BOSTON CONSULTING GROUP

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

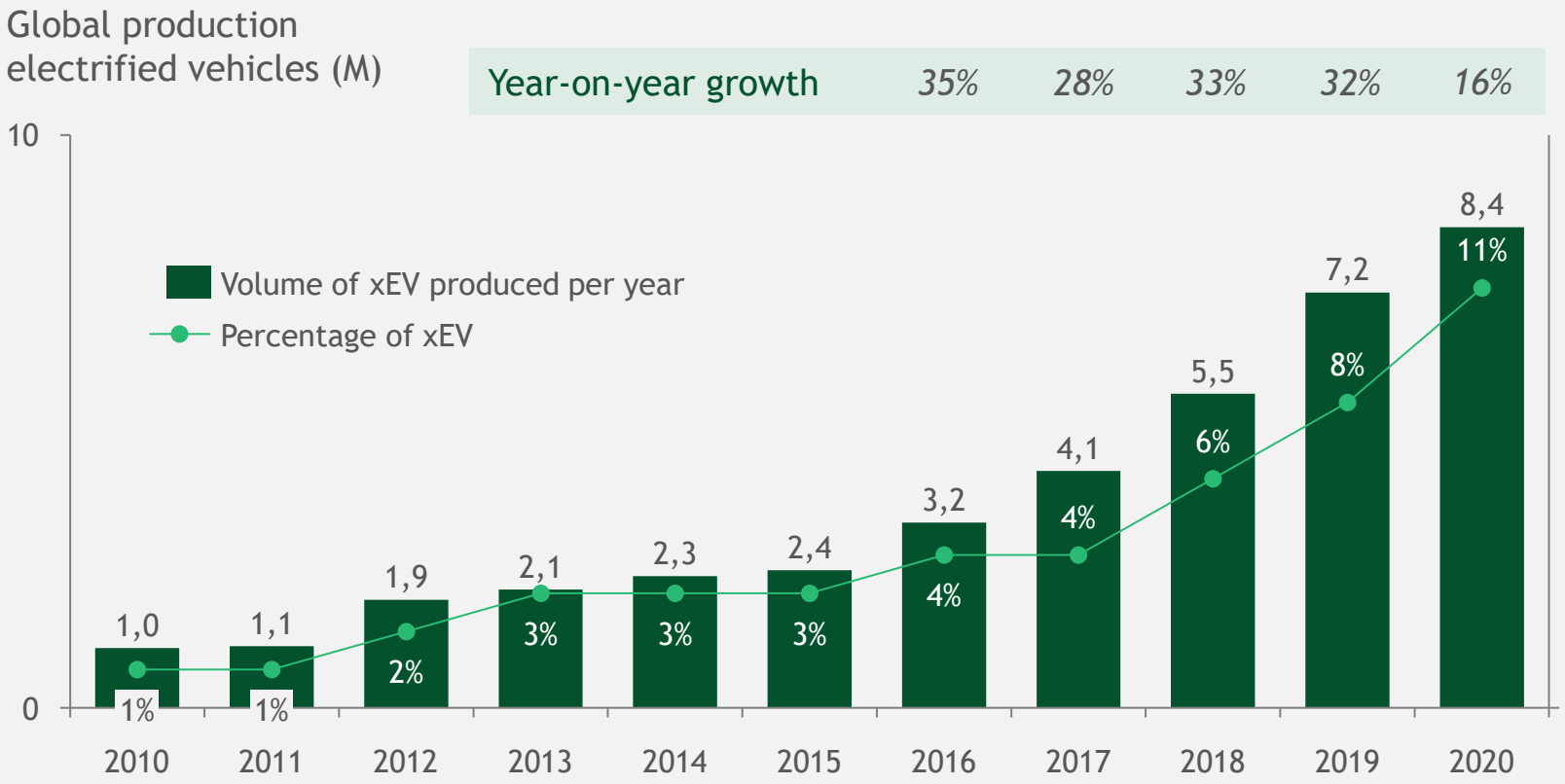
Global context and the Brazilian market

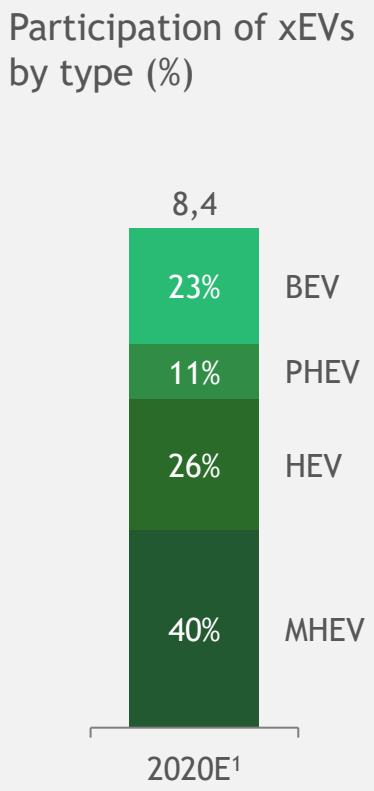
Demand for climate action is accelerating

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 AUM[1]	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; TFCD Status report* 2020; Analysis BCG

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





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

1

Increasingly strict regulation

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

2

Battery costs falling faster than expected

Technological advances and scale gains contributing to reduced battery costs

3

Global automakers expanding xEVs offering

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

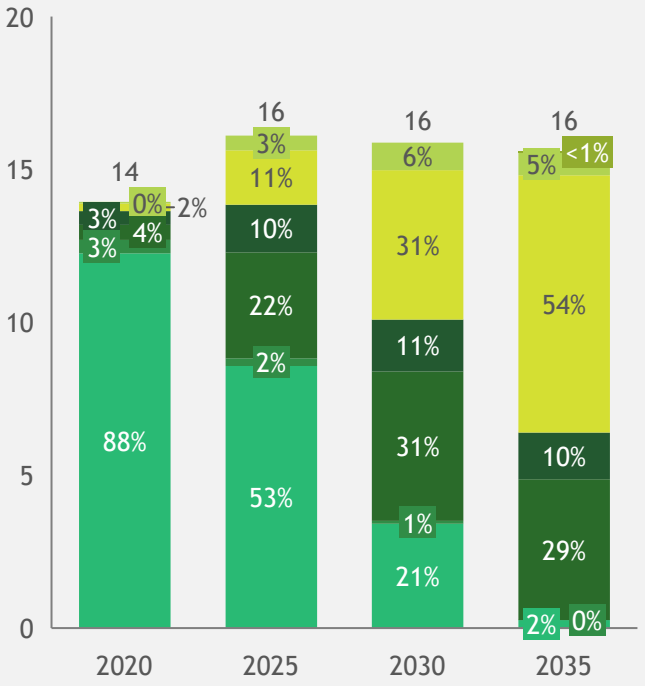
4

Pressure from investors and customers

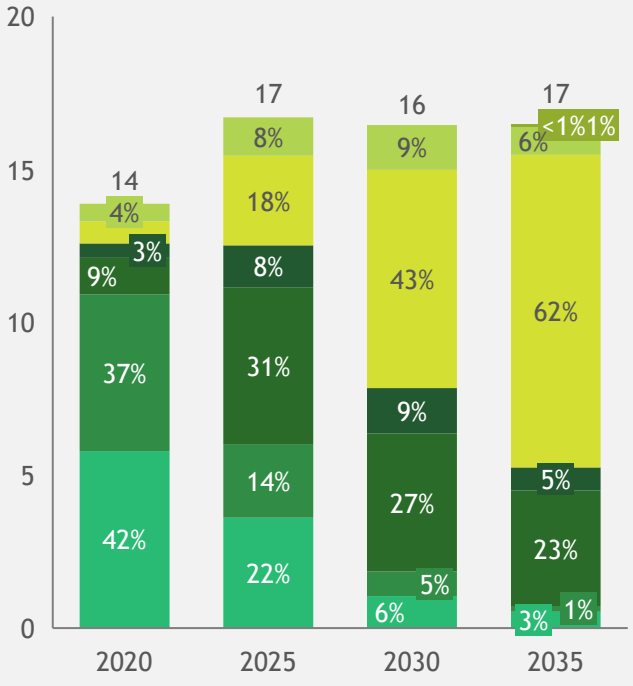
Clients, investors and society exerting pressure for decarbonization in order to meet the requirements to achieve a net-zero world by 2050

