The decarbonization path for the Auto sector in Brazil
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

<table>
<thead>
<tr>
<th>120 Countries</th>
<th>aim net zero in the Climate Ambition Alliance</th>
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<tbody>
<tr>
<td>~20% of customers</td>
<td>willing to pay more or shape climate behaviour</td>
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<td>$20T Global AUM&lt;sup&gt;1&lt;/sup&gt;</td>
<td>estimated to be allocated for investments in ESG in 2018</td>
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<td>~60% of the world’s largest companies</td>
<td>support the TCFD standard for climate disclosures</td>
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<tr>
<td>$306B losses in agriculture</td>
<td>due to the climate disaster in the U.S. in 2017</td>
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Customers are willing to pay higher prices or trade for eco-friendly products

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

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

**Climate change poses increasingly serious risks to global supply chains**

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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)

<table>
<thead>
<tr>
<th>Year</th>
<th>Volume of xEV produced per year</th>
<th>Percentage of xEV</th>
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<tbody>
<tr>
<td>2010</td>
<td>1,0</td>
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<td>2011</td>
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<tr>
<td>2017</td>
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<td>2018</td>
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<td>2019</td>
<td>7,2</td>
<td>8%</td>
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<tr>
<td>2020</td>
<td>8,4</td>
<td>11%</td>
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</table>

Participation of xEVs by type (%)

- BEV: 23%
- PHEV: 11%
- HEV: 26%
- MHEV: 40%

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)

Note: Forecast includes all light vehicles except vans;
In Brazil, local forces also influence the evolution of the routes.

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

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 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.

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

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

Segment B
- Reaches parity in 2035

Segment C
- Reaches parity in 2031

SUV Segment C
- Reaches parity in 2029

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)

**Segment B**

- **High** (60k km/year) 2025
- **Medium** (35k km/year) 2029

**Segment C**

- **High** (60k km/year) 2024
- **Medium** (35k km/year) 2027

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)

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)**

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<tr>
<th>Type</th>
<th>BR</th>
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**Amount of ethanol required in gasoline (%)**

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</table>

**World ethanol production in 2019 (B Liters)**

- US: 59.7
- BR: 32.4
- UE: 5.5
- CN: 3.4
- IN: 2.0
- CN: 1.9
- CH: 1.6
- AR: 1.1
- Others: 2.3

**Fuel sales by distributors (M m³)**

- 2003: 62
- 2011: 99
- 2019: 118

- Diesel: 49% (CAGR 3%)
- Gasoline: 32% (CAGR 4%)
- Ethanol: 19% (CAGR 13%)

**Launch of Gol Total Flex, the 1st car on gasoline and ethanol**

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.

<table>
<thead>
<tr>
<th>Measurement methodology</th>
<th>Emissions per fuel (g CO2 /km)</th>
<th>Average emission(^1) (g CO2 /km)</th>
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</thead>
<tbody>
<tr>
<td><strong>Tank to wheel</strong></td>
<td>Gasoline C(^2) 149</td>
<td>144</td>
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<tr>
<td></td>
<td>Ethanol 136</td>
<td></td>
</tr>
<tr>
<td><strong>Well to wheel</strong></td>
<td>Gasoline C(^2) 151</td>
<td>112</td>
</tr>
<tr>
<td></td>
<td>Ethanol 46</td>
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</tbody>
</table>

-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.

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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.

**Scenario 1**: Inertial

**Scenario 2**: Global convergence

**Scenario 3**: Biofuel protagonism

**Light vehicles**

**Heavy vehicles**
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**

**Inertial (L1)**

<table>
<thead>
<tr>
<th>Year</th>
<th>Fuel cell</th>
<th>PHEV</th>
<th>BEV</th>
<th>HEV</th>
<th>MHEV</th>
<th>Diesel</th>
<th>Gasoline</th>
<th>Flex</th>
<th>xEVs (%)</th>
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<td>2035</td>
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<td>67%</td>
<td>18%</td>
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<td>32%</td>
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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.

