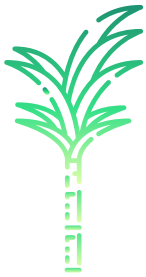
sustainable mobility: ethanol blending policy

THE BRAZILIAN CASE STUDY BY UNICA



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Thank you for your interest in this e-book on **ethanol blending policy**. Brazil has been blending ethanol with gasoline for more than 50 years and we are honored to share our insights. The large-scale use of biofuel has helped clean our air, save Brazilian lives and reduce greenhouse gases (GHG) that cause climate change.

Since the middle of the twentieth century, Brazilians have been blending ethanol with gasoline, and in the 1970s the practice was codified into law. The objective was to reduce the country's dependence on imported oil and develop our own source of fuel unaffected by foreign instability. The plan worked as the Brazilian sugarcane industry worked alongside government and private sector to bring forth a national transformation.

At the time, we were unaware of the science behind GHG and how these gases were warming the planet. Similarly, we believed the pollutants from fossil fuels were the price we needed to pay for having a modern transportation system.

Society's concerns with sustainability and health have fostered a renewed interest in biofuels. A turning point came in 2002 with the launch of flex-fuel vehicles when technology allowed us to measure the benefits of ethanol on the environment. The results were staggering: **We averted the emission of 556 million tons of CO2eq into the atmosphere and shifted our megalopolis, São Paulo, from the top to the end of the rank of the most polluted cities in the world.** The upshot is that every car in Brazil runs on pure ethanol or a 27% ethanol blend. Thanks to the abundant supply and the flex-fuel vehicles (FFVs), nearly 50% of our light fleet fuel demand is supplied by ethanol.

A recent study by the Brazilian Energy Research Agency (in Portuguese, EPE) concluded that using anhydrous ethanol mixed in 27% volume per volume (v/v) in gasoline saves 152 lives per year in the Metropolitan Region of São Paulo, with an associated increase in life expectancy of six days.

The benefits of a national blending policy are many. That is why we developed this e-book to share our learnings with policymakers, agricultural stakeholders, automotive manufactures and other leaders. The aim of the e-book is to be a conversation starter, and we look forward to the opportunity of engaging and discussing this further.

Yours sincerely,

Evandro Gussi
CEO

INTRODUCTION

Ethanol blends such as E10 and E20 dramatically reduce the greenhouse gas (GHG) emissions from automotive and motorcycle fleets.

For a country considering such a policy, its policymakers should keep in mind that blending:

- **Is a scalable option requiring minimal investment in infrastructure.**
- **Is less costly than other technologies.**
- **Can be easily applied to the existing fleet.**
- **Drastically reduces local pollutants in comparison to diesel and gasoline.**

Sustainable biofuels play an enormous role in both decarbonizing transportation and improving air quality. Brazil's energy transition started almost fifty years ago, with ethanol-run vehicles helping to support a reduction in carbon emissions. In Brazil, sugarcane ethanol has helped to prevent the release of 556 million tons of CO2 since 2003 when flex-fuel engines were launched. This has been achieved thanks to sugarcane ethanol that reduces up to 90% of GHG emissions throughout its lifecycle as compared to gasoline.

The City of São Paulo has managed to significantly reduce the amount of particulate matter (PM 2.5) in the air by increasing the use of ethanol, and there has been a significant impact on public health. According to IQ Air, in 2019 the megalopolis with the fourth-highest population in the world ranked 1210th in air pollution with a 15.3 µg / m^3 yearly average.

Biofuels are good for the environment and the economy. In Brazil, 2.3 million workers are directly and indirectly employed by the sugarcane value chain. Many of these Brazilian workers are in the rural parts of the country.

This e-book addresses five areas that decision makers should consider if they are planning a similar transition to biofuels:

01 PUBLIC POLICIES

02 FUEL SPECIFICATIONS

03 ENGINE SPECIFICATIONS AND ADAPTATIONS

04 ETHANOL IMPACT ON EMISSIONS

05 INFRASTRUCTURE ADAPTATIONS

01

public policies

PUBLIC POLICIES

Ethanol blends have been in use in Brazil since 1924, but it was only in the mid--1970s that they became mandated. The 1970s oil crisis emphasized the need to reduce the country's high dependence on oil imports. At the time 81% of Brazil's oil came from abroad. In response, **the government developed a public policy to incentivize the use of domestic ethanol as a fuel for the lightweight vehicle fleet. This included a combination of laws, regulations and financial incentives** which brought about a national blending program. **The blend percentage has varied until it stabilized in 2015 at 27% v/v ethanol blend for regular gasoline.**

The following are the most common questions regarding the development of public policies:

WHAT IS THE PURPOSE OF ADOPTING AN ETHANOL BLENDING POLICY?