USA, Europe and China lead global adoption of electrified vehicles

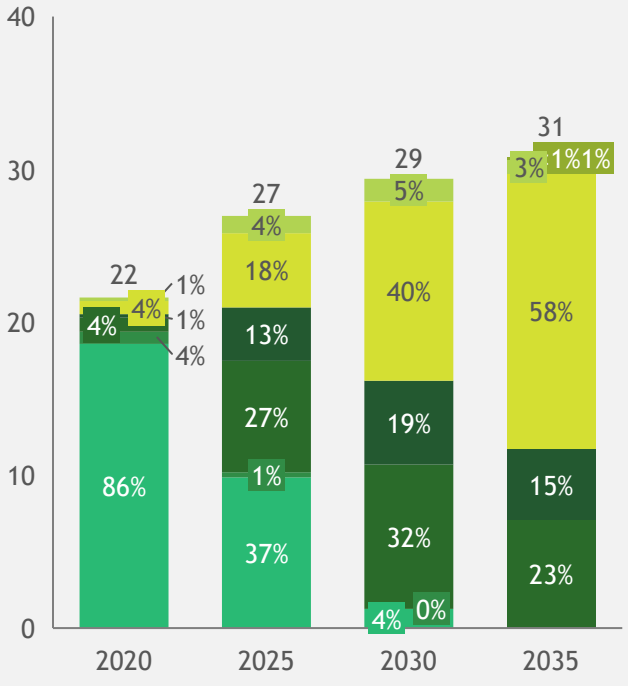
USA Volume Projections (M units)



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

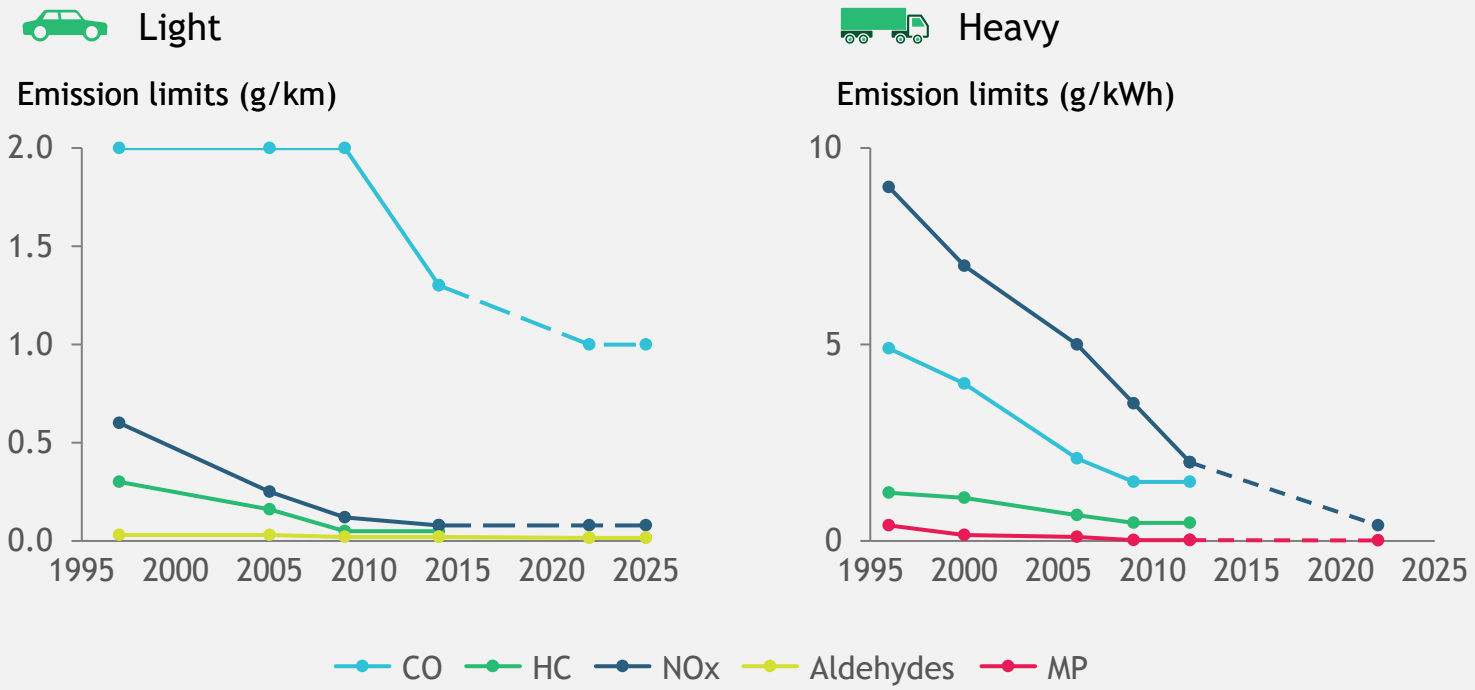
Biofuels as an alternative

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

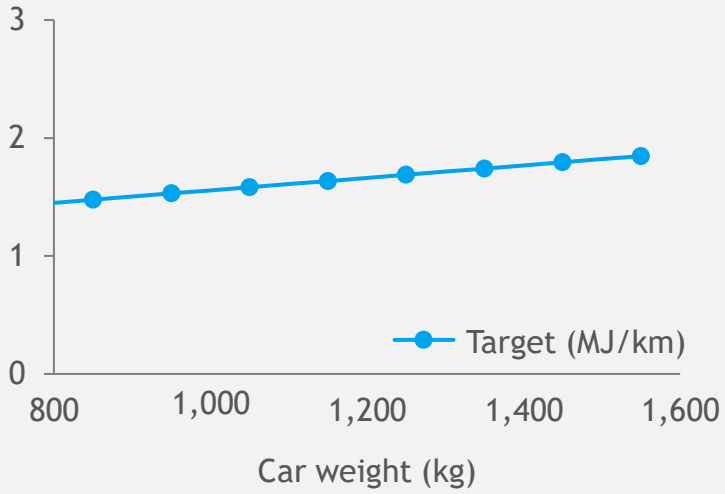
Proconve: Progressive reduction of pollutant limits in several phases



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

Route 2030: Control of energy efficiency levels

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

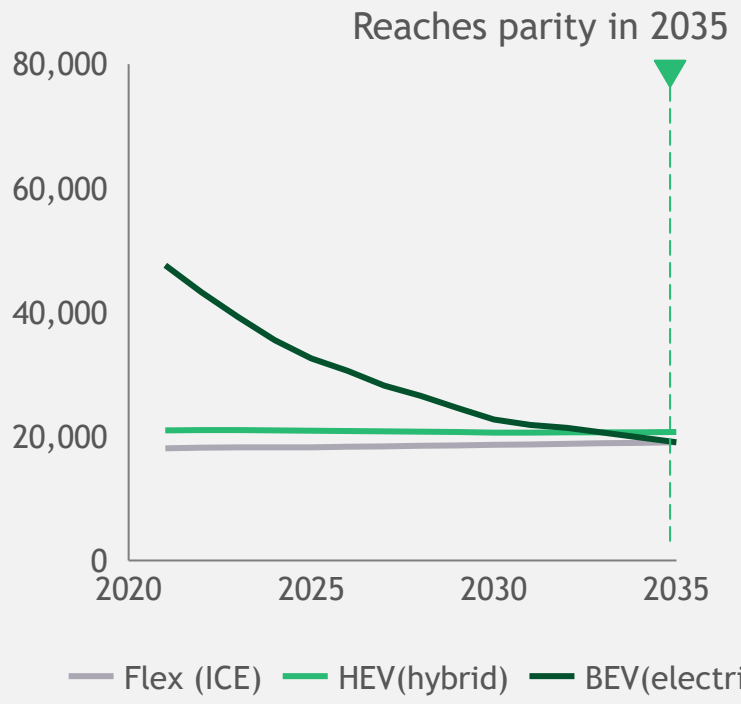


Light vehicles | For personal use, BEV to ICE parity reached around 2030 onwards, varying according to segment

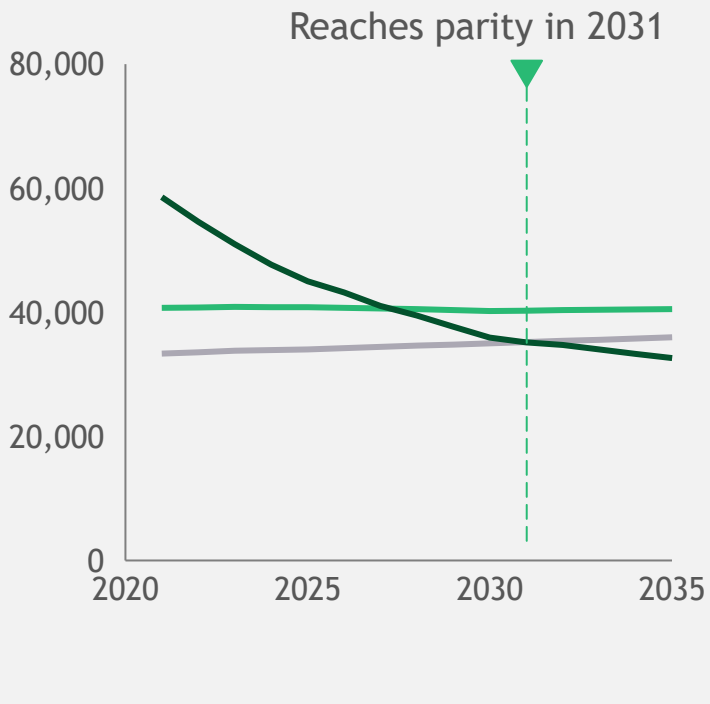
Total cost of ownership for light passenger cars (12,000 km/year)
R$/year

