direct capital to climate-resilient companies (e.g. BlackRock announcement)

\$20T Global AUM¹ estimated to be allocated for investments in ESG in 2018

ESG standards and climate reports continue to strengthen and become more common

~60% of the world's largest companies support the TCFD standard for climate disclosures

Climate change poses increasingly serious risks to global supply chains

\$306B losses in agriculture due to the climate disaster in the U.S. in 2017

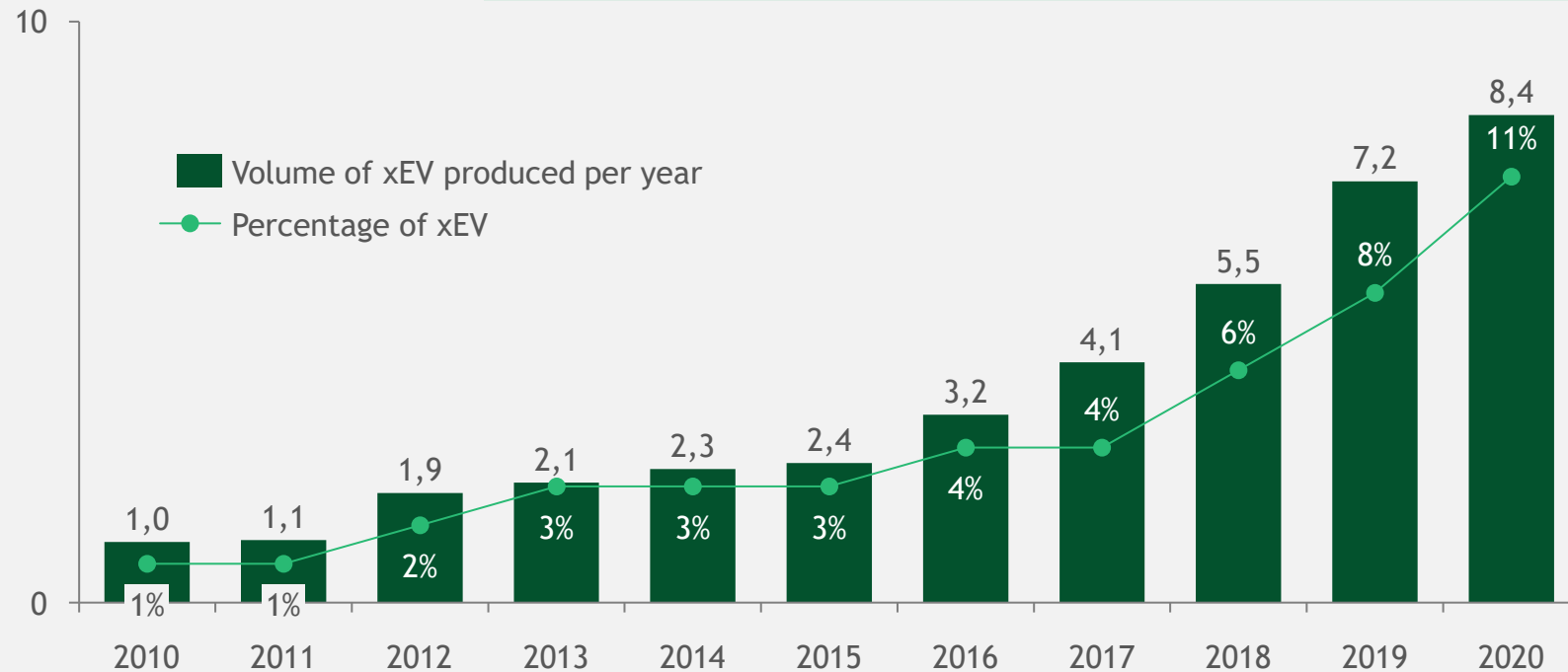
1. AUM: Assets Under Management

Sources: United Nations; Nielsen; Luc Hoffman Institute, *National Centers for Environmental Information*; World Economic Forum; TCFD Status report 2020; Analysis BCG

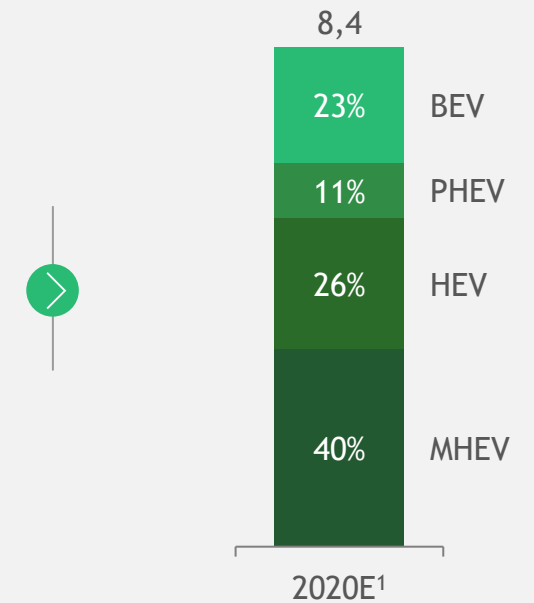
In this context, global sales of electrified vehicles (xEVs) have been growing in a significant way

Global production electrified vehicles (M)

Year-on-year growth	35%	28%	33%	32%	16%
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Participation of xEVs by type (%)



Note: xEV including: BEV = battery electric; PHEV = plug-in hybrid electric; HEV = full hybrid electric; MHEV = mild hybrid electric

1. 2020 forecast based on actual sales figures through October with estimates for November and December

Source: IHS Markit Alternative Propulsion Plus Data (Dec 2020); IHS Markit LV sales (Dec 2020); MarkLines; national vehicle registrations; BCG Analysis

Electrification is being driven by various forces



Increasingly strict regulation

Increasingly stringent CO2 emission standards across geographies, incentives for electric vehicle sales



Battery costs falling faster than expected

Technological advances and scale gains contributing to reduced battery costs



Global automakers expanding xEVs offering

Announcements of 400+ hybrid electric and plug-in models by 2025



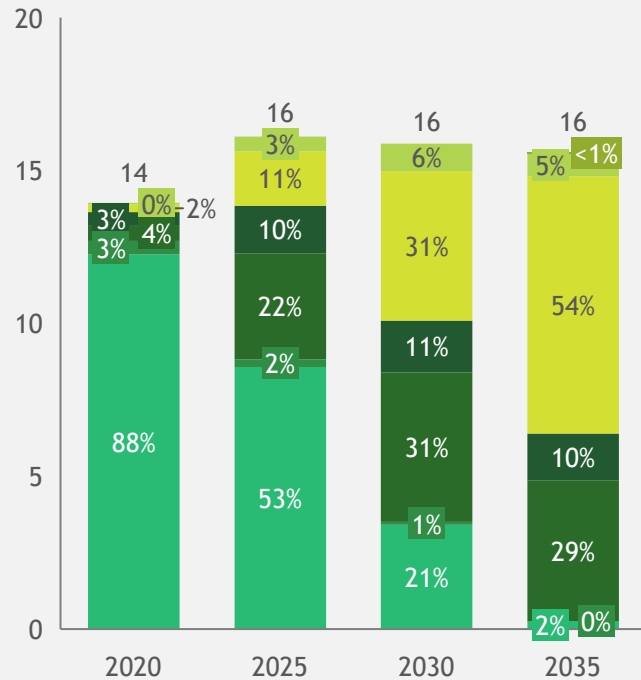
4 Pressure from investors and customers

Clients, investors and society exerting pressure for decarbonization in order to meet the requirements to achieve a net-zero world by 2050

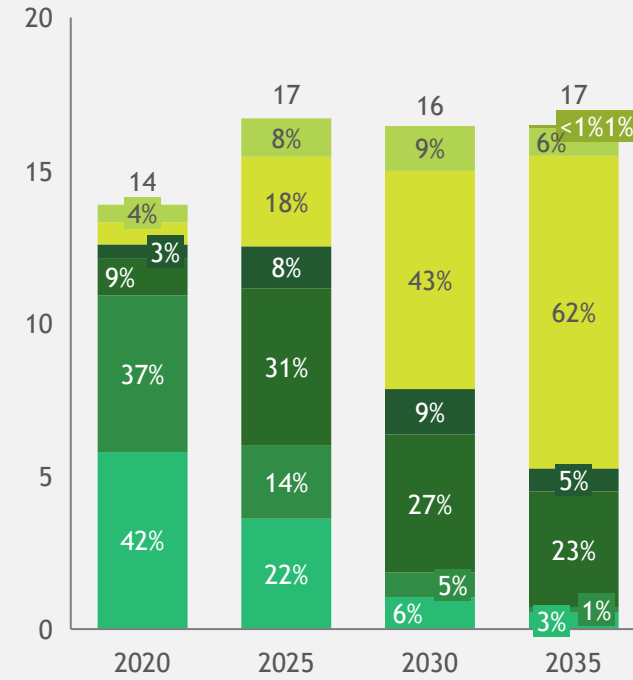
USA, Europe and China lead global adoption of electrified vehicles



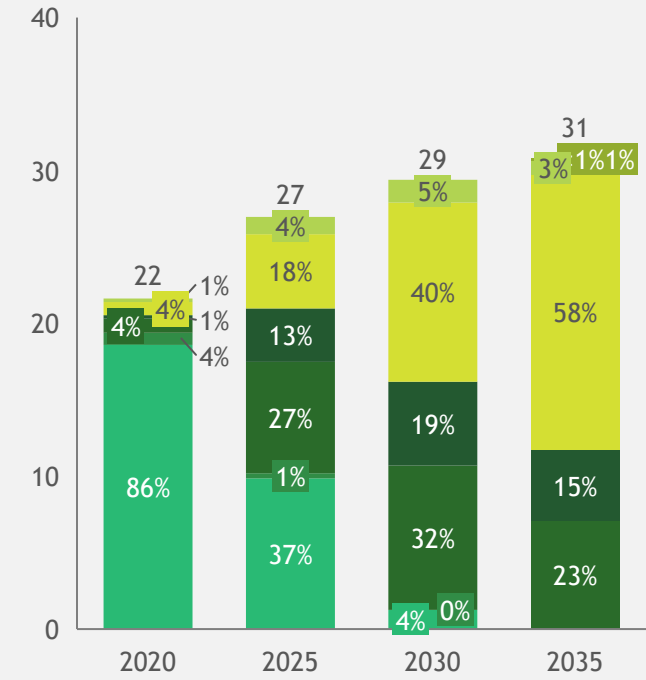
USA Volume Projections (M units)



EU volume projections (M units)



China volume projections (M units)



■ FCEV
 ■ PHEV
 ■ BEV
 ■ HEV
 ■ MHEV
 ■ Diesel
 ■ Gasoline

Note: Forecast includes all light vehicles except vans;
 Source: BCG Projections (April 2021 - www.bcg.com/publications/2021/why-evs-need-to-accelerate-their-market-penetration)



In Brazil, local forces also influence the evolution of the routes

Regulation and Incentives

Current regulation without direct link with CO2 and other greenhouse gases, as well as policies and incentives acting on multiple fronts



TCO (total cost of ownership)

Cost parity of electric vehicles vs. more distant internal combustion vs. more advanced markets, due to factors such as acquisition cost, fuel cost and usage profile



Portfolio and installed capacity

Portfolio more focused on the segments of lower added value (e.g. compact), excess installed capacity and the need for high investments for local production of xEVs