Policymakers should view a national blending policy through a strategic lens. In short order, **ethanol blending can improve a nation's social and economic development.** It is a turnkey solution delivering immediate results in the fight against climate change. It will decrease pollution in cities and is especially effective in decreasing fine particulate matter (PM 2.5) spewed from engines. It will enhance energy security by reducing dependence on imported oil, help with the trade balance and generate jobs and income in rural areas.

Brazilian researchers concluded that the existence of an ethanol plant in a municipality raises the average GDP per capita by **US$1,098**, while the fifteen nearest towns experience an average GDP increase of **US$ 475** when compared to similar locations in the same region.

WHAT ARE THE FIRST STEPS TO EVALUATE WHETHER AN ETHANOL BLENDING POLICY IS SUITABLE FOR A COUNTRY?

Policymakers must conduct an analysis to answer foundational questions before deciding on a blending policy.

Questions include: What biofuel supply options do I have? Could my internal biofuel supply meet a blend mandate demand? What type of technology would be needed? Where do I get the technology?

The first step is to analyze biofuel supply options. Crops such as sugarcane, maize, and other starchy feedstocks are well established and the technical requirements are minimal.

If the country's capacity to produce biofuel internally is not enough to meet the blend mandate, it can import or develop a mixed supply chain.

Currently, there is technological expertise in the market for the production of first--generation ethanol using sugarcane, maize, and other feedstocks. Countries such as Brazil and the US have multinational companies that export the ethanol distillery machinery. Other technologies are in earlier stages of use, such as cellulosic ethanol or algae ethanol. Brazil has an operating plant of cellulosic ethanol, also known as second generation ethanol.

WHAT WAS THE ROLE OF INDUSTRY IN DEVELOPING THE POLICY?

The government ensured every stakeholder had a seat at the table, convening the biofuel, agriculture, automotive and oil refineries as well as fuel distributors and fuel stations. The government presented the initial legislation and suggested blending targets based on current and future scenarios. It was made clear the government would be responsible for implementation and control. The agricultural sector provided the government with forecasts on its supply capability, as well as the investment needed to meet targets (green fields, industry, logistics, etc.). The automotive industry ran extensive tests using the blended fuel and mapped out required adaptations. Finally, oil companies, fuel distributors and fuel stations reorganized their business models to incorporate the blending and necessary logistics.

Gasoline in Brazil is blended by the distributors and there are no pumps supplying pure gasoline which means all traded volumes are already blended.

BASED ON BRAZIL'S EXPERIENCE, WHAT GUIDANCE CAN YOU OFFER POLICYMAKERS?

Our experience points to several factors that made the Brazilian policy a national success:

1. Develop a policy that will survive the test of time and remains immune to domestic political instability or change. The final policy must reflect a national consensus and be strong enough to continue regardless of what party or leader runs the government.

2. Recognize the power of the marketplace in the decarbonizing process and consider offering incentives such as credit emission rights for biofuel producers **(RenovaBio)**.

SEE MORE

3. Create mechanisms that recognizes the positive externalities of renewable biofuels such as tax differentiation.

4. Provide the right level of fiscal incentives to automakers to ensure their enthusiastic buy-in retooling cars and trucks for the new requirements.

5. Require mandatory renewable ethanol purchase contracts between producers and oil companies to meet projected ethanol demand. These contracts can be used as collateral to finance distillation capacity expansion.

6. Create a legal framework to support private investment in distillation capacity expansion.

7. Establish price parity between ethanol and its feedstock alternative uses (regarding sugarcane, this translates into a parity between the ethanol and sugar market values);

8. In burgeoning industries, it may be beneficial to establish pricing mechanisms to create incentives for required investments.

