Flex Fuel Vehicles in Brazil

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The Brazilian Automobile Industry

Local Manufacturers (2012) - 26 companies
Net Revenue (2011) - US $ 121,3 billions
Investments (1994 ~ 2011) - US $ 61,0 billions
Total Tax Generation (2011) - US $ 31,4 billions
Share of Industrial GDP (2011) - 21,0 %
Employment (direct + indirect) (2011) - 1,500,000 heads
## The Brazilian Automobile Industry

### Production Volume (2002 ~ 2012)

<table>
<thead>
<tr>
<th>Country</th>
<th>Production (2011)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st China</td>
<td>18,419,000</td>
</tr>
<tr>
<td>2nd USA</td>
<td>8,654,000</td>
</tr>
<tr>
<td>3rd Japan</td>
<td>8,399,000</td>
</tr>
<tr>
<td>4th Germany</td>
<td>6,311,000</td>
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<tr>
<td>5th South Korea</td>
<td>4,657,000</td>
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<tr>
<td>6th India</td>
<td>3,936,000</td>
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<tr>
<td>7th Brazil</td>
<td>3,407,861</td>
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<tr>
<td>8th Mexico</td>
<td>2,680,000</td>
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<tr>
<td>9th Spain</td>
<td>2,354,000</td>
</tr>
<tr>
<td>10th France</td>
<td>2,295,000</td>
</tr>
<tr>
<td>11th Canada</td>
<td>2,135,000</td>
</tr>
<tr>
<td>12th Russia</td>
<td>1,988,000</td>
</tr>
</tbody>
</table>

### Production Volume (2003 ~ 2012) Graph

- **2003**: 1,684,715
- **2004**: 2,124,177
- **2005**: 2,357,763
- **2006**: 2,403,693
- **2007**: 2,825,279
- **2008**: 3,050,631
- **2009**: 3,076,000
- **2010**: 3,382,143
- **2011**: 3,407,861
- **2012**: 3,342,617

**Y-axis**: Production Volume (in units)

**X-axis**: Year (2003 ~ 2012)
The Brazilian Automobile Industry

Production Profile (2012)

<table>
<thead>
<tr>
<th>Category</th>
<th>Units</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger Cars</td>
<td>2,623,704</td>
<td>78,5%</td>
</tr>
<tr>
<td>Light Commercials</td>
<td>549,249</td>
<td>16,4%</td>
</tr>
<tr>
<td>Trucks</td>
<td>132,820</td>
<td>4,0%</td>
</tr>
<tr>
<td>Buses</td>
<td>36,844</td>
<td>1,1%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Summary</th>
<th>Units</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>To Domestic Market</td>
<td>2,900,542</td>
<td>86,8%</td>
</tr>
<tr>
<td>To Export Market</td>
<td>442,075</td>
<td>13,2%</td>
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</tbody>
</table>

Domestic Market (2012)

<table>
<thead>
<tr>
<th>Locality</th>
<th>Units</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Locally Produced</td>
<td>3,007,006</td>
<td>79,1%</td>
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<tr>
<td>Imported</td>
<td>795,065</td>
<td>20,9%</td>
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</table>

Imported From

<table>
<thead>
<tr>
<th>Country</th>
<th>Units</th>
<th>Percentage</th>
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<tbody>
<tr>
<td>Argentina</td>
<td>349,168</td>
<td>43,9%</td>
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<tr>
<td>South Korea</td>
<td>151,875</td>
<td>19,1%</td>
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<tr>
<td>Mexico</td>
<td>109,033</td>
<td>13,7%</td>
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<tr>
<td>China</td>
<td>61,548</td>
<td>7,7%</td>
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<tr>
<td>Germany</td>
<td>53,016</td>
<td>6,7%</td>
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<tr>
<td>Others</td>
<td>70,425</td>
<td>8,9%</td>
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</tbody>
</table>
The Brazilian Automobile Industry

Automobile Fleet (2011)

Total Fleet: 34,654,969 vehicles
(5.5 inhabitants / vehicle)

(2 wheel vehicles, tractors and agriculture machinery are not included)
The Brazilian Ethanol Fuel Program

“PROALCOHOL”

This energy program was adopted by the Brazilian Government in 1975 due to the international oil crisis, aiming 2 applications:

1) to blend high volume of ethanol in gasoline (more than 15%);
2) to incentive the development of 100% ethanol fueled engines.
High volume content of ethanol in gasoline

Due to the ethanol availability (it’s a byproduct of sugar production), experiments with ethanol fueled vehicles were performed in Brazil since 1920;

In the time of World War (imported oil rationing), gasoline blended with ethanol (up to 5%) was intensely employed in Brazil with good results;

Since then, Brazil has continuously added different levels of ethanol in gasoline:

1938 ~ 1966 ⇒ 0% to 25%
1966 ~ 1981 ⇒ 10% to 14%
1981 ~ 1982 ⇒ 18% to 22%
1982 ~ today ⇒ 20% to 25%

Officially, the vehicles are certified for 22% ± 1% (E22).
From 1979 on the Brazilian automobile industry started to offer vehicles adapted to 100% ethanol fuel (E100).