Biofuels as an alternative

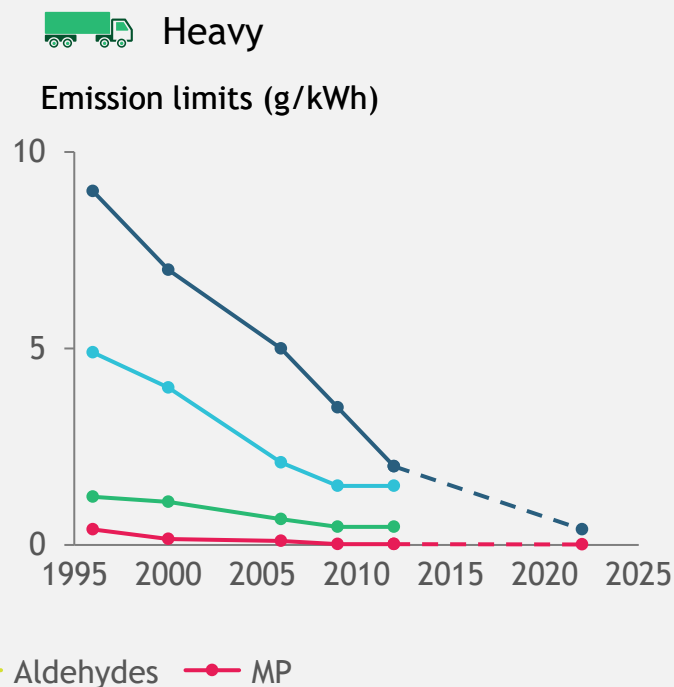
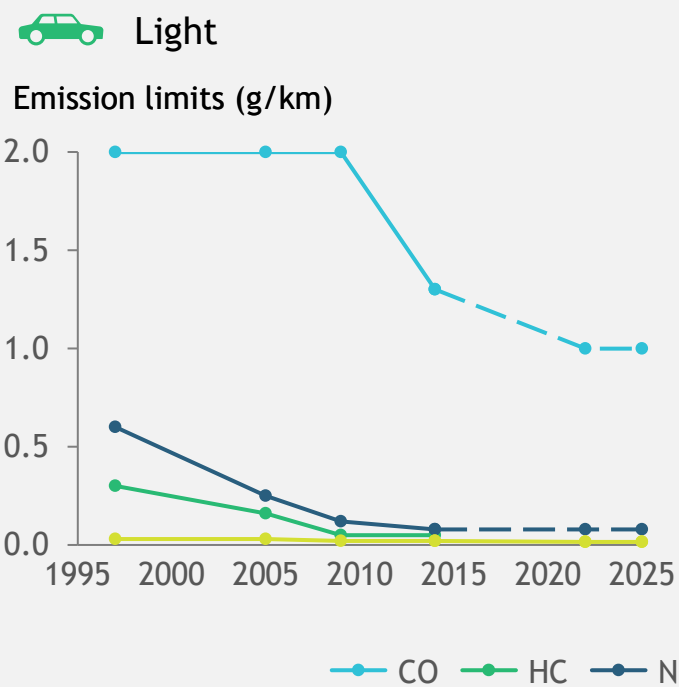
Extensive availability and existing infrastructure of biofuels in the country, especially ethanol, which has a more favorable CO2 emission profile than fossil fuels



Brazilian regulation follows international references, but without direct link to greenhouse gases

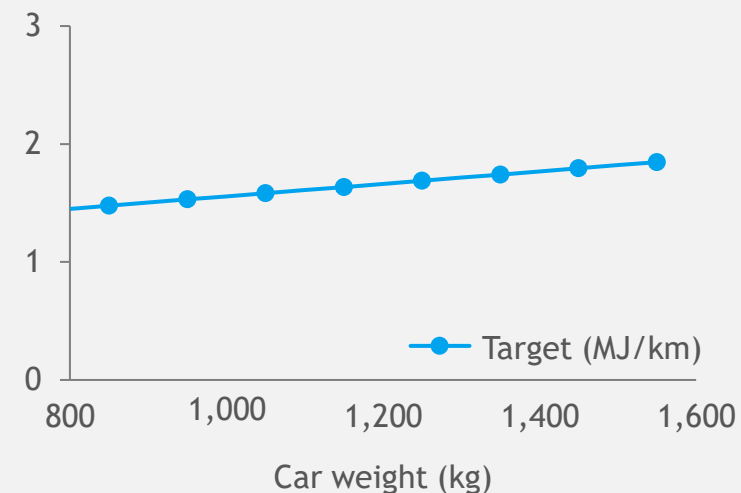
Examples

Proconve: Progressive reduction of pollutant limits in several phases



Route 2030: Control of energy efficiency levels

Example: Energy efficiency target for cars (1,564 kg) (MJ/km) from Oct/2022



Note: CO = Carbon monoxide, HC = Hydrocarbons, NOx = Nitrogen Oxides, MP = Particulate Matter
Source: Anfavea

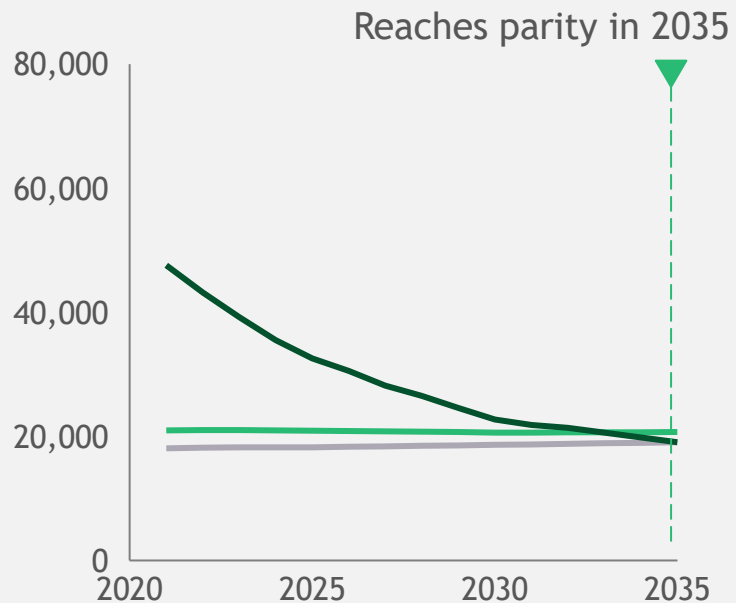


Light vehicles | For personal use, BEV to ICE parity reached around 2030 onwards, varying according to segment

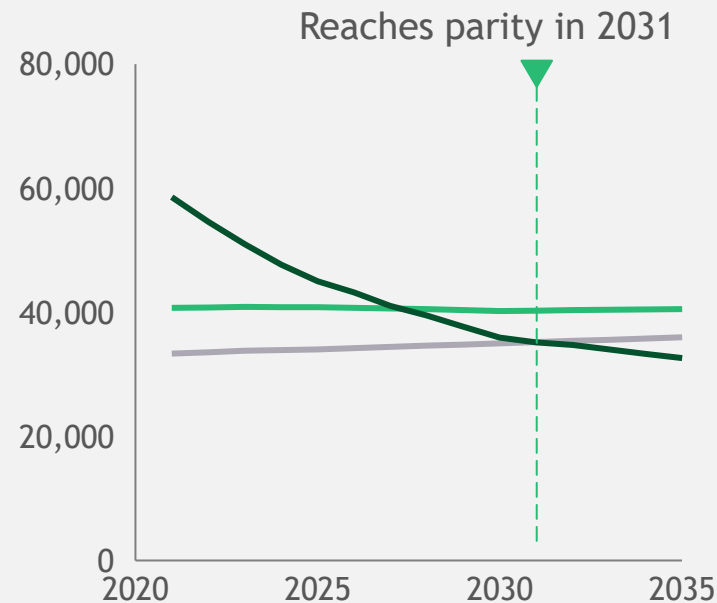
Total cost of ownership for light passenger cars (12,000 km/year)
R\$/year

ESTIMATES

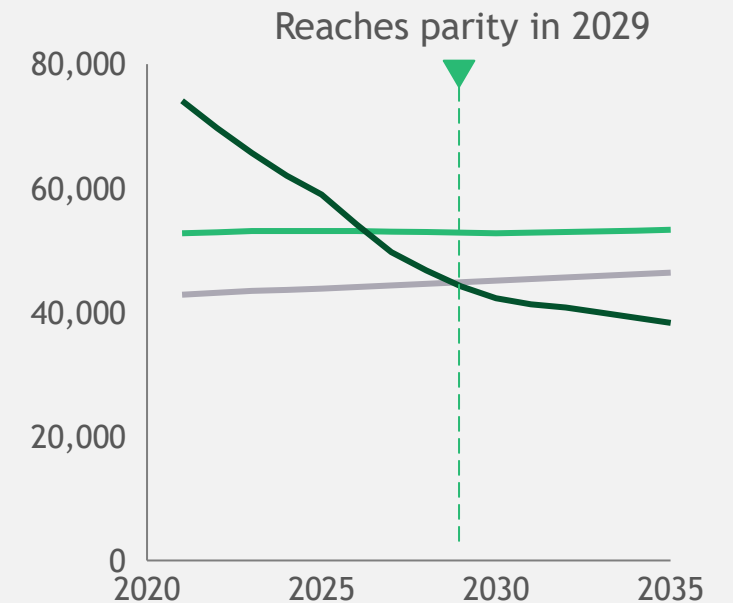
Segment B



Segment C



SUV Segment C



— Flex (ICE) — HEV(hybrid) — BEV(electric)

Note: Segment B: Includes Onix, HB20; Segment C: Includes Civic, Corolla; Segment SUV C: Includes Compass, HEV - Hybrid Electric Vehicle; BEV - Battery Electric Vehicle
Sources: Anfavea, Inmetro, automakers' websites, FIPE, ANP, ANEEL, BCG global projections, Bacen, BCG analysis and estimates

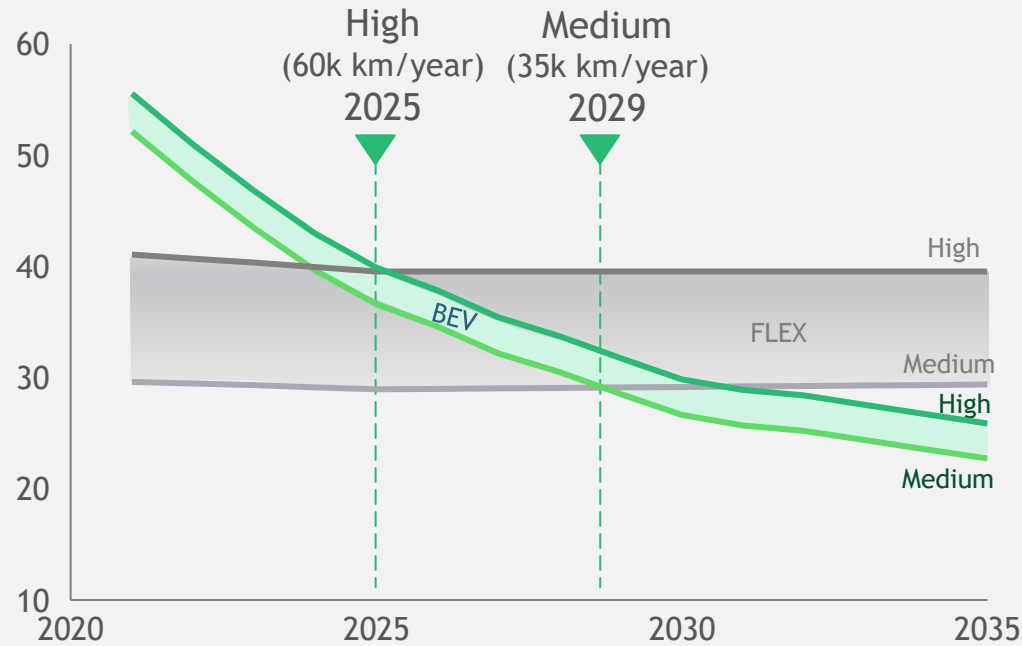


For specific missions such as ride hailing, parity could be reached in the middle of this decade