HOW HAS THE INDUSTRY BEEN INCENTIVIZED AND/OR PENALIZED FOR NOT COMPLYING WITH HIGHER BLENDS?

Failure to comply may subject the violator to fines, seizure of goods and products, cancellation of product registration, suspension of product supply, total or partial temporary suspension of the operating establishment or installation, cancellation of registration of an establishment or installation and revocation of the authorization to carry out the said activity. In the Brazilian experience, compliance has been widespread, and sanctions are rare. We believe this reinforces the importance of bringing the different stakeholders into the process as early as possible.

02

fuel specification

FUEL SPECIFICATION

The current Brazil specification is 27% v/v of anhydrous ethanol blended with gasoline. Anhydrous ethanol is a pure substance that has at least 99.6% v/v alcoholic strength. This change was introduced following extensive testing by trade associations representing cars, motorcycles and auto-part manufacturers to demonstrate technical and environmental feasibility. Industry consensus ensured all the actors along the value chain were heard and their concerns addressed in adopting the new blending standards.

IS THERE A PARTICULAR SPECIFICATION TO BE ADOPTED FOR GASOLINE WHEN BLENDED WITH ETHANOL? WHAT ARE THE REFERENCE FUEL SPECIFICATIONS FOR E20?

The composition of gasoline does not have to be changed to be blended with anhydrous ethanol. In fact, the ethanol blend eliminates the need for aromatic additives for octane improvements such as toluene and xylene.

For further details on gasoline composition in Brazil, please refer to the following documents.

RESOLUTION No. 764, OF DECEMBER 20, 2018
National Press.pdf. Commercial Gasoline E27

RESOLUTION No. 807, OF JANUARY 23, 2020
National Press.pdf.

ARE ETHANOL AND METHANOL THE SAME? DO THEY HAVE THE SAME EFFECT ON VEHICLES AND THE ENVIRONMENT?

Chemically speaking, methanol has one carbon in its formula (CH3OH) while ethanol has two carbons (C2H5OH). From a practical standpoint, both are alcohols with similar characteristics but they differ in degree of toxicity. **While we may use diluted ethanol to prepare a drink, methanol is highly toxic and affects the nervous system which is why we avoid using it as an additive in gasoline.**

WHAT IS THE OCTANE LEVEL IN AN ETHANOL BLEND? WHAT IMPACT DOES IT HAVE ON PERFORMANCE AND DRIVABILITY?

Ethanol blending results in octane improvement, but occurs only if the fuel specification requires it. Otherwise, oil companies would be incentivized to use cheaper fractions to the blend which would keep the motor octane number/research octane number (MON/RON) at the same lower-performing level.

An octane rating (or octane number) is a standard measure of an engine's gasoline capability against compression. The octane rating of gasoline is a measure of the fuel's tendency to burn in a controlled manner. This is important to know when choosing a fuel for a particular engine. The MON/RON are reached after running tests and observing how the engine behaves with a certain fuel. Improved octane levels heighten an engine's performance and efficiency.

E10 blends are typically rated as being two to three octane numbers higher than regular gasoline. Modern engines, designed to take advantage of higher RON from E20 blends, can reach 3% consumption efficiency with drivability improvements.

WHAT IS PHASE SEPARATION AND HOW CAN IT AFFECT ENGINE PERFORMANCE?

Gasoline and anhydrous ethanol form a homogeneous mixture. The presence of water in the mixture above a certain limit causes the ethanol to separate from the gasoline forming two phases. Before long, the gasoline will become stale and unusable.

A proper blend will prevent phase separation. Each ethanol blend level has a different tolerance for water.

Ambient temperature also may influence phase separation. For E20, phase separation occurs when water concentration in the mixtures is above 1% at 68 °F/20 °C.

To prevent phase separation tanks, fuel trucks and pipelines must be kept dry prior to receiving any fuel, particularly gasoline with ethanol blends. This paper details the procedures and lessons learned over time in Brazil. This experience has led to a quality control and monitoring system imposed on fuel retailers. Similar material is available on the US RFA (Renewable Fuel Association) website.

03

Engine specifications and adaptations

ENGINE SPECIFICATIONS AND ADAPTATIONS

Most automotive manufacturers already produce vehicles compatible with up to 20% ethanol blend (E20). Nonetheless, Brazil created a task force to identify, correct and share technical bulletins to help prevent failure repetitions and misinformation in the marketplace during the implementation phase.