ESTIMATES

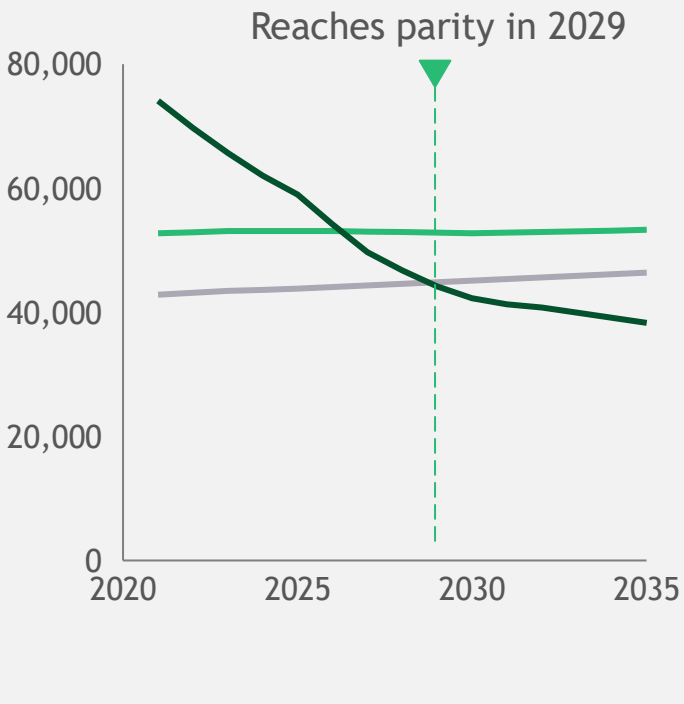
Segment B



Segment C



SUV Segment C



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

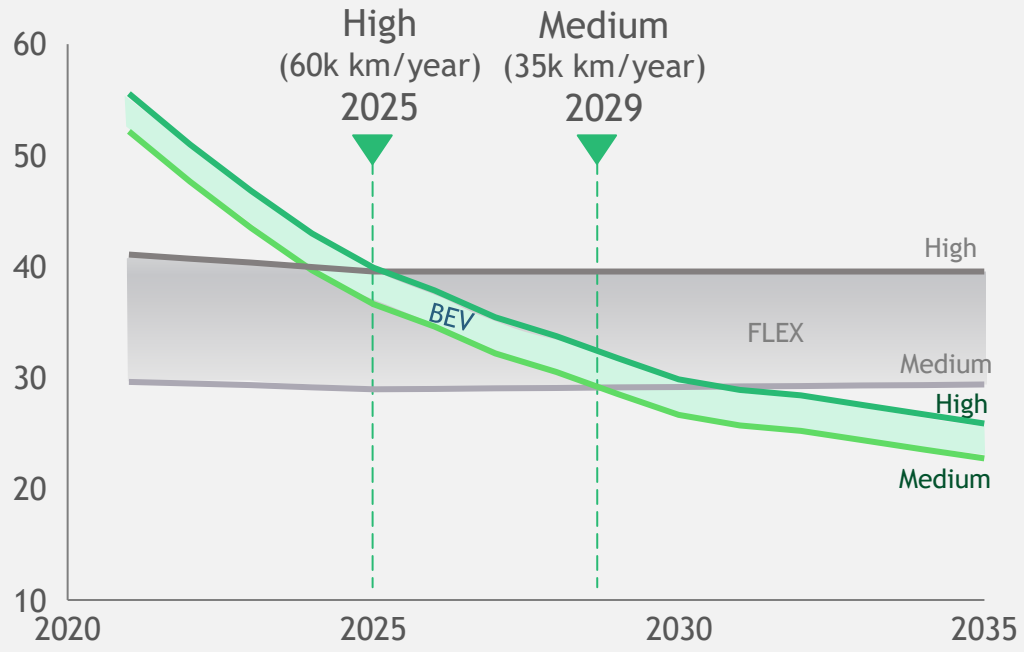
Note: Segment B: Includes Onix, HB20; Segment C: Includes Civic, Corolla; Segment SUV C: Includes Compass, HEV - Hybrid Electric Vehicle; BEV - Battery Electric Vehicle
Sources: Anfavea, Inmetro, automakers' websites, FIPE, ANP, ANEEL, BCG global projections, Bacen, BCG analysis and estimates

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

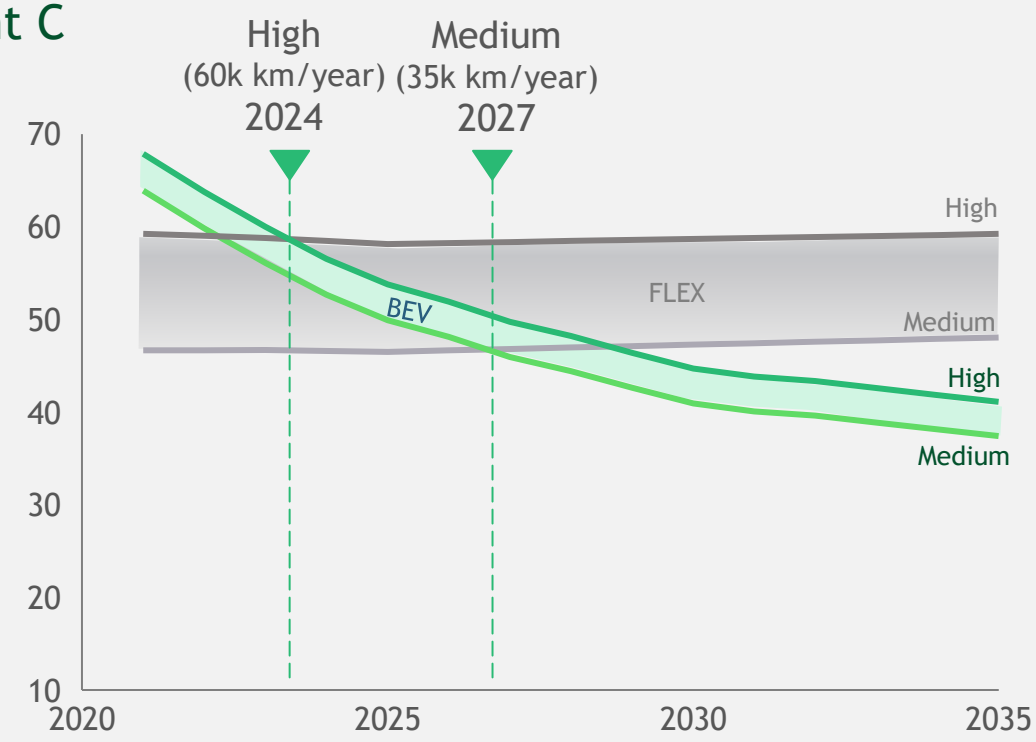
Total cost of ownership for professional light vehicles, per level of use (R$ thousand/year)

ESTIMATES

Segment B



Segment C

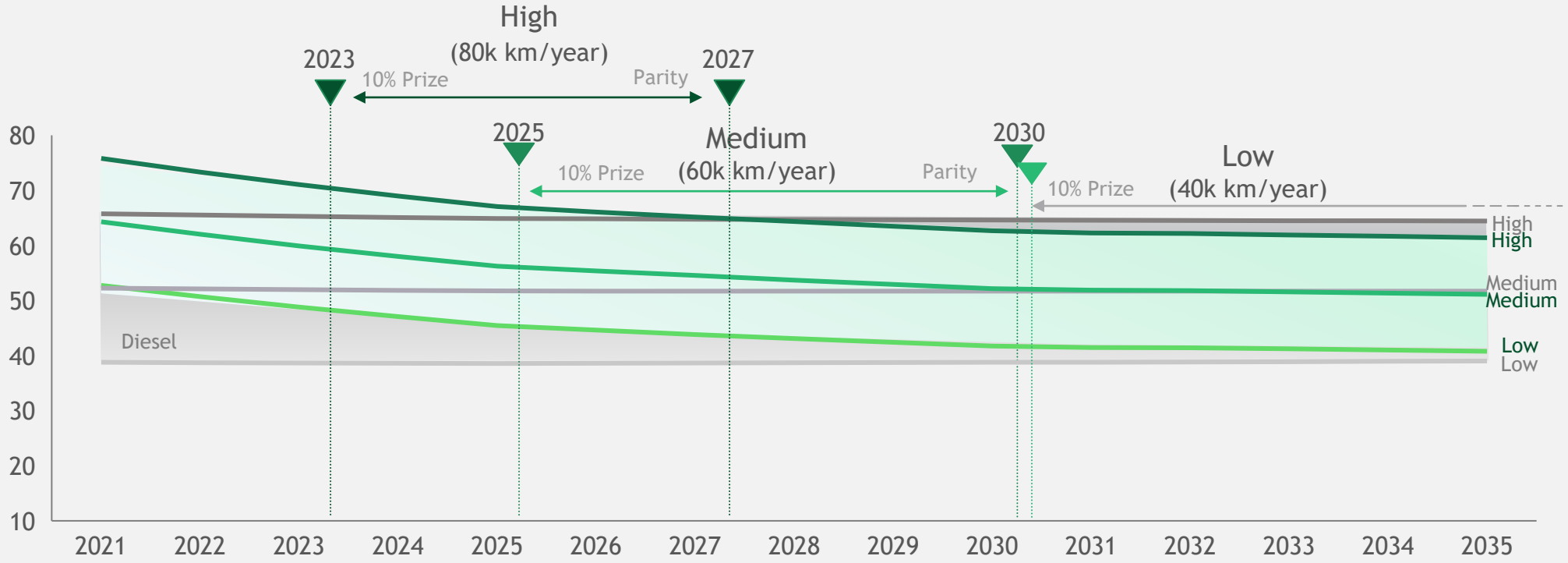


Note: Includes financing cost; BEV - Battery Electric Vehicle
Source: Anfavea, Inmetro, automakers' websites, FIPE, ANP, ANEEL, BCG global projections, Bacen, BCG Analysis