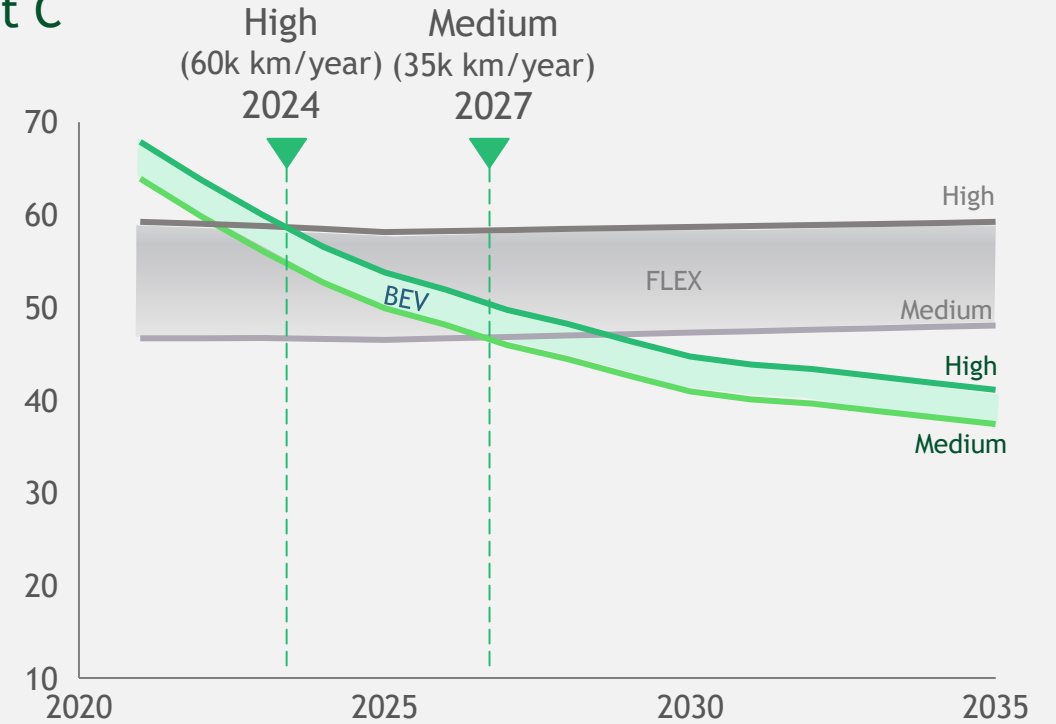
Total cost of ownership for professional light vehicles, per level of use (R\$ thousand/year)

ESTIMATES

Segment B



Segment C



Note: Includes financing cost; BEV - Battery Electric Vehicle

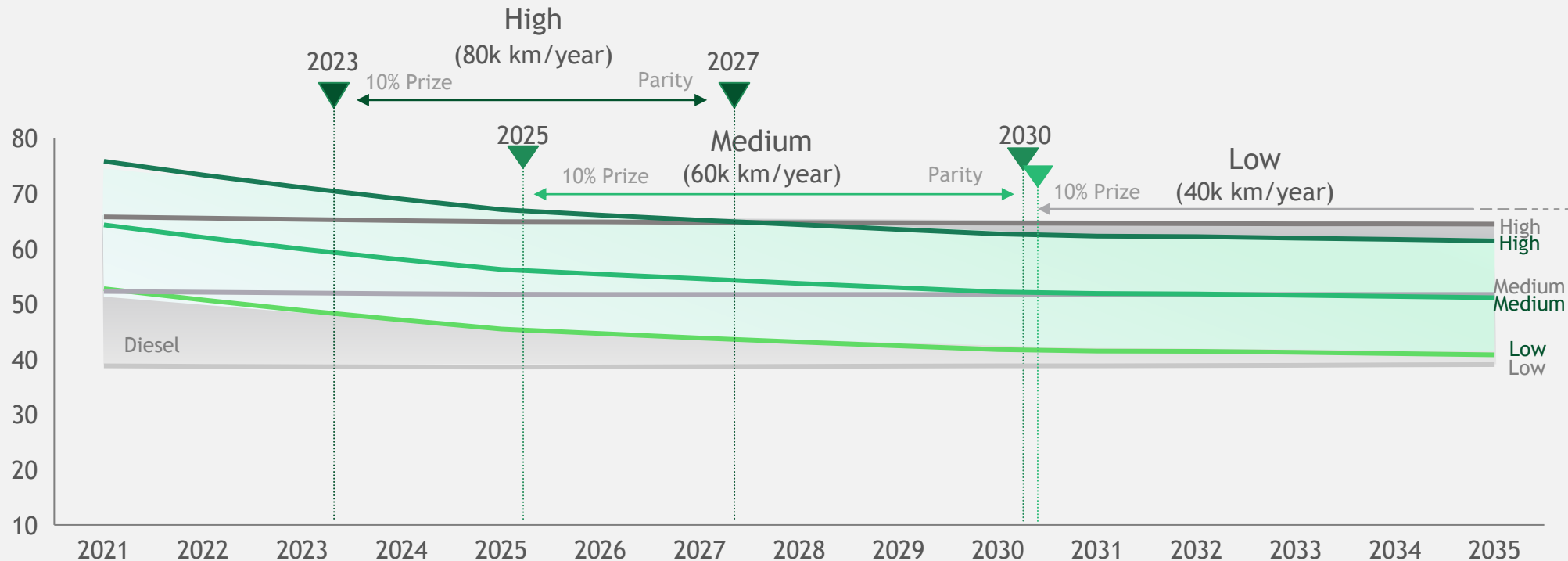
Source: Anfavea, Inmetro, automakers' websites, FIPE, ANP, ANEEL, BCG global projections, Bacen, BCG Analysis



Urban light trucks | Willingness to pay premium may anticipate transition, particularly in cases of heavy use

Total cost of ownership for 11 years for urban trucks, per level of use (R\$ thousand/year)

ESTIMATES



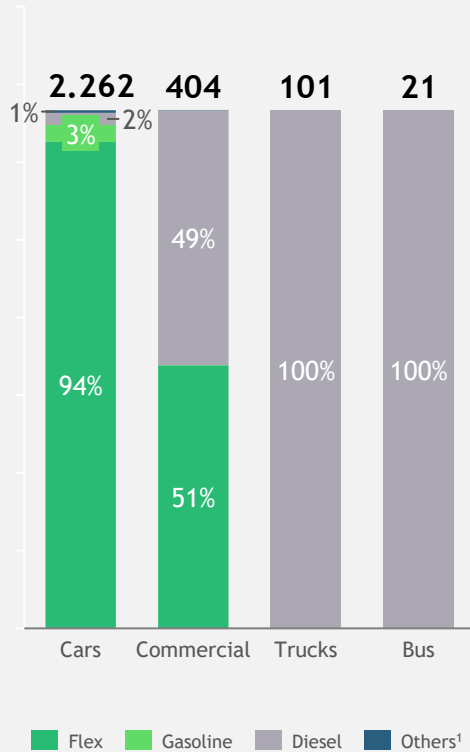
Note: Includes cost of financing, acquisition, battery replacement for BEV, fuel, maintenance, IPVA and residual value. Acquisition cost of Diesel vehicle increases in the period, but is offset by the improved efficiency of the engine; BEV - Battery Electric Vehicle

Source: Anfavea, Inmetro, automakers' websites, FIPE, ANP, ANEEL, BCG global projections, Bacen, BCG Analysis

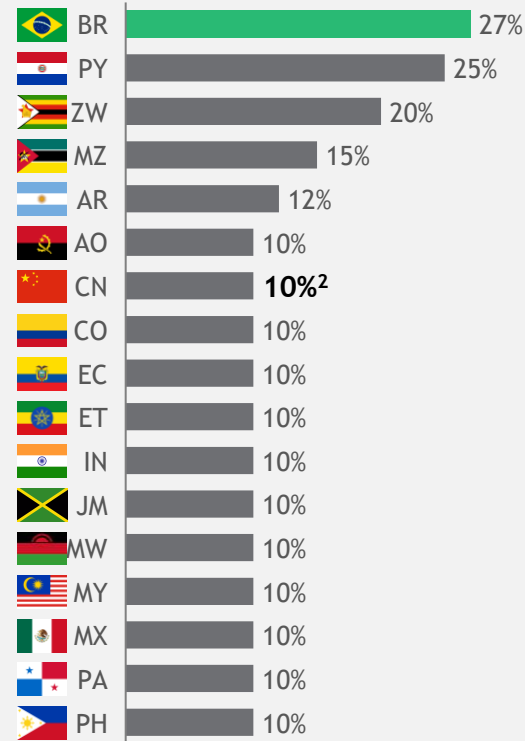


Widespread availability of flex cars and ethanol production allow greater biofuel relevance in Brazil vs. other countries

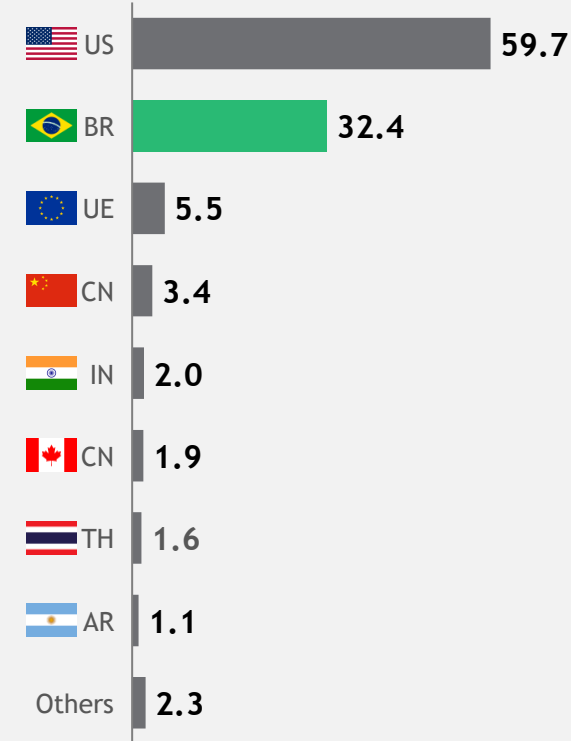
Licensed vehicles in 2019 (k)



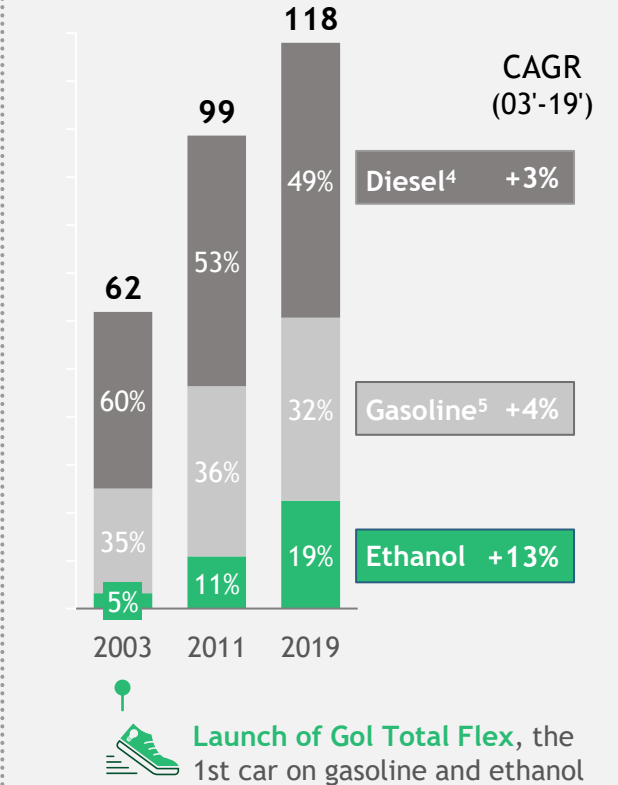
Amount of ethanol required in gasoline (%)