For quality control, ethanol blends should be tested before launching via a controlled environment. One way to test the blends is to use the government fleet of vehicles at known gas stations. This provides a unique opportunity to detect and resolve any problems before the product reaches the consumer.

DO E10 AND E20 BLENDS REQUIRE ANY CHANGES IN TWO-WHEEL AND FOUR-WHEEL COMPONENTS?

Transitioning from E0 to E10: Problems are exceedingly rare when changing from E0 to E10. When problems occur it is generally due to the non-compatibility of sealing materials, particularly rubber. Rubber seals have since been replaced by fluorinated compounds in the manufacturing processes, but older fleets require greater scrutiny when it comes to the inspecting the seals.

E10 to E20: It is generally accepted that up to E20 there are no material incompatibility problems for vehicles running on E10. Additional studies indicate that E30 can be compatible as well. Some models will require modification of the fuel filter with older ones requiring new seals and plastic parts that have contact with the fuel. For warranty purposes, the Original Equipment Manufacturer (OEM) should be consulted before making any adaptations, reinforcing the need to have manufacturers fully on board from the beginning.

For the successful introduction of a blending policy, it is crucial to consider the vehicles' age, technology, maintenance level, previous fuel and fuel quality in order to avoid an inaccurate assessment. Preparing for the blend's impact on the engine is essential. **The most important preparation is to evaluate the state of the feet.** This is crucial, because any problems occurring after the fuel specifications have been changed, whether linked or not with the new blend, can create negative reputational issues and must be prevented. Therefore, some countermeasures must be anticipated, such as requesting a fuel system check, tank cleaning, filter replacement and a maintenance check of the ignition system and sparkplugs.

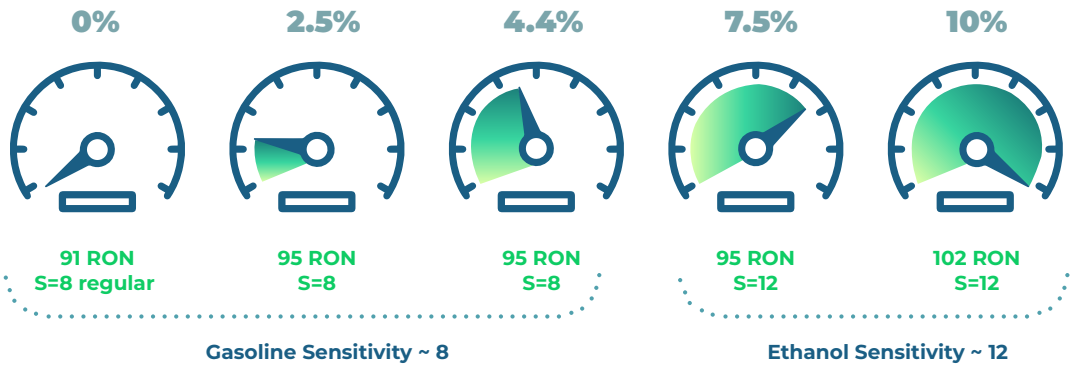
WHAT HAS BEEN THE IMPACT OF INCREASING THE ETHANOL CONTENT BEYOND A VEHICLE'S DESIGNED SPECIFICATION ON DRIVABILITY AND PERFORMANCE?

The United States has E15 and Brazil has E27 and both established blends have proven very reliable. The major global automakers have operations in both countries and can share key learnings with their counterparts in other countries. The study "Review and Evaluation of Studies on The Use of E15 In Light-Duty Vehicles" is comprised of tests and evaluations on models built from 2001 onward and can provide a more in-depth analysis.

HOW HAVE HIGHER-OCTANE NUMBERS BEEN TRANSLATED INTO TECHNOLOGY CHANGE?

Much depends on the engine technology.
For instance, a Gasoline Direct Injection (GDI) engine makes better use of higher octane fuel, but modern engines with knock sensors can as well. **Ethanol not only improves RON but also sensitivity which is a big advantage for fuel injection engines.** The illustration below shows the efficiency improvement with higher RON obtained with ethanol blends when compared to gasoline.