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)

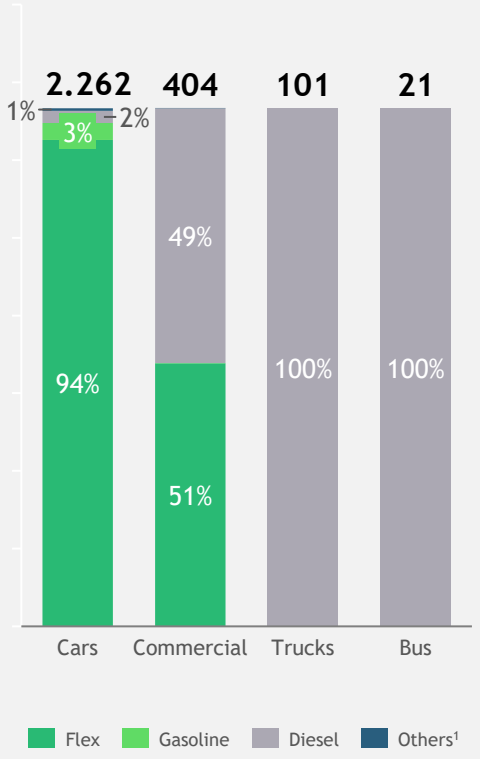
ESTIMATES



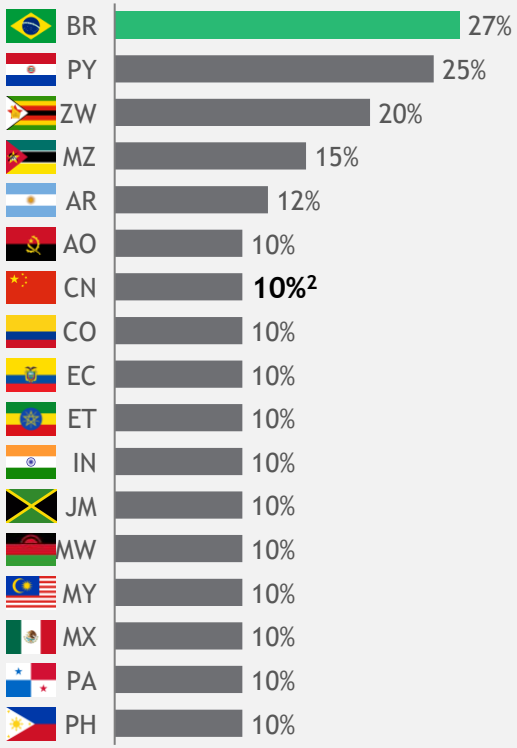
Note: Includes cost of financing, acquisition, battery replacement for BEV, fuel, maintenance, IPVA and residual value. Acquisition cost of Diesel vehicle increases in the period, but is offset by the improved efficiency of the engine; BEV - Battery Electric Vehicle
Source: Anfavea, Inmetro, automakers'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

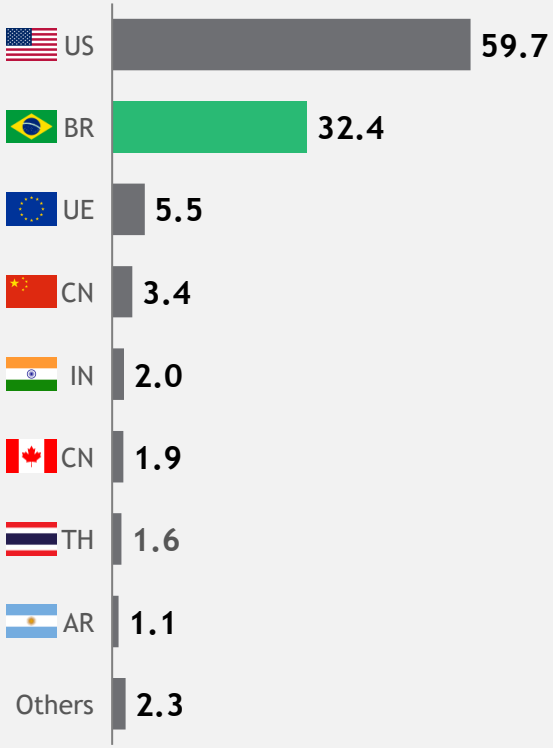
Licensed vehicles in 2019 (k)



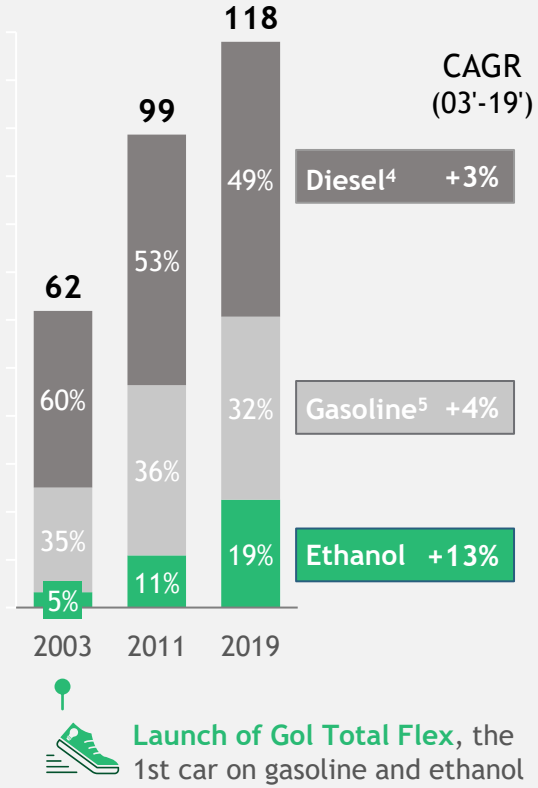
Amount of ethanol required in gasoline (%)



World ethanol production in 2019[3] (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

Measurement methodology	Emissions per fuel (g CO2 /km)		Average emission[1] (g CO2 /km)
Tank to wheel *Only the emission CO2 in the exhaust*	Gasoline C[2]	149	144
	Ethanol	136	
Well to wheel *Including production, refining and distribution*	Gasoline C[2]	151	112
	Ethanol	46	

-22%

Estimate including carbon capture (sugarcane-based ethanol)

Methodology for measuring and reporting of emissions will be important in the definition of the Brazilian route