World ethanol production in 2019³ (B Liters)



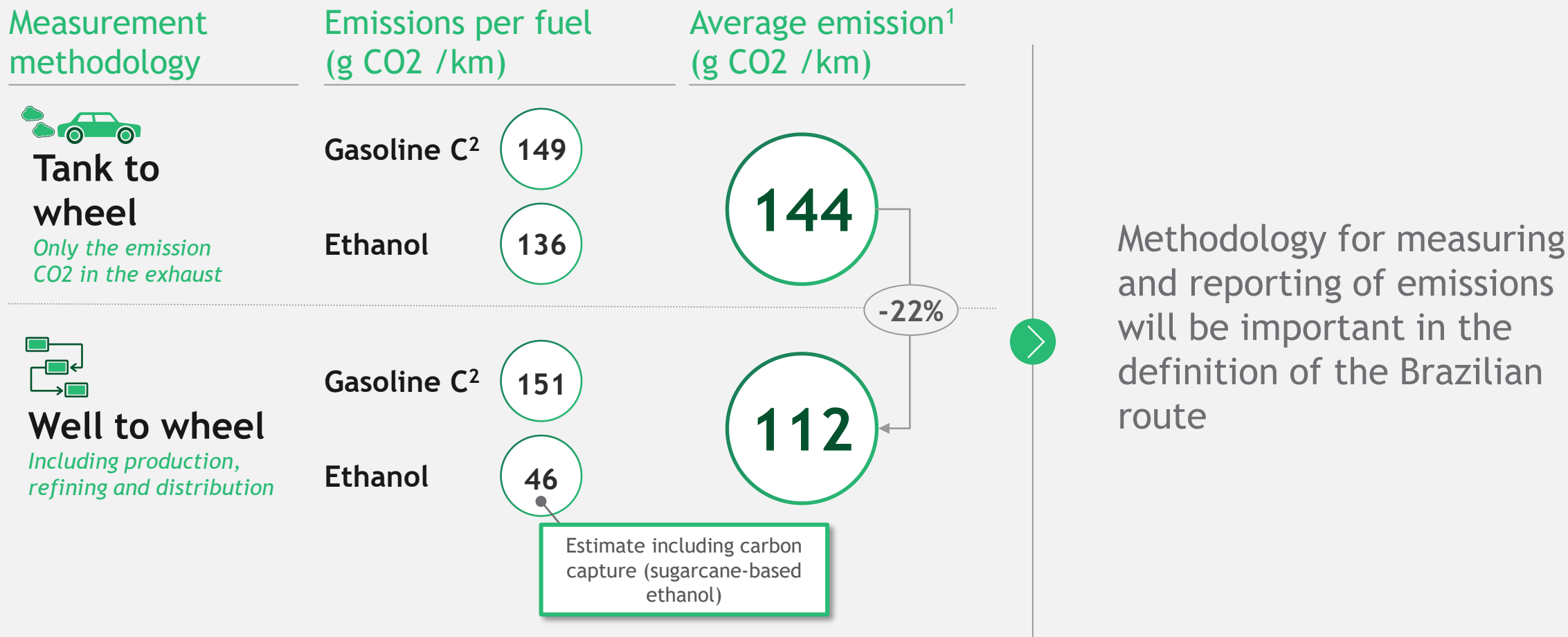
Fuel sales by distributors (M m³)



1. "Other" includes Electric, Hybrid and an insignificant number of vehicles that only use ethanol. 2. In 15 regions. 3. World ethanol production of 109.9 Billion liters in 2019. 4. Includes biodiesel. 5. Gasoline C Note: Usa does not have a national requirement of the amount of ethanol in gasoline - but on average, gasoline consumed has 10% ethanol by volume. Source: Anfavea; ANP; Renewables 2020 - Global Status Report; ETENE Sector Notebook 2020



Biofuels, such as ethanol, have a more favorable CO2 emission profile vs. fossil fuels in the "well-to-wheel" metric



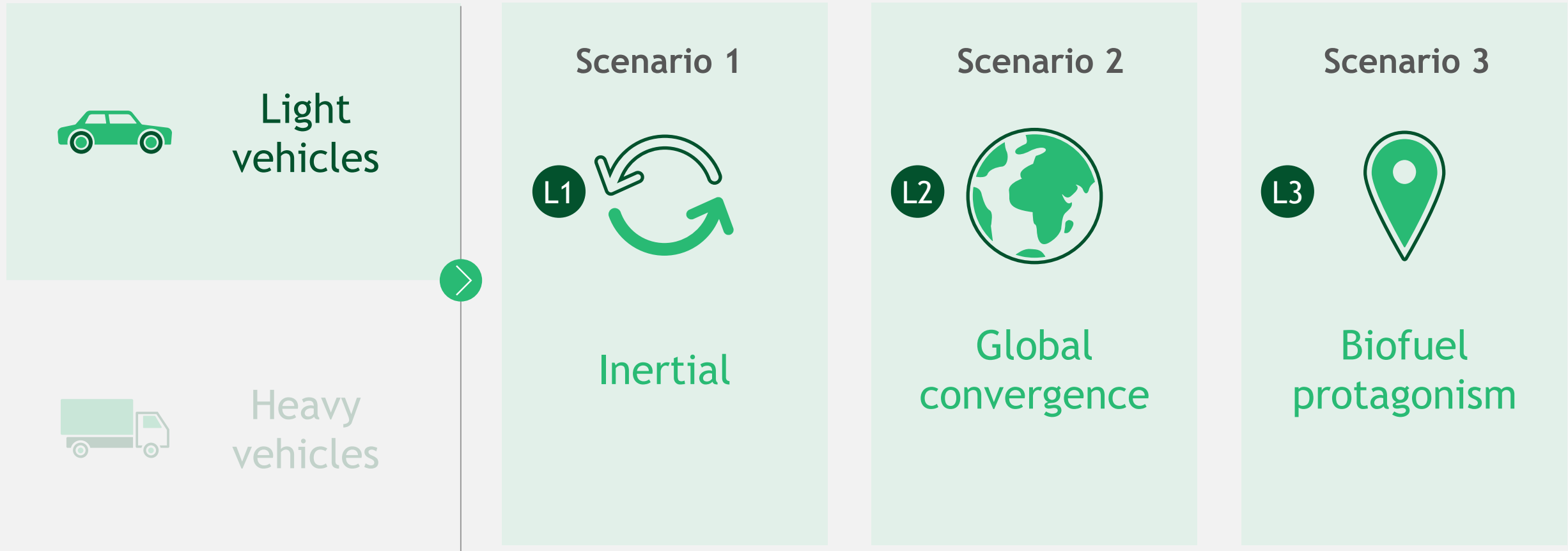
1. Considering proportion of the national consumption of gasoline and ethanol 2019 (63% gasoline, 27% ethanol); 2. Petrol values A of 153 g/km wheel ed if and -185 g/km well by wheel

Notes: Emissions for Hyundai IONIQ and Hyundai i30, similar attributes, ethanol emissions buoyed According to Embrapa study; Brazilian energy matrix emits 88g/CO2/kWh; Gasoline considers 27% ethanol;. Source: press search, Embrapa, "Synthesis Report, 2019" - EPE

Development scenarios



The interaction of forces can shape different decarbonization routes in Brazil in the next 10-15 years





L1. Inertial scenario

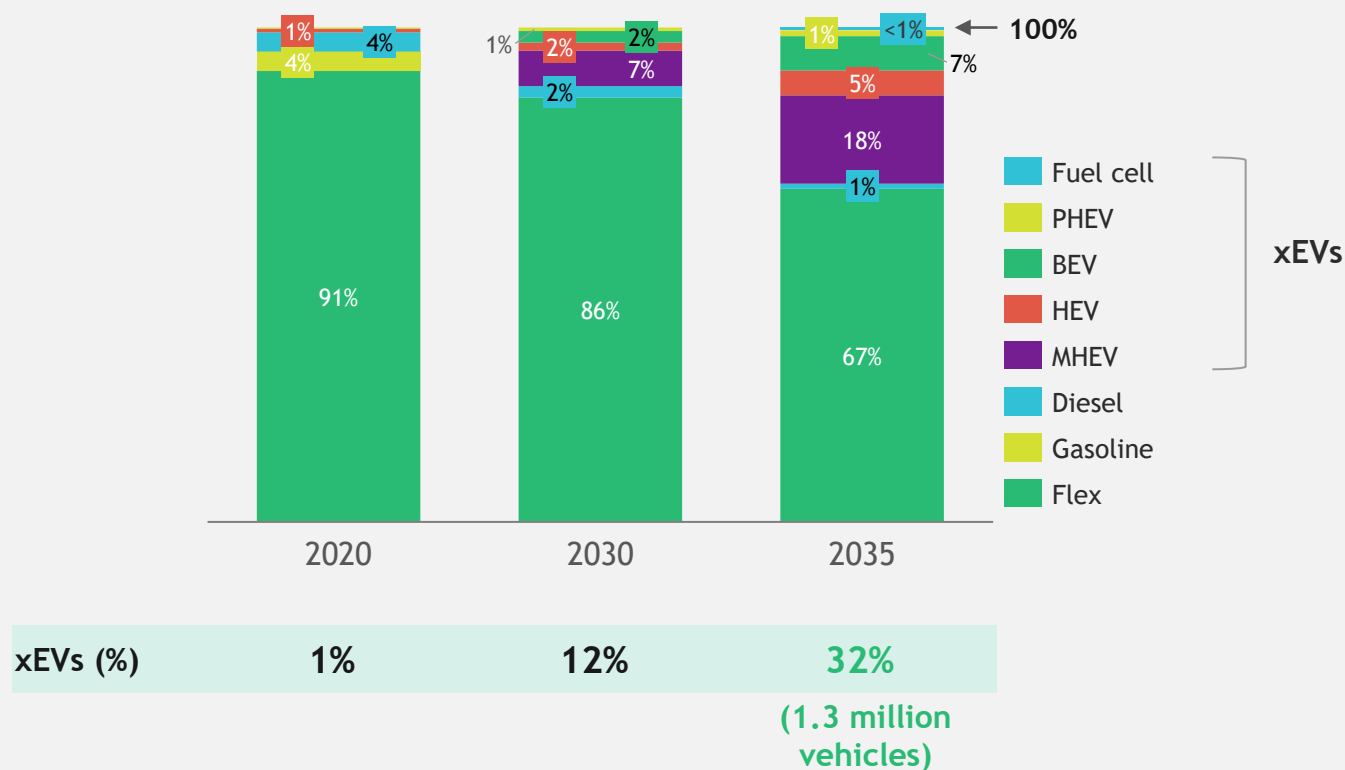
In this scenario, combustion engines sustain high penetration over the next 15 years, particularly in the volume segments

Electrification aimed at serving specific segments, meeting emission requirements and demands of corporate customers, leading to a low level of electrification of the higher volume segments

Annual sales mix

ESTIMATES

Inertial (L1)



Note: Light-duty vehicles, including Passenger Cars and Light Commercial Vehicles;
 xEVs - electrified vehicles; PHEV - Plug-in Hybrid Electric Vehicle; BEV - Battery Electric Vehicle;
 HEV - Hybrid Electric Vehicle; MHEV - Mild Hybrid Electric Vehicle.
 Source: BCG analysis and projections