The sensitivity (RON-MON) is an important indicator of fuel properties for modern engines



Flex-fuel vehicles

All members of the **Brazilian National Automakers Association (ANFAVEA)** produce flex-fuel vehicles, and **more than 90% of new vehicles sold in Brazil include flex-fuel technology.** Flex-fuel cars and motorcycles can run on any percentage of ethanol blending even on pure ethanol.

The flex-fuel system was developed in Brazil and is simpler and less expensive technology than the US E85 and the France E85 offerings. Designed by individual OEMs, flex-fuels rely on extensive collaboration between auto-part makers and suppliers.

Flex-fuel technology is constantly evolving because Brazilian law offers tax incentives to encourage higher efficiency.

The referenced papers provide an excellent overview of the latest advancements for four-wheel and two-wheel vehicles.

- Evolution of Flex-Fuel Technology: A Case Study on Volkswagen Brazil
- High-Efficiency Flex-Fuel Engines, The Route for Brazilian Mobility
- The Impact of The Flex Engine on The Brazilian Motorcycle Market and Honda's Leadership
- Tsi Flex – The Flex Fuel Potential of a Turbocharged Direct Injection

04

Impact of ethanol on emissions

IMPACT OF ETHANOL ON EMISSIONS

IMPACT OF ETHANOL ON EMISSIONS

Where as **the initial motivation for an ethanol blending policy in Brazil was to reduce dependence on imported oil, it also provided immeasurable benefits to climate change and public health.** Air pollution caused by burning fossil fuels increases the risk of cardiovascular diseases, lung and respiratory diseases and diabetes, and is responsible for the death of 4.2 million people per year according to the World Health Organization (WHO).

Many crop-based biofuels, such as sugarcane, have a low net GHG emission thanks to the carbon capture provided by the plant's growth. In addition, the oxygen contained in biofuel molecules such as sugarcane ethanol makes internal combustion engines highly efficient and reduces the formation of many hazardous substances, including toxic fine particulate matter.

WHAT IS THE IMPACT OF ETHANOL BLENDS ON GHG EMISSIONS?

Using a **well-to-wheel*** analysis, E20 shows significant potential for reducing GHG emissions up to 11% when compared to E10. The mixture of 27% ethanol with gasoline (E27) adopted in Brazil provides a 15% reduction in CO2eq emissions compared to pure gasoline. When the E27 is used in hybrid cars, the CO2eq reduction can reach 50% when compared to an engine running on pure gasoline. These results are instantaneous once the proper policies are in place.

***The well-to-wheel analysis gives the overall picture of the energy resource utilization and its GHG emissions from the primary energy source (well) to its point of utilization (wheels). This analysis sums up not only the tailpipe emissions, but also the emissions involved in the production, transportation and distribution of fuel.**

WHAT IS THE IMPACT OF ETHANOL BLENDS ON THE EMISSION OF TOXIC SUBSTANCES AND PARTICULATE MATTER?

Ethanol enables reductions in the emission of highly toxic pollutants compared to gasoline. Turbocharged direct injection engines can reduce fine particulate matter PM 2.5 emission by **96%**, carbon monoxide CO by **81%**, polycyclic aromatic hydrocarbons (PAHs) from **67%** to **96 %** and decreases genotoxic potential from **72%** to **83%**.

A study by the University of São Paulo concluded that the use of ethanol in the eight main metropolitan regions of Brazil has prevents almost **1,400 deaths** and more than **9,000 hospital admissions** per year caused by respiratory and cardiovascular problems associated exclusively with the use of fossil fuels.

Fine particulate matter PM 2.5, a serious problem in big cities, can penetrate the bronchioles of the lung and enter the bloodstream, causing inflammation. “Fetuses, babies, children under 5 years of age and the elderly are more susceptible to diseases caused by particulate matter, such as asthma, chronic obstructive pulmonary disease, pneumonia, respiratory tract infections, cardiac arrhythmias, and coronary ischemic conditions", the Brazilian Energy Research Agency (EPE) has concluded.

High-Octane Mid-Level Ethanol Blend Market Assessment

EPE Impact on Health

WHAT IS THE IMPACT ON EVAPORATIVE EMISSIONS OR UNBURNT FUEL?