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

Light vehicles

Heavy vehicles

Scenario 1

L1

Inertial

Scenario 2

L2

Global convergence

Scenario 3

L3

Biofuel protagonism

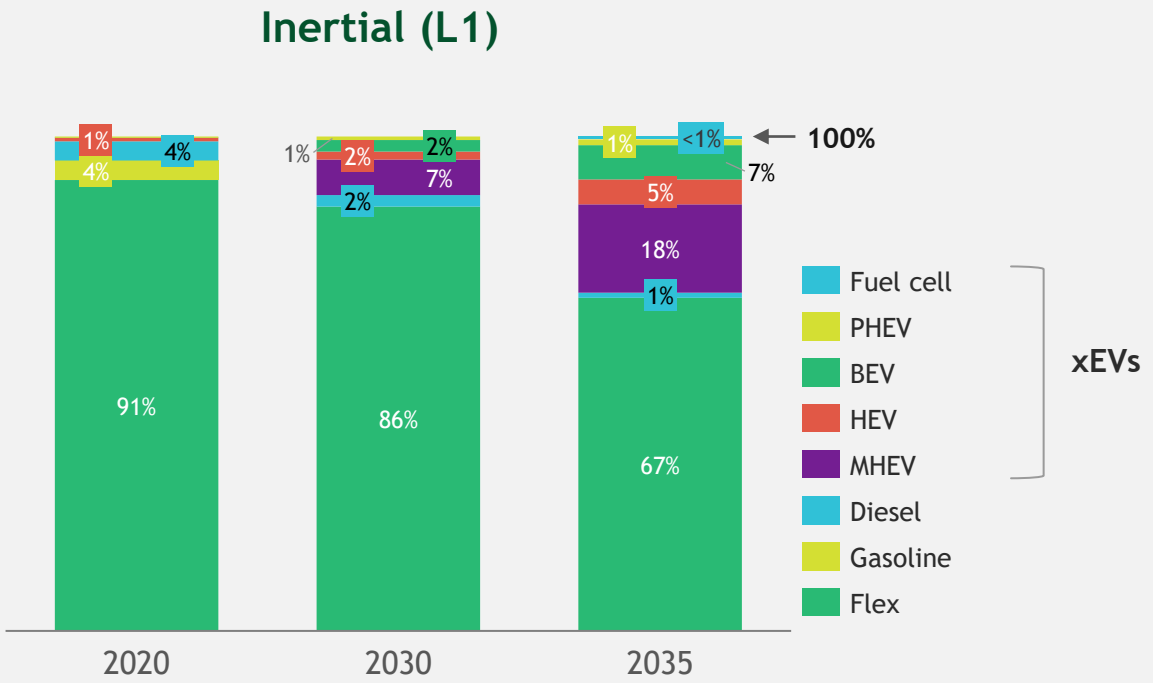
L1. Inertial scenario

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



	2020	2030	2035
xEVs (%)	1%	12%	32% (1.3 million vehicles)

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

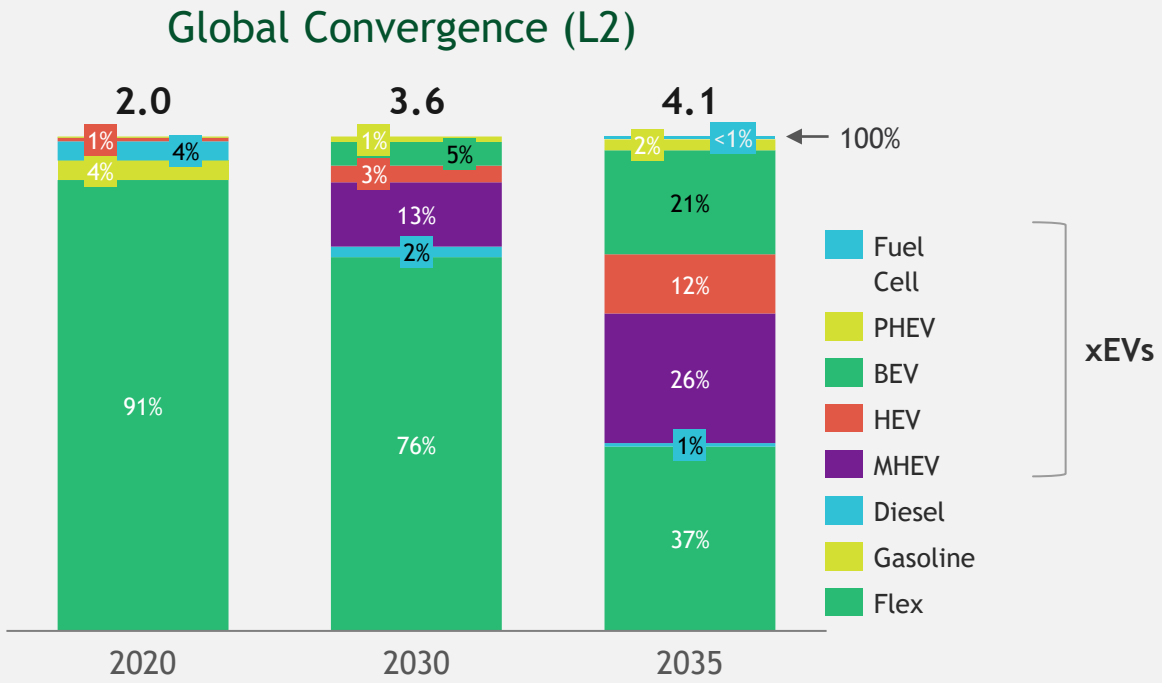
L2. Global convergence

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



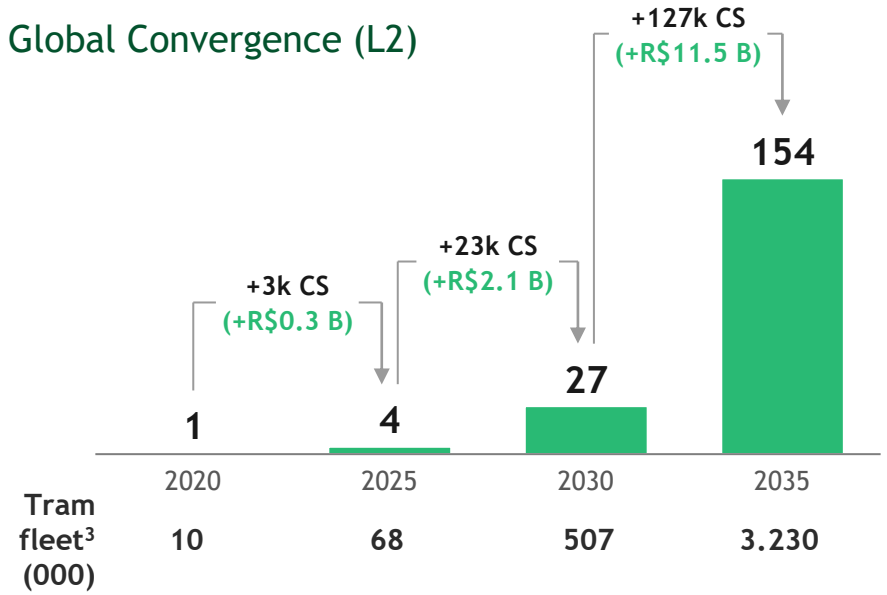
	2020	2030	2035
xEVs (%)	1%	22%	62% (2.5 million vehicles)

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

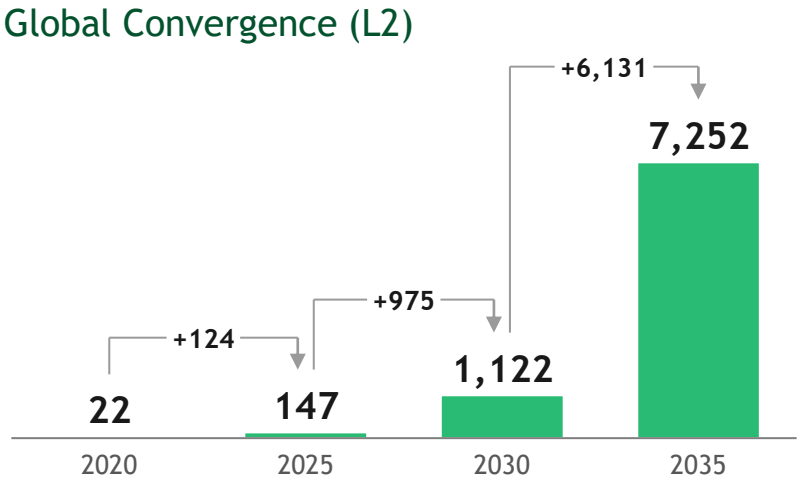
Convergence scenario points to the need to install 150,000 chargers and investments of R$ 14B until 2035

Estimates

Estimated charging stations (CS) needed to meet fleet of xEVs[1]



Estimated impact on electricity consumption[2] (GWh)/year



Total in the period **R$ 14 B[4]**

investments in charging points
penetration of BEVs/PHEVs in the convergence scenario

~1.5% of electricity consumed by the country (2019)