L2. Global convergence

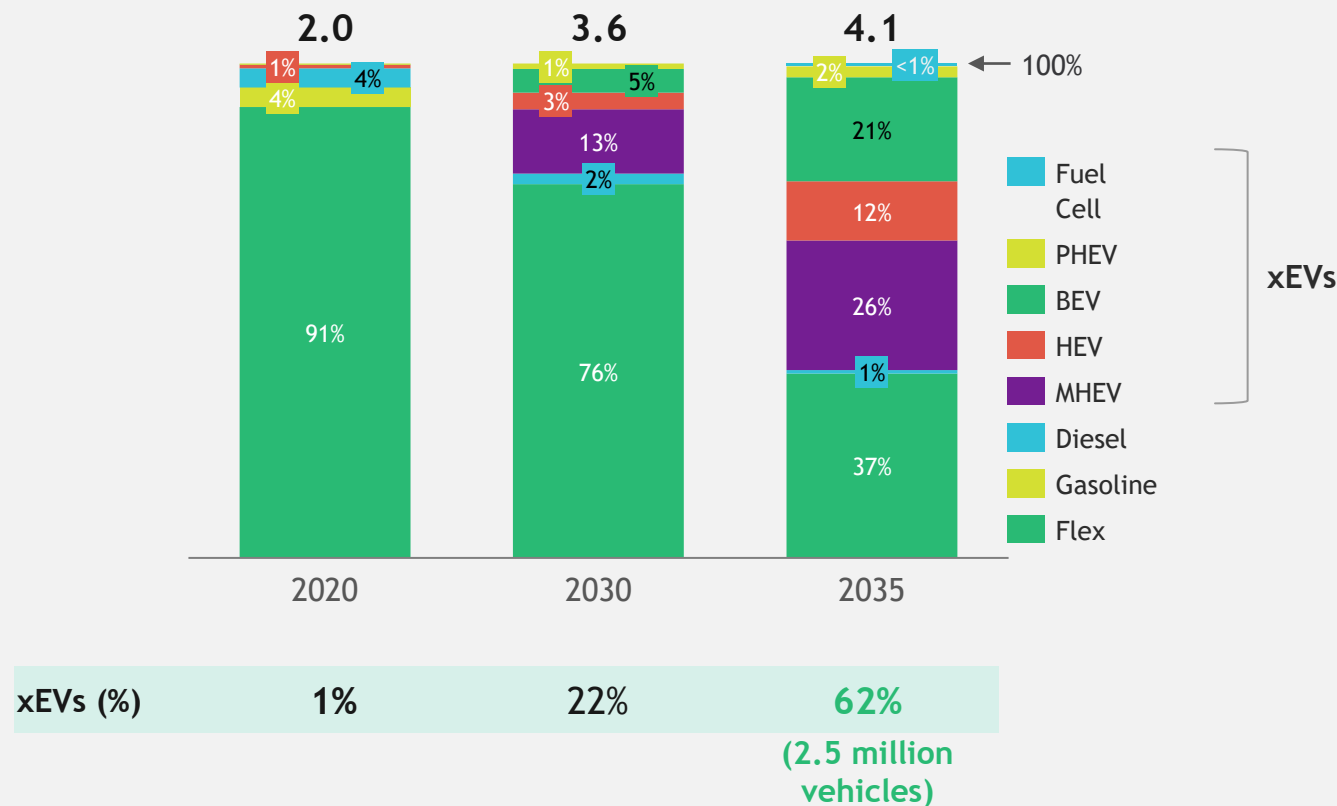
In this scenario, technological evolution and adoption rate allow xEVs to gain **scale** in Brazil in the period, reaching in 2035 **levels of penetration per segment similar to those in Europe in 2030**

Brazil approaches electrification **levels of more advanced markets**, automakers follow global electrification strategies

Annual sales mix, light vehicles

ESTIMATES

Global Convergence (L2)



Note: Light-duty vehicles, including Passenger Cars and Light Commercial Vehicles; xEVs - electrified vehicles; PHEV - Plug-in Hybrid Electric Vehicle; BEV - Battery Electric Vehicle; HEV - Hybrid Electric Vehicle; MHEV - Mild Hybrid Electric Vehicle. Source: BCG analysis and projections



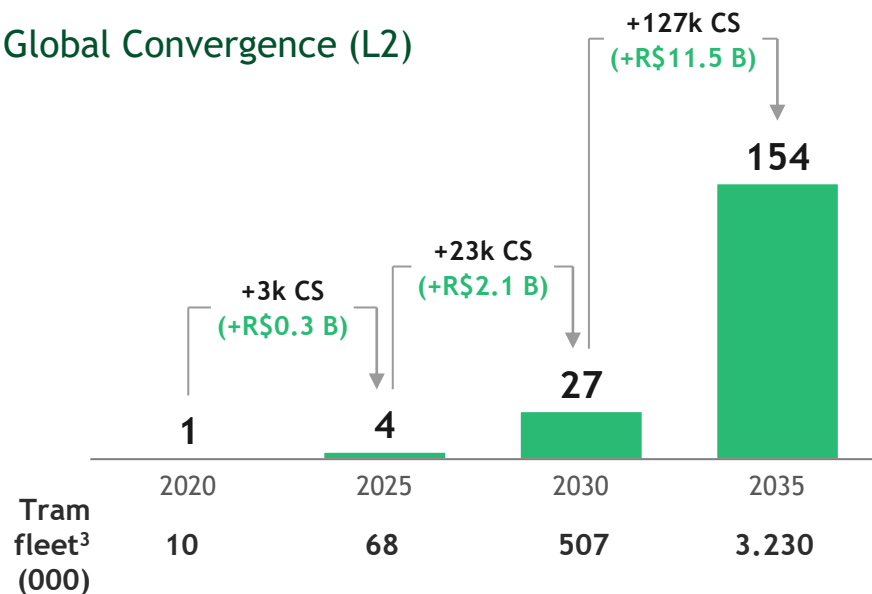
Convergence scenario points to the need to install 150,000 chargers and investments of R\$ 14B until 2035

Estimates

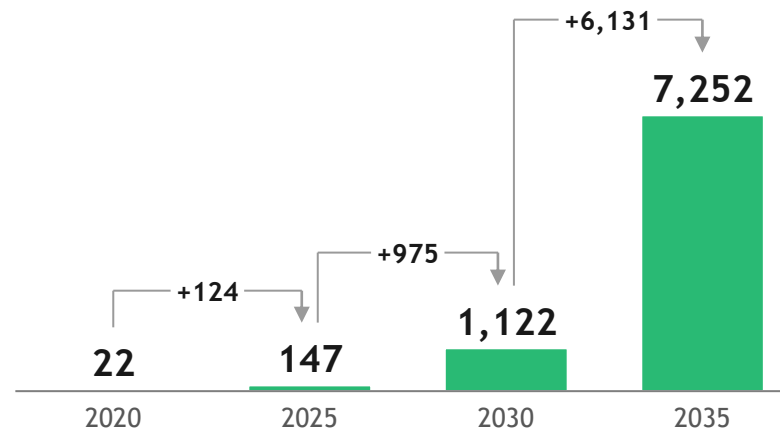
Estimated charging stations (CS) needed to meet fleet of xEVs¹

Estimated impact on electricity consumption² (GWh)/year

Global Convergence (L2)



Global Convergence (L2)



Total in the period R\$ 14 B⁴
investments in charging points
penetration of BEVs/PHEVs in the convergence scenario



~1.5% of electricity consumed by the country (2019)
represents the demand for electricity to supply
BEVs/PHEVs in 2035 in the convergence scenario

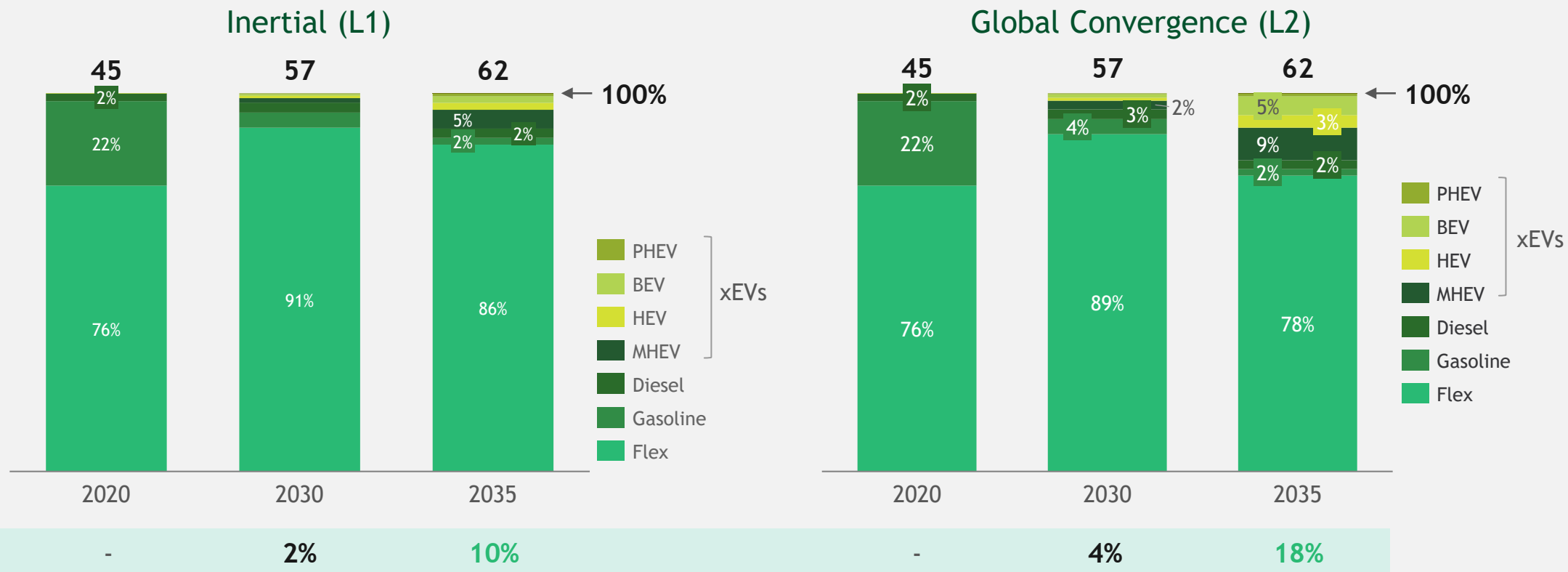
1. Energy efficiency of 3.54 km/kWh for PHEVs and 5.27 km/kWh for BEVs, average travel distance of 12,000 km/year and 61% of km driven by PHEVs on battery electrics according to Europe; 2. 21 EV/CP in 2020, 12 EV/CP in 2025, 15 EV/CP in 2030 and 21 EV/CP in 2035; 3. BEVs and PHEVs. Includes hardware and installation cost only. Grid connection costs can vary between €2k and €40k in Europe. Average cost R\$ 10k per slow charging station, R\$ 55k for fast charging stations and R\$ 300k for ultra fast charging stations. Hardware price drops with annual rate varying linearly from 5% in 2021 to 0.7% in 2035. Note: -75% of Brazilian power plants driven by renewable sources. Source: Press search, ICCT; ANEEL; Anuário Estatístico de Energia Elétrica 2020; BCG Analysis



Current fleet | Flex vehicles are still expected to represent most of the fleet by 2035, assuming current renewal rates

Fleet per year and powertrain - millions of vehicles

ESTIMATES



Note: Light-duty vehicles, including Passenger Cars and Light Commercial Vehicles;
 xEVs - electrified vehicles; PHEV - Plug-in Hybrid Electric Vehicle; BEV - Battery Electric Vehicle; HEV - Hybrid Electric Vehicle; MHEV - Mild Hybrid Electric Vehicle.
 Source: Anfavea, BCG Analysis