A higher blend will lower evaporative emissions. Approximately 10% of evaporative emissions occur during vehicle operation but most is released during refueling of cars and gas station tanks. Any measure to control evaporative emissions at these stages will therefore be more effective than any onboard measure. An example would be removing via suction gases during the filling procedure.

DO CARS OPERATING ON HIGHER ETHANOL BLENDS THAN THEY WERE DESIGNED FOR EMIT GREATER CONCENTRATIONS OF POLLUTANTS THOUGH THEIR EXHAUST?

Much depends on the type of technology used in the combustion chamber, injection and exhaust system. In Brazil, emission limits established by the government (Air Pollution Control Program for Motorcycles and Similar Vehicles – PROMOT - and Air Pollution Control Program for Motor Vehicles - PROCONVE policies) have led the automotive and two-wheeler manufacturers to make the improvements needed to reduce and control emissions for both gasoline and ethanol to the same level.

05

Infrastructure adaptations

INFRASTRUCTURE ADAPTATIONS

INFRASTRUCTURE ADAPTATIONS

Biofuel blending is a turnkey solution requiring **very little infrastructure change or capital investment and yet has a great many positive effects.**

WHAT INFRASTRUCTURE CHANGES HAVE BEEN INTRODUCED BY SUGAR MANUFACTURERS AND ETHANOL DISTILLERIES AND THEIR SUPPLY CHAINS IN THE TRANSITION TOWARD HIGHER ETHANOL BLENDS?

An anhydrous ethanol blending policy requires industrial facilities with the capacity to manufacture biofuels at a speed and volume that meets high demand. **Ethanol for E10 follows the same product specifications as used in the E27 blend.**

The location of these facilities depends on each feedstock. Grains, such as corn, can be easily transported and stocked for longer periods. Sugarcane, on the other hand, must be processed shortly after harvest and therefore proximity of manufacturing facilities is essential to guarantee efficiency. In Brazil, most distilleries are integrated within sugar mills, enabling companies to immediately divert raw material to one facility or the other.

WHAT HAVE BEEN THE MAIN CHANGES INTRODUCED BY OIL COMPANIES IN THE INFRASTRUCTURE AND SUPPLY CHAINS IN THE TRANSITION TOWARD HIGHER ETHANOL BLENDS?

Oil refineries do not require any adaptation for a blending program and can continue to sell pure gasoline as always.

WHAT INFRASTRUCTURE CHANGES HAVE BEEN INTRODUCED BY DISTRIBUTORS AND THEIR SUPPLY CHAINS IN THE TRANSITION TOWARD HIGHER ETHANOL BLENDS?

In Brazil, mixing is carried out by distributors at their bases. The distributor's base is where different fuels, such as gasoline, diesel, ethanol and biodiesel are received and blended before being transported to fueling stations. In these locations, specific tanks are required for storing anhydrous ethanol and special loading equipment enables mixing when filling high-duty distribution vehicles.

WHAT INFRASTRUCTURE CHANGES HAVE BEEN INTRODUCED BY RETAILERS AND THEIR SUPPLY CHAINS IN THE TRANSITION TOWARD HIGHER ETHANOL BLENDS?

Since all gasoline sold has ethanol in it, no changes are required at the fuel stations. If the policy is designed to provide consumers with options (pure gasoline or blended at various degrees) then extra pumps will be needed. Informed choices may be influenced by policy design, infrastructure particularities, number of fueling stations as well as other factors.

Brazil has adopted a pattern of testing mixed gasoline when fueling stations receive the cargo and follows quality control parameters defined by the Brazilian Agency for Petrol, Gas and Biofuels.

CONCLUSION

Brazil's national blending policy has been a **resounding success.** Through this approach we have achieved **energy independence** and put in place a system that did not required extensive infrastructure investment. The biggest return on investment are the **environmental and health benefits for today's Brazilians and future generations.**

The system we developed works for Brazil, but each country must develop its own system based on what is right for them.

We stand ready to help any government or industry seeking to transition away from traditional fossil fuels. UNICA is open to offering technical support in the agricultural and industrial sectors and to exchanging ideas in public policy, sus-tainability and trade.

We look forward to hearing from you.

SUSTAINABLE ENERGY AND FOOD
FROM BRAZIL TO THE WORLD

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