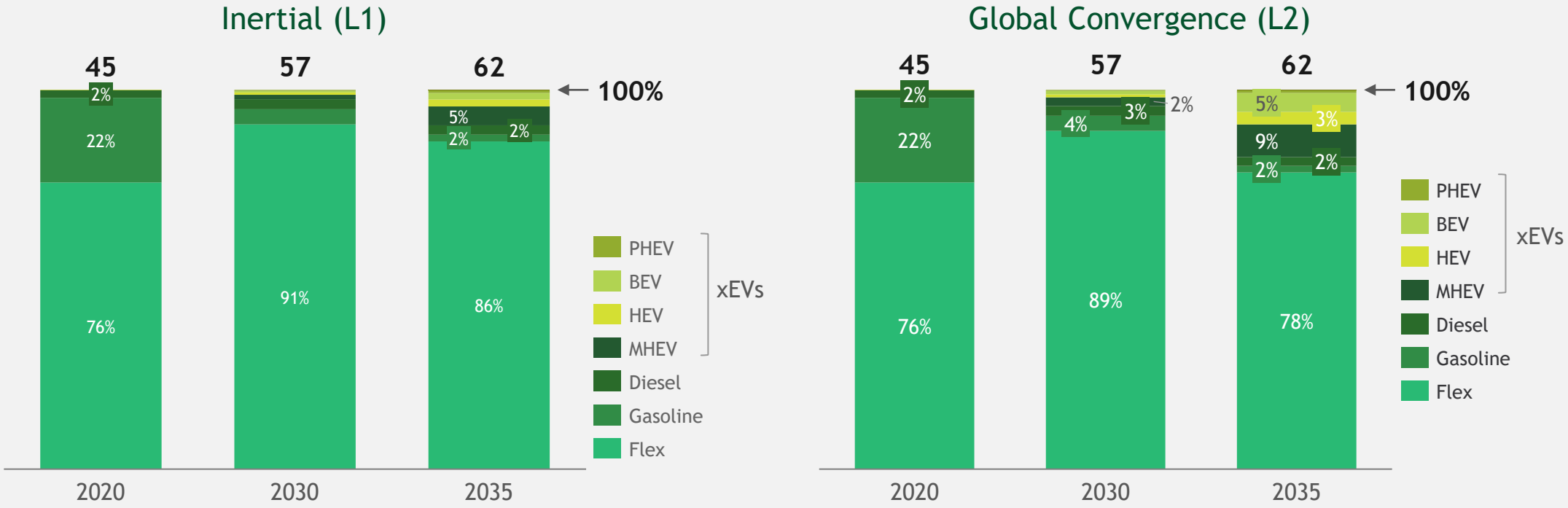
represents the demand for electricity to supply
BEVs/PHEVs in 2035 in the convergence scenario

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



	Inertial (L1) 2020	Inertial (L1) 2030	Inertial (L1) 2035	Global Convergence (L2) 2020	Global Convergence (L2) 2030	Global Convergence (L2) 2035
xEVs (%)	-	2%	10%	-	4%	18%

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

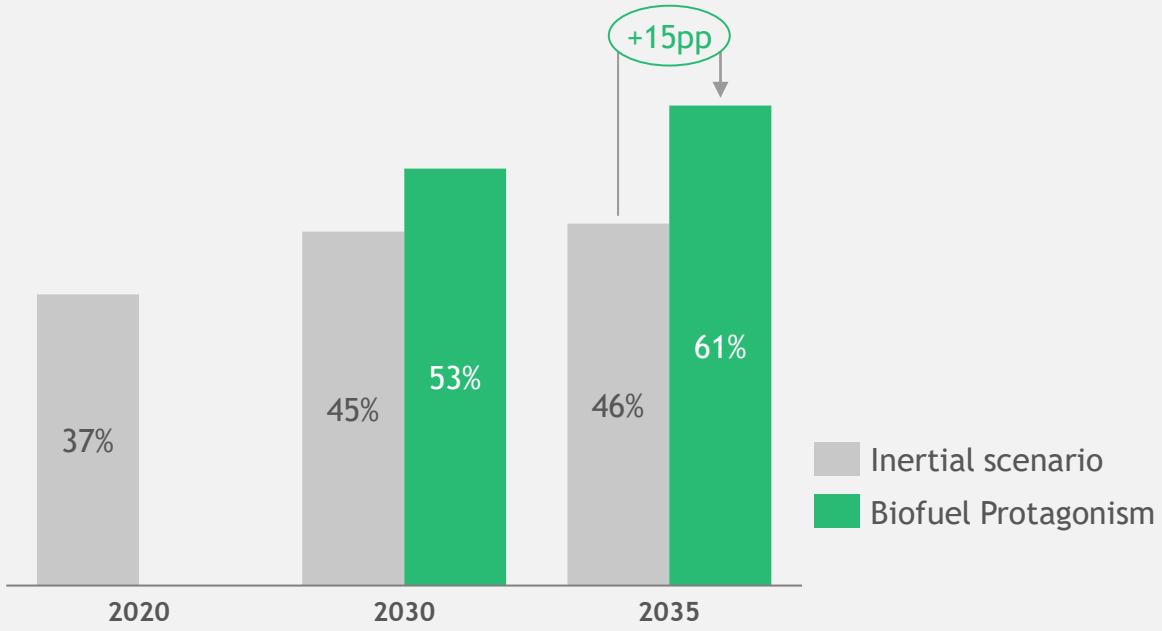
L3. Biofuel protagonism

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

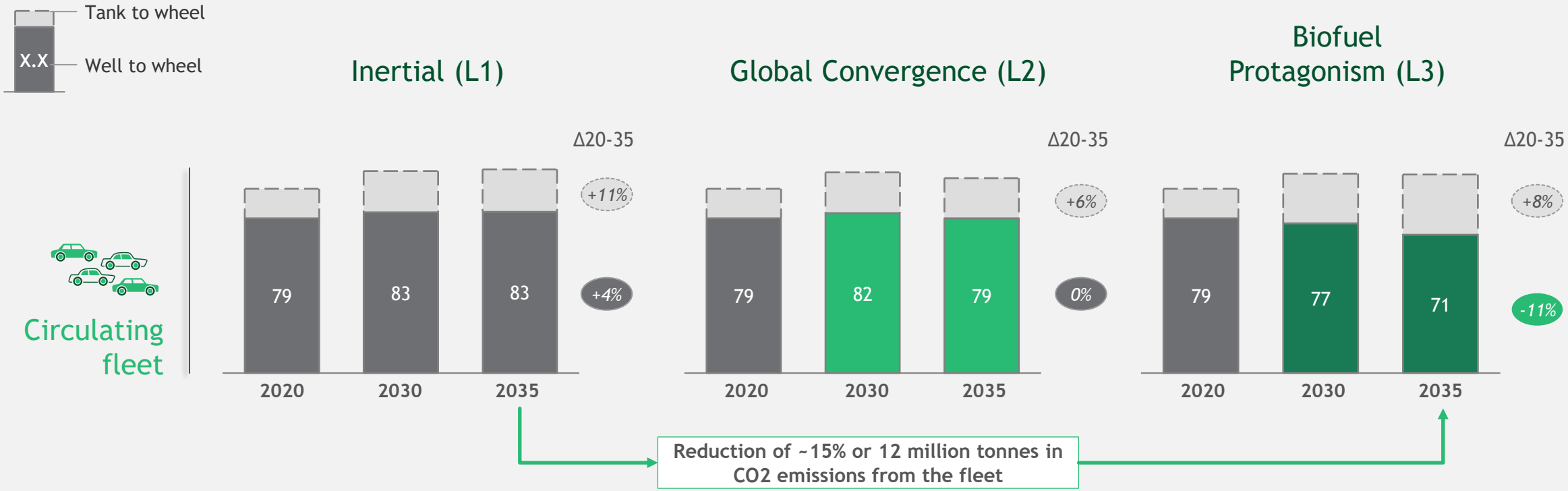
+18B l	Additional ethanol consumption in 2030 vs 2020
R$ 55 billion	Potential investment needed in the next 15 years for additional ethanol production
1-2M Ha	Additional planted area to meet ethanol demand

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



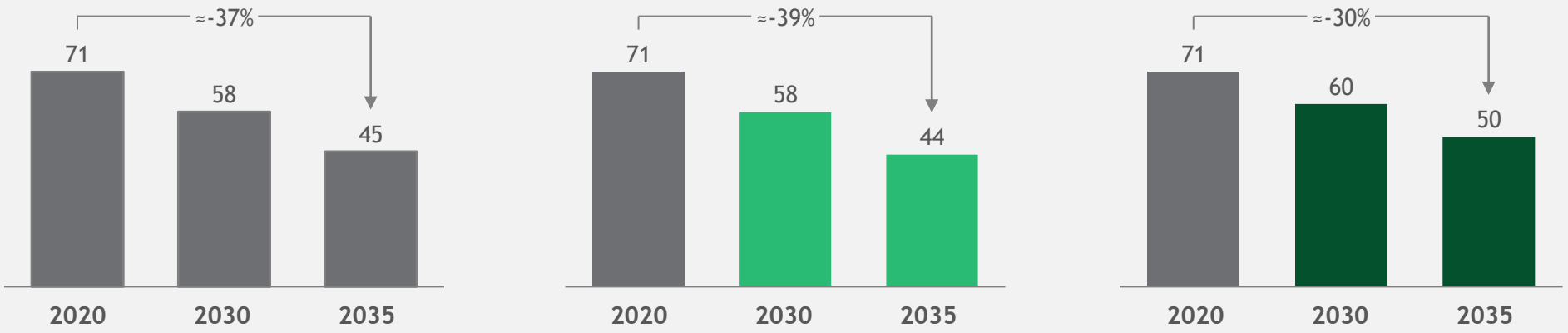
Note: Assumes growth of 37% in the current fleet between 2020 and 2035; emission factors (Kg/l exhaust and well to wheel, resp.) of 2.01 and 2.04 for gasoline, 1.2 and 0.4 for ethanol and 2.4 and 2.7 for diesel. Passenger vehicles only.
Source: Anfavea; Sindipeças; CBCS; BCG Analysis