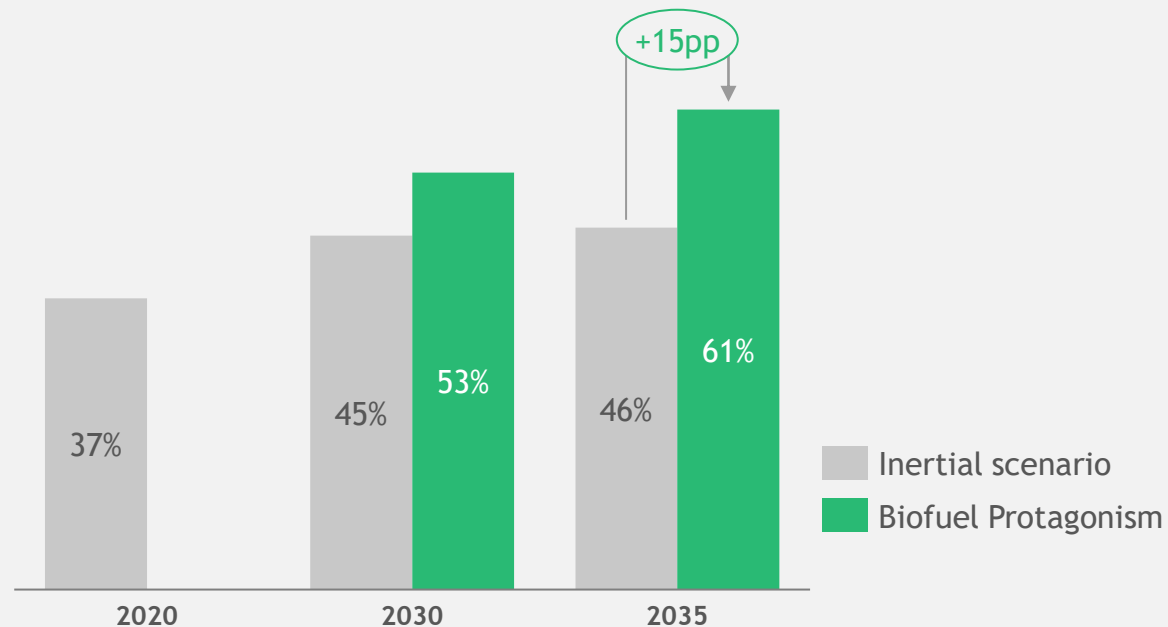
L3. Biofuel protagonism

In this scenario, ethanol gains more prominence **as a path** to decarbonization, made **possible by favorable regulation**, flex fleet and extensive production and distribution infrastructure

Scenario assumes an **increase of +15 p.p. of ethanol in the fuel mix**, reaching **61% of consumption**, and for comparison purposes, penetration of xEV in sales equal to the inertial scenario

ESTIMATES

Light vehicles (% ethanol / total fuel)



- Effects of increased penetration of ethanol
- ⊖ CO2 emissions (well to wheel)
 - ⊕ Emission of local pollutants
 - ⊖ Gasoline consumption

<p>+18B l Additional ethanol consumption in 2030 vs 2020</p>	<p>R\$ 55 billion Potential investment needed in the next 15 years for additional ethanol production</p>	<p>1-2M Ha Additional planted area to meet ethanol demand</p>
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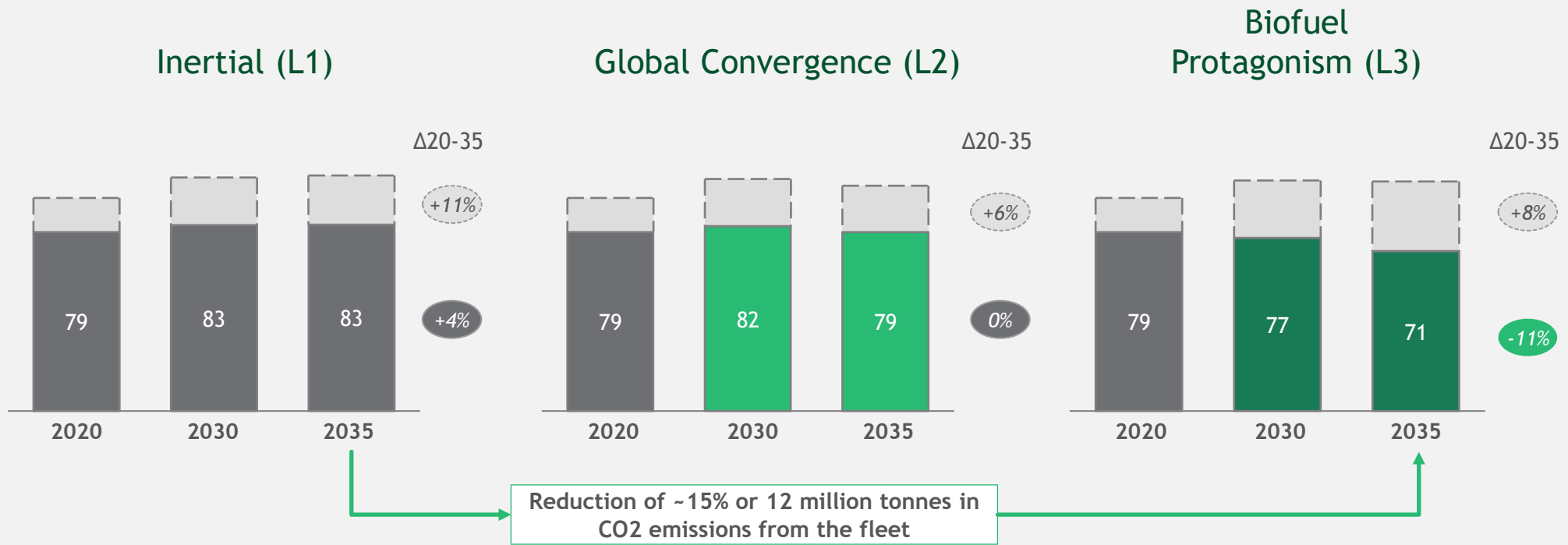
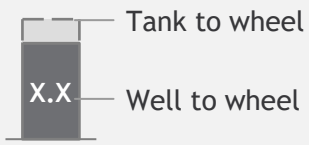
Note: Light vehicles, including passenger cars and light commercial vehicles
 Source: Anfavea, epe, Ministry of Agriculture, Livestock and Supply; IBGE; BCG Analysis



CO2 - light vehicles | Increased use of ethanol can accelerate short-term decarbonization by reducing circulating fleet emissions

ESTIMATES

CO2 emissions - million tonnes CO2 / year



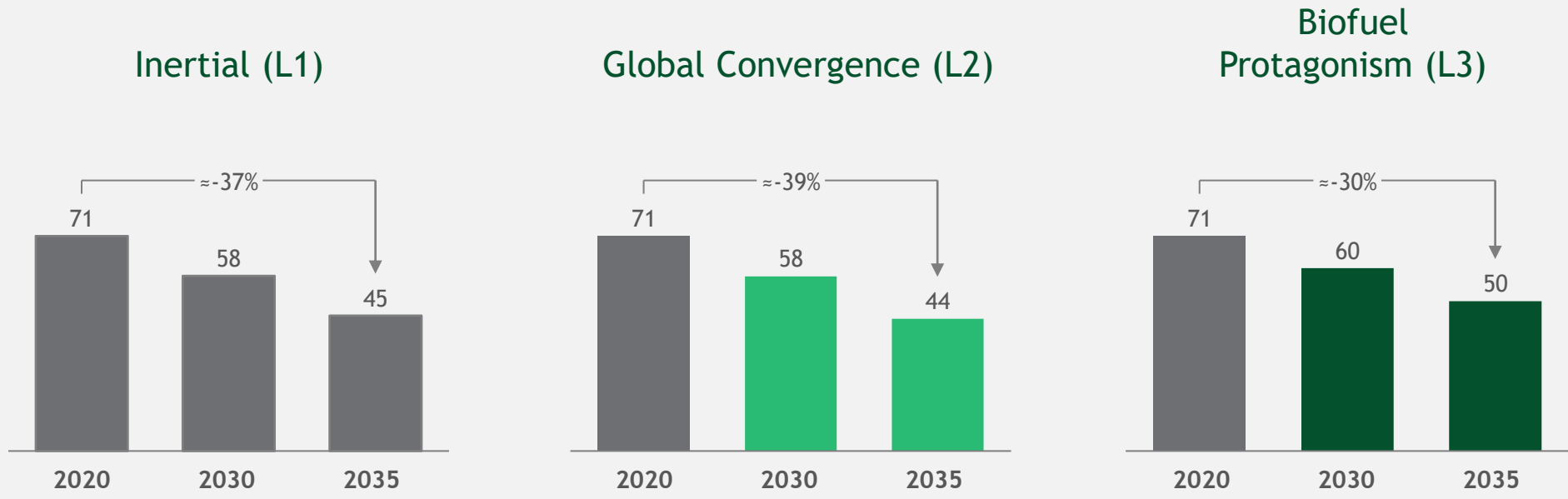
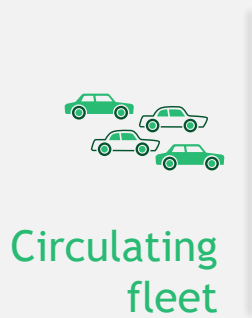
Note: Assumes growth of 37% in the current fleet between 2020 and 2035; emission factors (Kg/l exhaust and well to wheel, resp.) of 2.01 and 2.04 for gasoline, 1.2 and 0.4 for ethanol and 2.4 and 2.7 for diesel. Passenger vehicles only. Source: Anfavea; Sindipecas; CBCS; BCG Analysis



Local pollutant emissions - light vehicles | Significant reduction in all scenarios due to fleet renewal

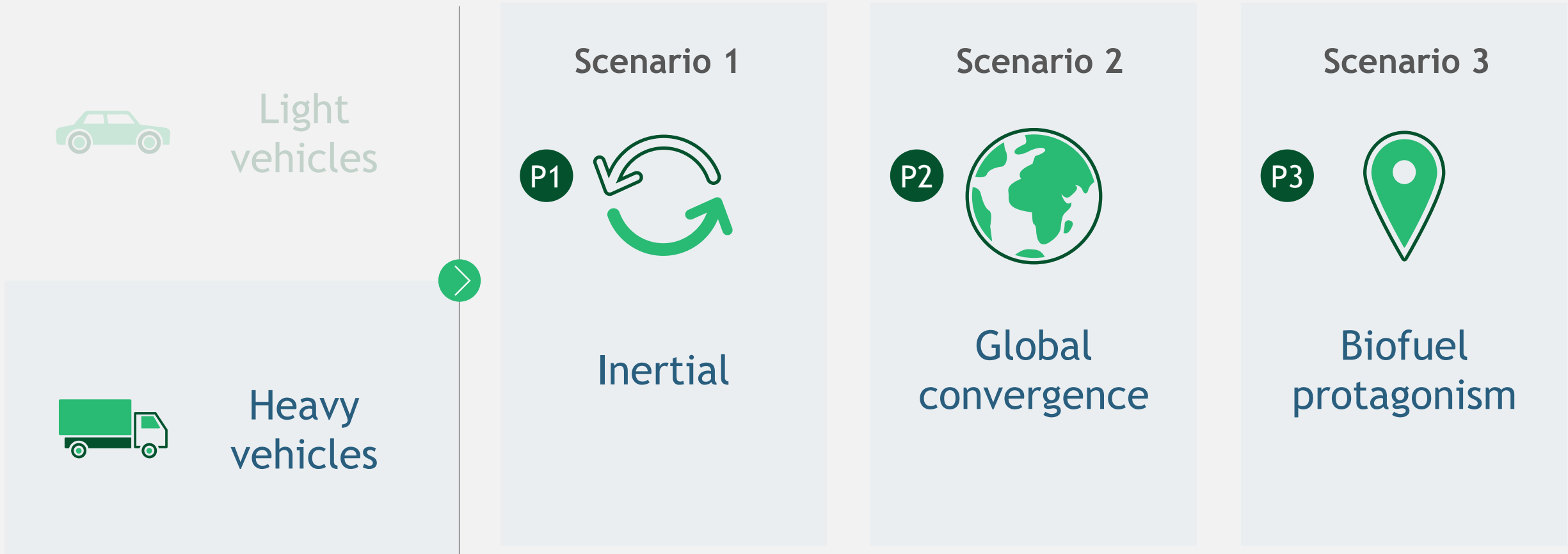
ESTIMATES

NMOG + NOx emissions - thousands of tons / year



Note: Passenger vehicles only; 54% growth in the new fleet between 2019 and 2035, and 37% in the circulating fleet between 2020 and 2035.
Source: Anfavea; CETESB; CONAMA; INMETRO; BCG Analysis