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

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

<table>
<thead>
<tr>
<th>Year</th>
<th>Tram fleet</th>
<th>Estimated CS (CS)</th>
<th>Estimated Investments ($)</th>
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<td>2020</td>
<td>10 (000)</td>
<td>+3k CS (+R$0.3B)</td>
<td></td>
</tr>
<tr>
<td>2025</td>
<td>68 (000)</td>
<td>+23k CS (+R$2.1B)</td>
<td></td>
</tr>
<tr>
<td>2030</td>
<td>507 (000)</td>
<td>+127k CS (+R$11.5B)</td>
<td></td>
</tr>
<tr>
<td>2035</td>
<td>3,230 (000)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total in the period R$ 14 B

~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: ~73% 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**

<table>
<thead>
<tr>
<th></th>
<th>2020</th>
<th>2030</th>
<th>2035</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inertial (L1)</td>
<td>45</td>
<td>57</td>
<td>62</td>
</tr>
<tr>
<td>xEVs (%)</td>
<td>-</td>
<td>2%</td>
<td>10%</td>
</tr>
<tr>
<td>Flex</td>
<td>2%</td>
<td>5%</td>
<td>2%</td>
</tr>
<tr>
<td>BEV</td>
<td>22%</td>
<td>91%</td>
<td>86%</td>
</tr>
<tr>
<td>PHEV</td>
<td>76%</td>
<td>9%</td>
<td>4%</td>
</tr>
<tr>
<td>Global Convergence (L2)</td>
<td>45</td>
<td>57</td>
<td>62</td>
</tr>
<tr>
<td>xEVs (%)</td>
<td>-</td>
<td>4%</td>
<td>18%</td>
</tr>
<tr>
<td>Flex</td>
<td>2%</td>
<td>3%</td>
<td>1%</td>
</tr>
<tr>
<td>BEV</td>
<td>22%</td>
<td>89%</td>
<td>78%</td>
</tr>
<tr>
<td>PHEV</td>
<td>76%</td>
<td>9%</td>
<td>2%</td>
</tr>
</tbody>
</table>

**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

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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.

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

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

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

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

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.

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**

**Global Convergence (P2)**

- **NEVs**
  - 2020: 94%
  - 2030: 122%
  - 2035: 122%

**NEVs¹ (%)**
- 2020: 0%
- 2030: 26%
- 2035: 32%

**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

<table>
<thead>
<tr>
<th></th>
<th>2020</th>
<th>2025</th>
<th>2030</th>
<th>2035</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global Convergence (P2)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BEV¹</td>
<td>2.2</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
</tr>
<tr>
<td>Gas</td>
<td>100%</td>
<td>95%</td>
<td>98%</td>
<td>100%</td>
</tr>
<tr>
<td>Fuel Cell</td>
<td></td>
<td>2%</td>
<td>1%</td>
<td>2%</td>
</tr>
<tr>
<td>NEVs¹ (%)</td>
<td>0%</td>
<td>2%</td>
<td>4%</td>
<td>6%</td>
</tr>
<tr>
<td>NEVs¹</td>
<td>0%</td>
<td>5%</td>
<td>12%</td>
<td></td>
</tr>
</tbody>
</table>

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)

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 wheel\(^1\)

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

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**Reduction of ~9% or 15 Mt in CO₂ emissions from the fleet**
Local pollutant emissions - heavy vehicles | Significant reduction in all scenarios given fleet renewal

NOx emissions - thousands of tons / year

<table>
<thead>
<tr>
<th>Circulating fleet</th>
<th>Inertial (P1)</th>
<th>Global Convergence (P2)</th>
<th>Biofuel Protagonism (P3)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unitary (Kg/year)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2020</td>
<td>2030</td>
<td>2035</td>
</tr>
<tr>
<td></td>
<td>1,013</td>
<td>644</td>
<td>454</td>
</tr>
<tr>
<td></td>
<td>≈ -55%</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>532</td>
<td>298</td>
<td>210</td>
</tr>
</tbody>
</table>

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
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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