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

ESTIMATES

NMOG + NOx emissions - thousands of tons / year

Circulating fleet



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

Light vehicles

Heavy vehicles

Scenario 1

P1

Inertial

Scenario 2

P2

Global convergence

Scenario 3

P3

Biofuel protagonism

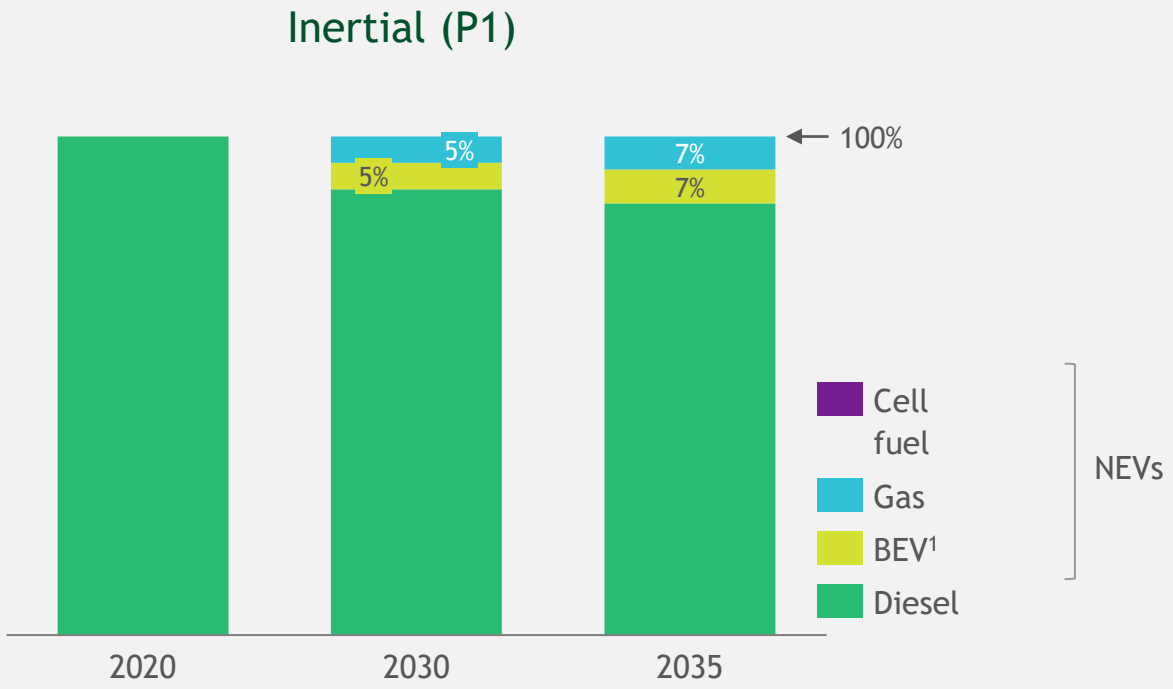
P1. Inertial scenario

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



NEVs¹ (%)	0%	10%	14%

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

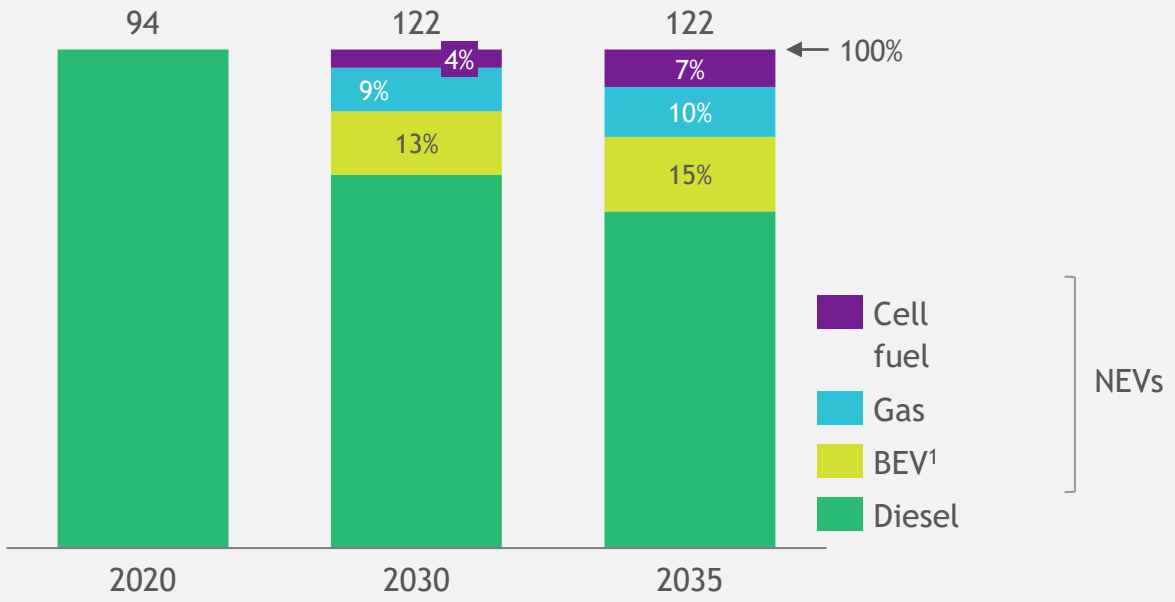
In this scenario, technological developments and the pace of adoption allow new technologies to gain scale in Brazil, reaching 2035 penetration levels similar to those in Europe in 2030

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

Annual sales mix, heavy vehicles

ESTIMATES

Global Convergence (P2)



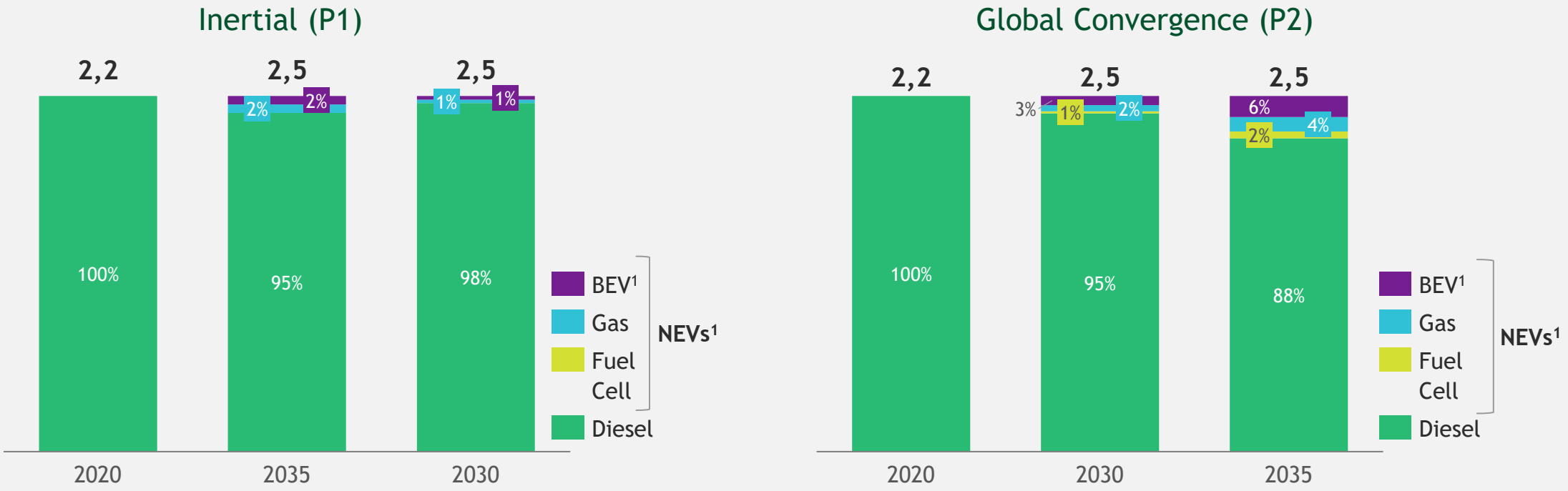
	2020	2030	2035
NEVs[1] (%)	0%	26%	32%

Note: Includes medium and heavy trucks and buses;
1. NEV - New Energy Vehicle; BEV - Batery 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