The interaction of forces can shape different decarbonization routes in Brazil in the next 10-15 years



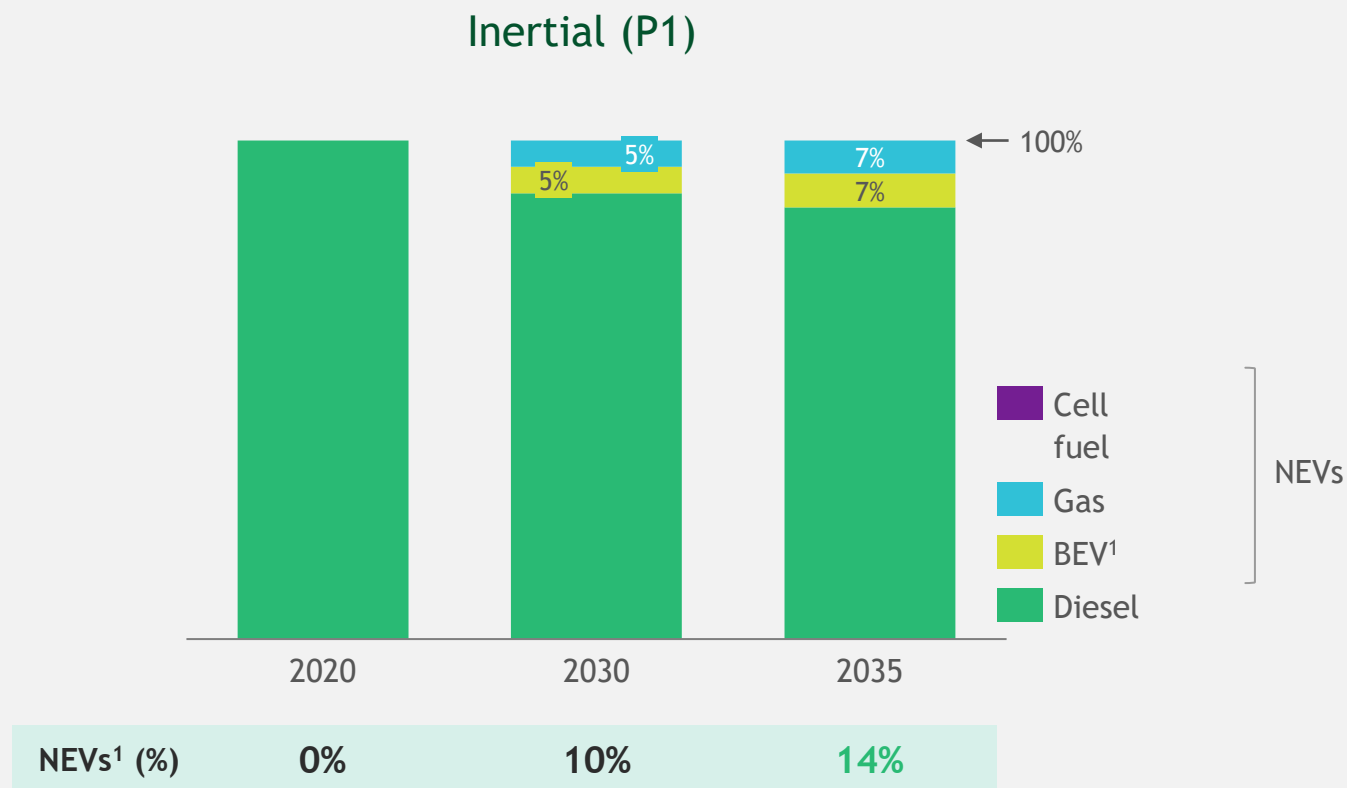
P1. Inertial scenario

In this scenario, new engine technologies (NEVs, new energy vehicles) are focused on specific applications and to meet the demands of large customers

Diesel engine remains dominant in heavy vehicles

Annual sales mix, heavy vehicles

ESTIMATES



Note: Includes medium and heavy trucks and buses;
 1. NEV - New Energy Vehicle; BEV - Battery Electric Vehicle
 Source: BCG analysis and projections

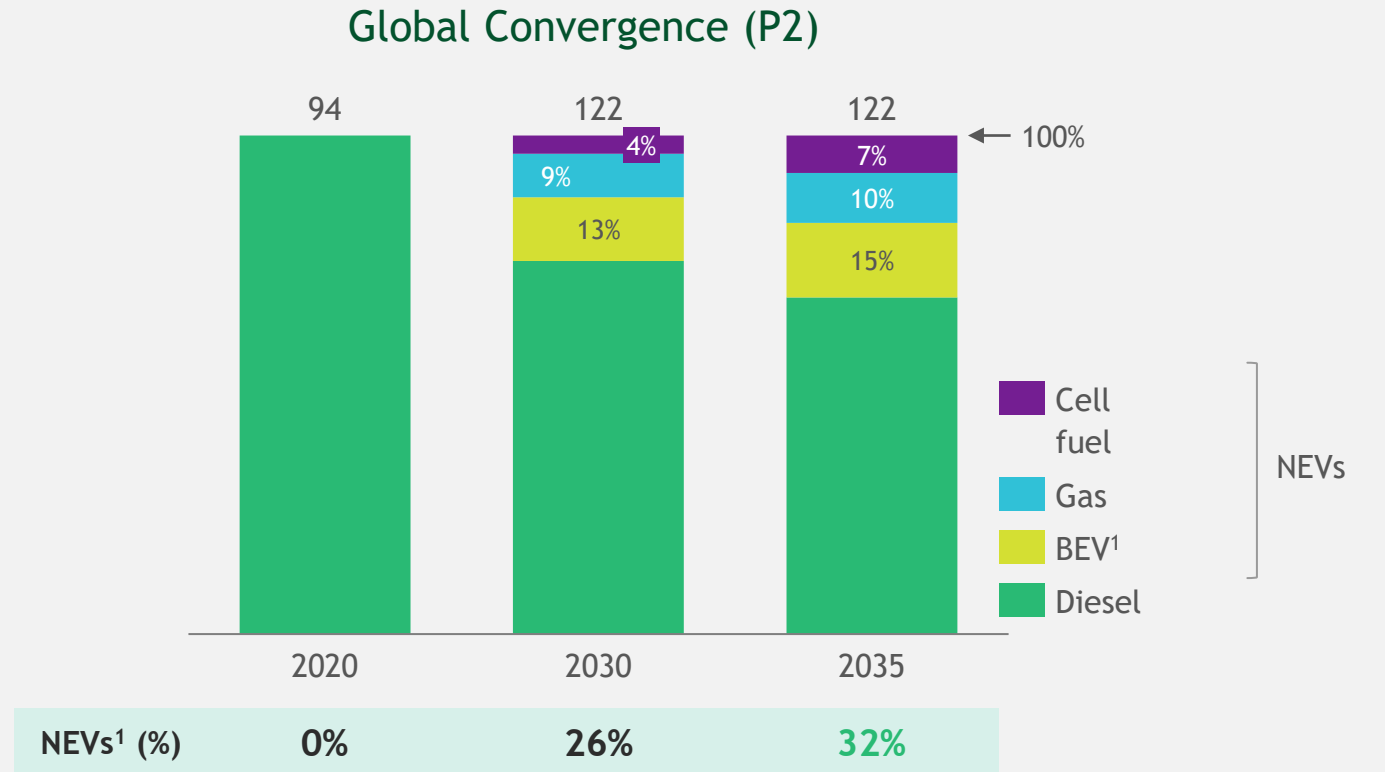
P2. Global Convergence

In this scenario, technological developments and the pace of adoption allow new technologies to gain scale in Brazil, reaching **2035 penetration levels similar to those in Europe in 2030**

Brazil approaches levels of **new energy vehicles of more advanced markets**, and automakers follow **global strategies for NEVs**

Annual sales mix, heavy vehicles

ESTIMATES



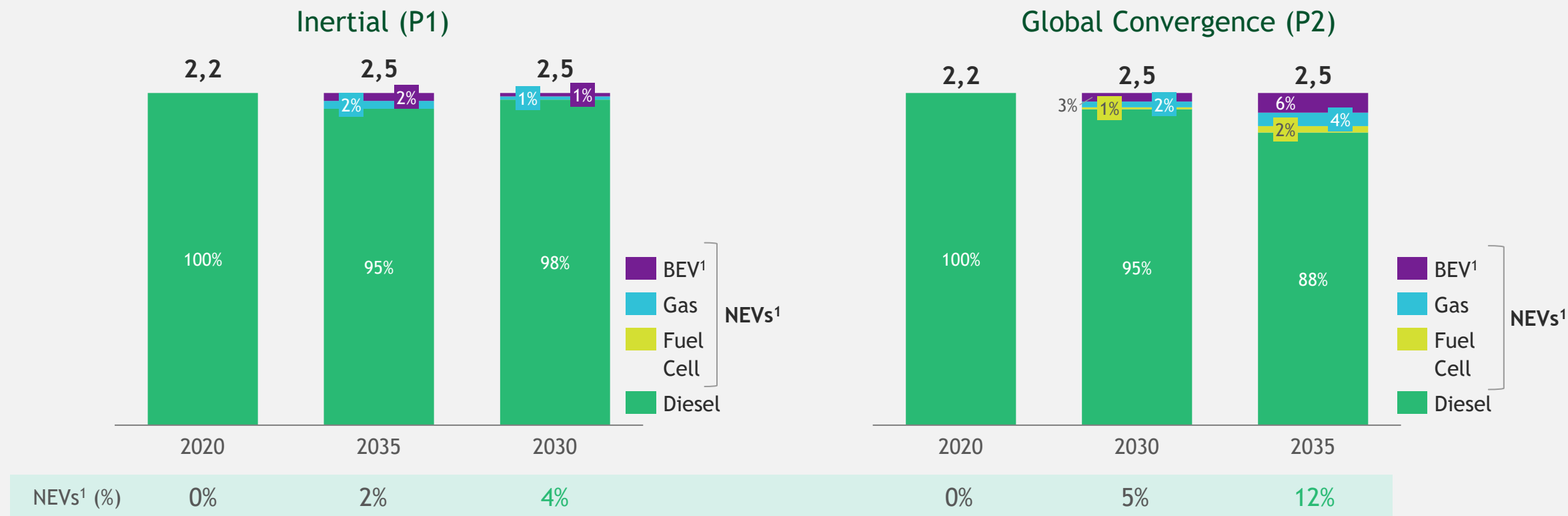
Note: Includes medium and heavy trucks and buses;
 1. NEV - New Energy Vehicle; BEV - Battery Electric Vehicle
 Source: BCG analysis and projections



Fleet - heavy vehicles | Diesel-powered internal combustion engine expected to remain dominant in fleet in period, assuming current renewal rate

Fleet per year and motorization - millions of vehicles

ESTIMATES



Note: Includes medium and heavy trucks and buses;
 1. NEV - New Energy Vehicle; BEV - Battery Electric Vehicle
 Source: BCG analysis and projections