At that time, the Brazilian Government also took some measures to incentive the use of ethanol (fuel price control, subsided loans to ethanol producers, obligation for all fuel stations to offer ethanol, tax reduction for ethanol fueled vehicles, etc.). Consequently, the E100 vehicle sales was a big success.
The PROALCOHOL Crisis

Due to economic problems, in 1987 the ethanol subsides were removed and its price became more expensive and closer of gasoline. In 1989, due to the inflation and price control, the ethanol producers decided to export more sugar causing a market ethanol shortage.

Therefore, the sales of 100% ethanol fueled vehicles were seriously affected.
Ethanol again?

At the end of 1990s, the ethanol supply was normalized and the price became stable and cheap;

The “clime changes” became a matter of great concern and the renewable fuels started to be valorized by the media, including ethanol.

So, the customers started to have interest on ethanol again.
Flex Fuel Vehicles (FFV)

Introduced in the Brazilian Market in March of 2003.

At this moment: 13 brands and 163 models.
The Flex Fuel are designed to be indistinctly fueled with gasoline (E22), ethanol (E100) or any blend of these two fuels. For the customers, it means to choose the fuel at each vehicle filling, according to fuel price, characteristics of quality, performance or even availability.

Through some special electronic sensors, the on-board computer recognizes the fuel and properly adjust the engine combustion parameters, without any interference from the driver.
Flex Fuel Sales

18,3 millions of FFV sold

87,0%

7,5%
The Brazilian Ethanol Fuel

2 different kinds of ethanol:

1. **Sugar Cane**
   - **Fermentation & Distillation**
   - **“Hydrous” Ethylic Alcohol (~ 6,8% H₂O)**
     - Application:
       - To use as straight fuel.
       - (E-100)

2. **Drying Process**
   - **“Anhydrous” Ethylic Alcohol (< 0,7% H₂O)**
     - Application:
       - To blend with gasoline.
       - (E-20 ~ E-25)
The Technology to Use Ethanol Fuel

Technically, the use of ethanol brings some concerns on:

- Compatibility with metallic materials (corrosion);
- Compatibility with plastic or rubber materials (chemical attack);
- High fuel consumption (low energy content);
- Loss of drivability (change of combustion air/fuel ratio);
- Difficulty in the engine cold start (low vapor pressure).

However, it all depends on:

1. Percentage of ethanol blended at gasoline;
2. Ethanol fuel specification and quality;
3. The vehicle technological level (age).
Eventual Modifications for Ethanol

- Electronic Fuel Injection or Carburetor
- Fuel Pump
- Fuel Filter
- Ignition System
- Fuel Pressure Device
- Cold Start System
- Basic Engine
- Motor Oil
- Exhaust Pipe
- Catalytic Converter
- Fuel Tank
- Intake Manifold
- Evaporative Emission System
- Exhaust Pipe
## Probably Necessary Modifications

**(Otto Cycle Engines)**

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<td>15 ~ 25%</td>
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</table>

- **Not Necessary**
- **Probably Necessary**

- For any vehicle
- For fleets up to 10 years old
- For specially designed vehicles
Engine and Vehicle components changes


2. Inlet Manifold: Optimized geometry to reach quickly the ideal temperature after cold start.

3. Fuel supply: Every plastic and metallic parts must resist to Gasoline and also Ethanol.

4. Catalytic converter: The type and amount of noble metals must be adjusted.

5. Exhaust system: Internal surface of pipes must be protected against oxidation. The dimension considers high water level inside the pipes.

6. Ignition system: Different ignition timing for each fuel. Spark plugs with optimized heat value.
Engine and Vehicle components modification

Cold start system: As the ethanol does not evaporate at low temperatures, it is necessary a small tank with gasoline for helping cold start.

The additional tank is not necessary with mixtures up to 85% ethanol (E85).

ECU and Software: Additional functions are included to determine ethanol ratio in fuel and calculate fuel injection amount and ignition time.

Fuel filter: Filter element material and its porosity must be arranged.

Pressure regulator: The fuel pressure must be increased. Internal surface must be protected against corrosion.

Fuel injectors and lambda sensor: The fuel injectors must be protected against corrosion. The lambda sensor will determine the air/fuel ratio for every possible mixture.

Fuel pump: It must provide fuel in higher pressure and flow. Internal components must be protected against corrosion.
Evolution in flex vehicles: Electric Cold Start

In 2009, it was introduced the first flexible vehicle produced in Brazil that doesn’t need the injection of gasoline to support the cold start.

This vehicle has an electrical heater that works integrated with the injectors and warms the ethanol (when it is necessary), assuring a perfect start of the engine even at low temperatures.
Ethanol Engines: Relative Performance

Three different vehicles of same model, each one adjusted and calibrated to a specific fuel.
**Fuel Consumption**

<table>
<thead>
<tr>
<th></th>
<th>E0</th>
<th>E22</th>
<th>E100</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Energy Content:</strong></td>
<td>31.65 MJ/L</td>
<td>28.99 MJ/L</td>
<td>20.09 MJ/L</td>
</tr>
<tr>
<td><strong>Fuel Consumption:</strong></td>
<td>1.0 L/100km</td>
<td>1.09 L/100km</td>
<td>1.58 L/100km</td>
</tr>
<tr>
<td><strong>Autonomy for 1.0 L:</strong></td>
<td>100.0 km</td>
<td>91.7 km</td>
<td>63.3 km</td>
</tr>
</tbody>
</table>

**Ethanol Price must be ≤ 70% of E22 price**
Thank you

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