	2020	2035	2030	2020	2030	2035
NEVs[1] (%)	0%	2%	4%	0%	5%	12%

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

P3. Biofuel protagonism

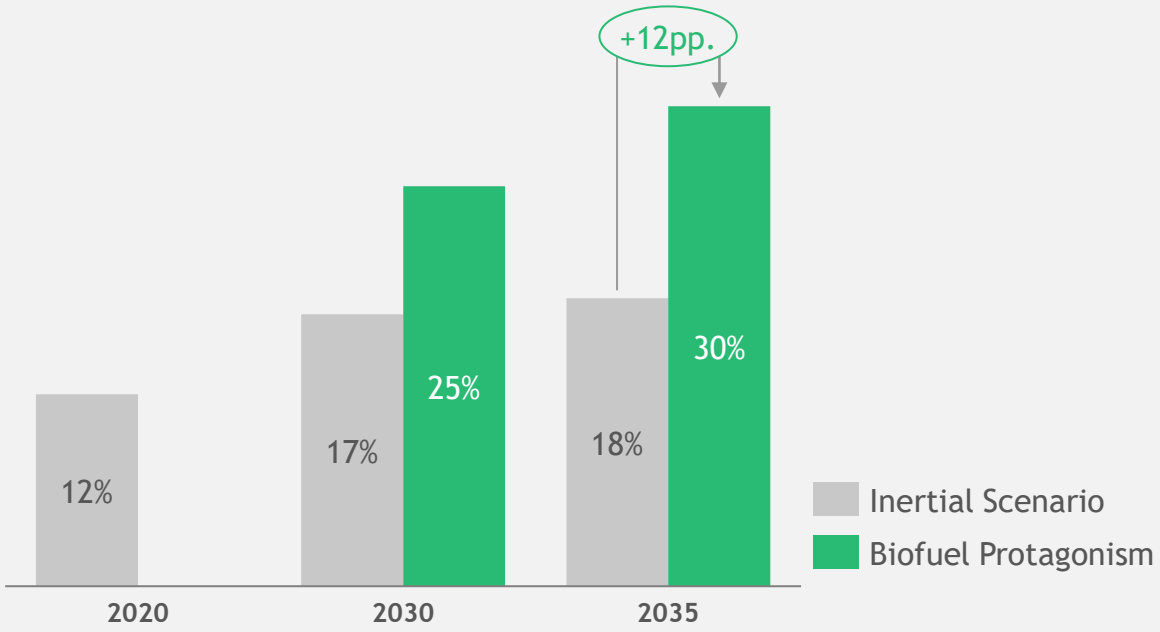
In this scenario, Biodiesel/HVO and other biofuels gain prominence as a path to decarbonization, made possible by favorable regulation and investments

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, nev penetration into new sales equal to the inertial

Heavy vehicles (% biofuels / fuels)

ESTIMATES



Impacts of higher biofuel penetration.

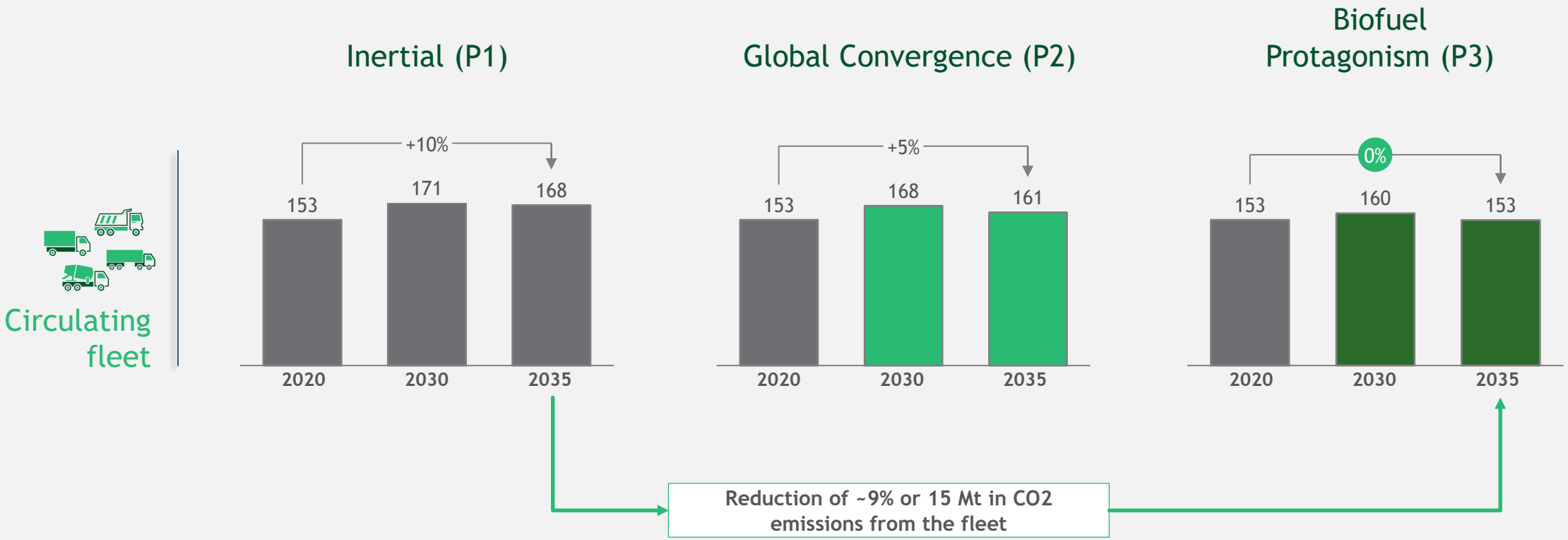
- CO2 emissions (well to wheel)
- Pollutants (HVO)
- Diesel Consumption

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

CO_2 - heavy vehicles | Increased application of biofuels can help reduce CO_2 by reducing current fleet emissions

CO_2 emissions - millions of tons CO_2 / year, vision well to wheel[1]

ESTIMATES



1. Considers carbon capture

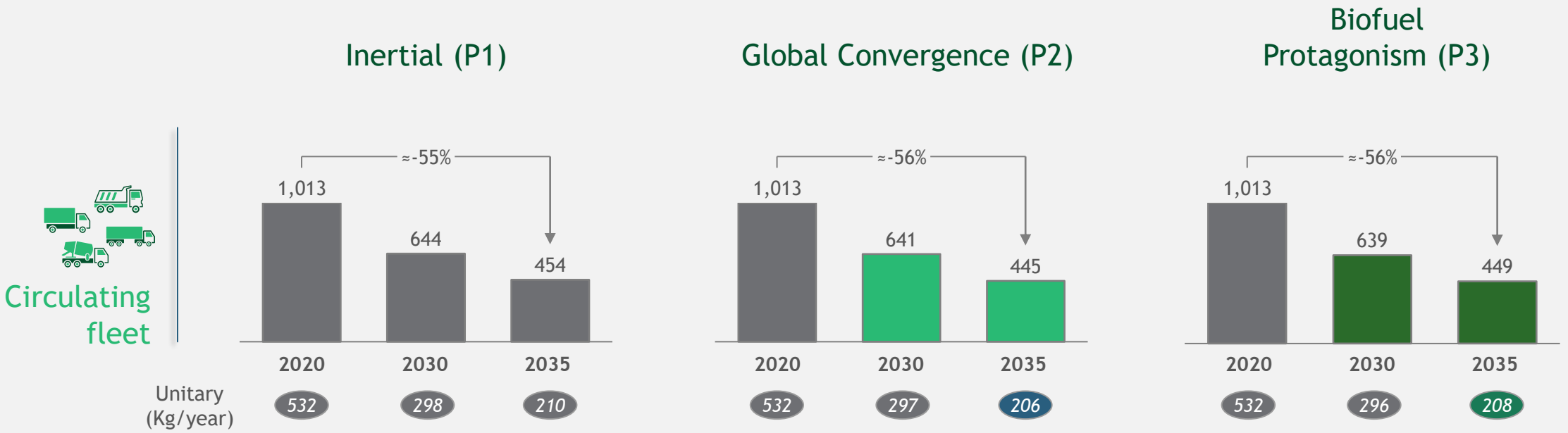
Note: New fleet growth of 12% between 2019 and 35, and of 14% of the circulating fleet between 2020 and 35; Emission factors (Kg/l exhaust and well-to-wheel, resp.) of 2.01 and 2.04 for gasoline, 1.2 and 0.4 for ethanol, 2.4 and 2.7 for diesel, 1.4 and 0.7 for HVO and 2.0 and 2.3 for NG. Considers only 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 20ptos 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.

This study was prepared by BCG based on the information available on the date of its publication. BCG does not warrant or make any statement regarding the accuracy, reliability, completeness or timeliness of the information, as well as its usefulness for any purpose. The reader is responsible for verifying the relevance and accuracy of the content of this study. To the fullextent permitted by applicable law, BCG is not liable for any loss and damage arising out of or relating to the use of the study by any person and the reader waives any right or claim he may have against BCG related to the presentation at any time. Access to and reading of the study implies the agreement of the reader with the previously established.

BCG does not undertake to update the document after the date of its publication, although the information may become outdated or inaccurate. Furthermore, any assessments, projected market information and conclusions contained in this document are based on standard evaluation methodologies, are not definitive predictions and are not guaranteed by BCG. BCG used data from various sources and assumptions provided to BCG from other sources. BCG did not independently verify the data and assumptions of these sources. Changes in data or assumptions will have an impact on analyses and conclusions.

This study is not intended to make or influence any recommendation and should not be interpreted as such by any person, physical or legal.

No part of the presentation may be reproduced in any way without the prior authorization of BCG.

BOSTON
CONSULTING
GROUP

bcg.com