P3. Biofuel protagonism

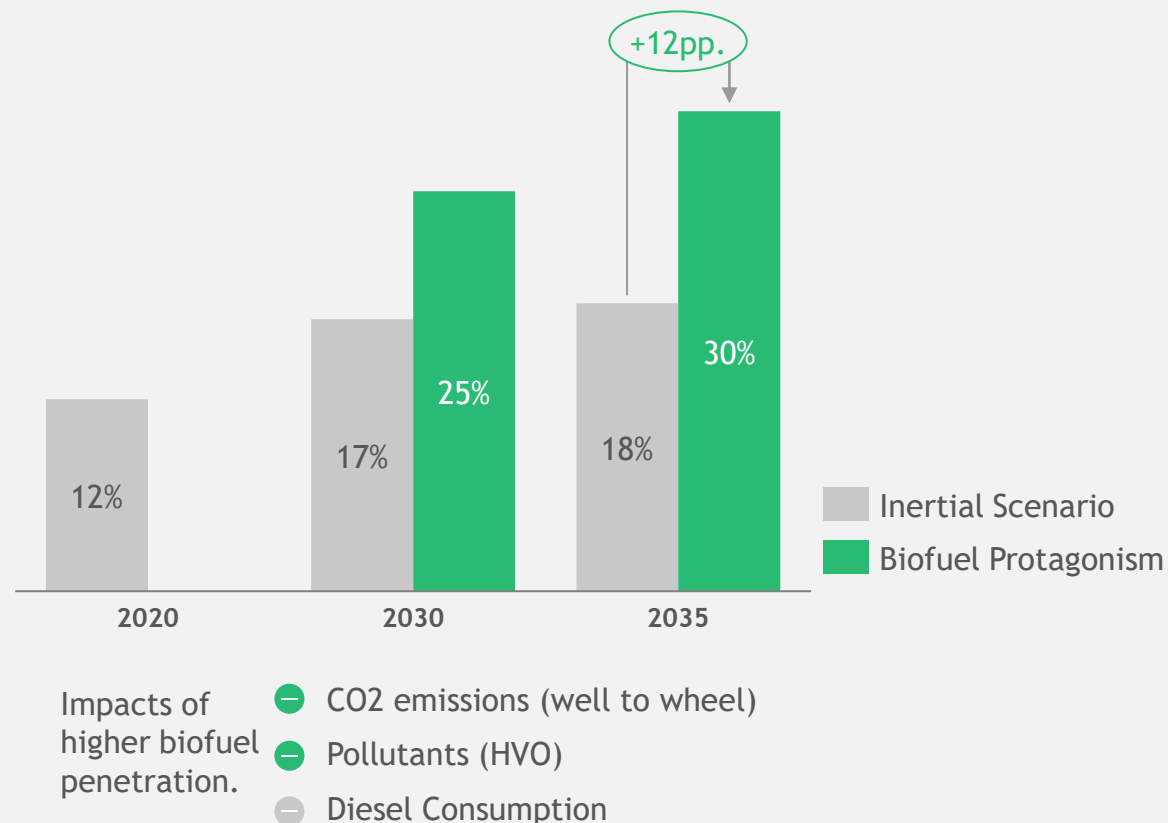
In this scenario, Biodiesel/HVO and other biofuels gain prominence **as a path to decarbonization**, made possible by favorable regulation and investments

Scenario assumes as premise, **increase of relevance of HVO to 15% of the mix**, vs. 3% in the inertial scenario (and 15% of biodiesel)...

... and for comparison purposes, new penetration into new sales equal to the inertial

Heavy vehicles (% biofuels / fuels)

ESTIMATES



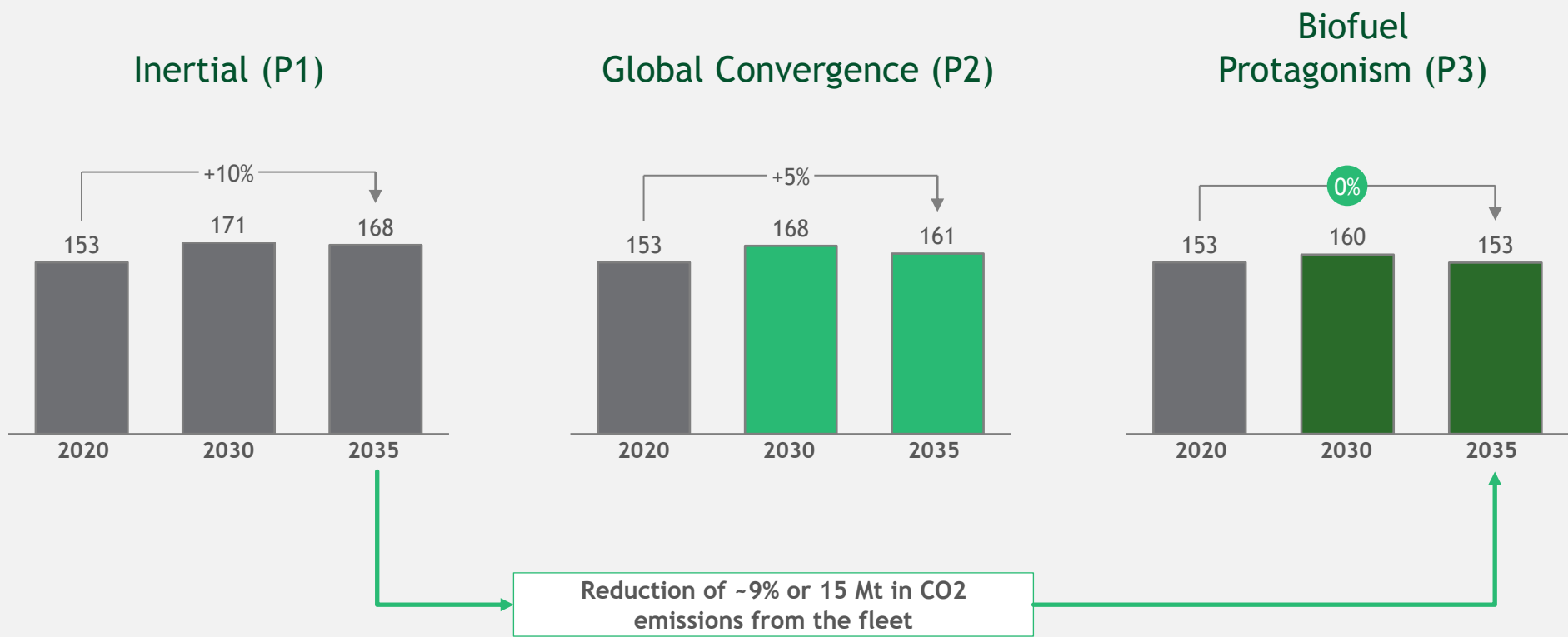
Note: Includes medium and heavy trucks and buses; HVO - hydrotreated vegetable oil ("green diesel")
 Source: Anfavea; BCG analysis



CO₂ - heavy vehicles | Increased application of biofuels can help reduce CO₂ by reducing current fleet emissions

CO₂ emissions - millions of tons CO₂ / year, vision well to wheel¹

ESTIMATES



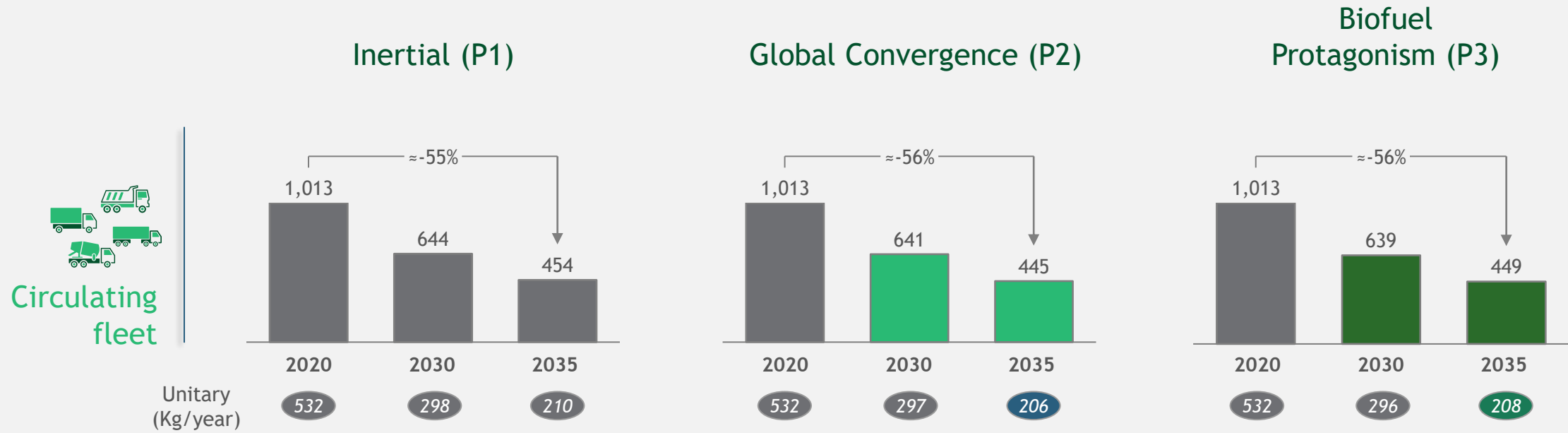
1. Considers carbon capture
 Note: New fleet growth of 12% between 2019 and 35, and of 14% of the circulating fleet between 2020 and 35; Emission factors (Kg/l exhaust and well-to-wheel, resp.) of 2.01 and 2.04 for gasoline, 1.2 and 0.4 for ethanol, 2.4 and 2.7 for diesel, 1.4 and 0.7 for HVO and 2.0 and 2.3 for NG. Considers only medium and heavy trucks
 Source: Anfavea; BCG Analysis



Local pollutant emissions - heavy vehicles | Significant reduction in all scenarios given fleet renewal

NOx emissions - thousands of tons / year

ESTIMATES



Note: Considering medium and heavy trucks only; NOx emissions from HVO 10% lower than from Diesel; 2% increase in emissions from Biodiesel for each 20pts of concentration in Diesel; Growth of the new fleet 12% between 2019 and 35, and 14% of the circulating fleet between 2020 and 35.
Source: Anfavea; CETESB; CONAMA; INMETRO; BCG Analysis

Key messages

Climate change context poses unprecedented challenges for the automotive sector

In the long run, the application of electrification technologies, combined with a clean energy matrix, seem a path of no turn to zero vehicle emissions

In markets such as the U.S., Europe and China, the combination of regulation and incentives, technological advances and the movement of automakers, should accelerate the electrification of vehicles already in this decade

In Brazil, given the local context, electrification and the broader use of biofuels can be complementary ways for the sector to move towards decarbonization

On the electrification side, xEV vehicle sales can reach 62% in 2035 (23% electric or plug-ins)

- Fleet of pure electric or plug ins can reach 3 million by 2035 in a scenario of global convergence ...
- ... requiring investments of ~R\$ 14B to deploy 150,000 charging stations and meet the growing demand for electricity, of the order of 7,200 GWh in 2035

Biofuels can be a solution to accelerate decarbonization, taking advantage of the country's agricultural vocation, flex fleet and existing production and distribution infrastructure in the country

- In light vehicles, each 1 p.p. of ethanol increase in the mix can remove 0.8 Mt/yr of CO₂ from the circulating fleet
- In heavy vehicles, every 1 p.p. increase in biofuels in the mix can remove 1.25 Mt/yr of CO₂ from the fleet

Regardless of the path, the time is to prepare for the transformation that must take place along the automotive chain, including investments in production and infrastructure, capacity building and new mobility models

Disclaimer

This study reflects the view of BCG based both on its global experience in the subject, as well as on its experience in the Automotive sector in Brazil, in addition to interviews conducted during the preparation of this study. In particular, the study reflects elements of discussion with ANFAVEA (Association of Motor Vehicle Manufacturers) and its Associates and partners in Brazil. Furthermore, this study stems from the hiring for the writing of a report in which BCG was remunerated by ANFAVEA.

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