ABSTRACT

This paper will present the BEST project – BioEthanol for Sustainable Transport, developed by CENBIO–Brazilian Reference Center on Biomass. It’s an European Union initiative, coordinated by the Stockholm City Hall, that aims to promote the ethanol usage, replacing diesel, in the urban public transport. Apart from São Paulo, leading city in the Americas, another eight cities located in Europe and Asia take part in the project. One of the Brazilian project’s goals is to evaluate ethanol usage as diesel fuel replacement in public transport buses by comparatively following the operational output of the experimental fleet (fuel consumption, performance and occurred failures), taking as reference an equivalent diesel bus. The utilized test vehicles will be evaluated and monitored to demonstrate ethanol energetic efficiency and, after the results, the BEST project and the European Union will set a blue print for public policies to incentive ethanol usage in the urban public transport. The time is very favorable to the Brazilian program, as it is an alternative to diminish the metropolitan region pollution where the technology will be demonstrated. The vehicle will reduce in up to 80% gases emissions responsible for global warming. The engine utilized in the tests is well advanced even for European pollution standards. It is expected that this competitive advantage and the BEST project development in São Paulo will attract the attention of other places in Brazil for this technology.

INTRODUCTION

The BEST Project – BioEthanol for Sustainable Transport is an initiative of the European Union, coordinated by Stockholm’s City Hall, in Sweden. Its goal is to encourage the ethanol use, substituting diesel oil, in the urban public transport in Brazil and worldwide. The vehicles used in the tests will be monitored and evaluated to demonstrate the energetic efficiency of ethanol and, after the results, BEST Project and the European Union will supply recommendations for the formulation of public policies of encouragement.

CENBIO – Brazilian Reference Center on Biomass, from IEE – Institute of Eletrotechnics and Energy, from USP – University of São Paulo, develops two of the project’s goals.
Besides São Paulo, which is pioneer in the Americas, other eight cities, located in Europe and Asia, take part in the Project: Stockholm (Sweden), Madrid and Basque Country (Spain), Rotterdam (Netherlands), La Spezia (Italy), Somerset (England), Nanyang (China) and Dublin (Ireland).

One of the BEST Project’s Brazilian goals is to evaluate the use of ethanol as an alternative fuel to diesel oil, in buses used for public transportation, through comparative following of the operational performance of experimental fleet, taking as reference the equivalent diesel bus.

The applied technology, diesel engine adapted to work with ethanol, developed by the Swedish Scania company, is available and technically improved. In Sweden around 600 buses moved by Brazilian ethanol circulate, being that around 380 of these are in Stockholm.

The moment is very favorable for the program in Brazil, second greatest worldwide ethanol producer (18 billion liters, with the possibility of reaching 38 billion liters in 2012), because nowadays, diesel costs almost double the ethanol price in Brazil, besides the existence of the tendency of continuous raising of the oil prices.

**ETHANOL IN BRAZIL**

Brazil has the greatest biomass commercial program in the world, PROÁLCOOL – National Program for Alcohol, which was launched in 1975 by the Federal Government with the goal of producing ethanol and sugar from sugarcane to reduce oil importations.

In Brazil, ethanol is compulsorily added to gasoline, in percentage defined by the Federal Government, that varies from 20 to 25% in volume, producing the called gasohol, that substituted tetra etila lead and the MTBE – Merc Terc Butil Etil, that were added to the fossil fuels to increase its octane number.

Brazil is leader in the worldwide sugarcane ethanol market, with current production of 18 billion liters \(^1\), being 2/3 of this volume produced in the State of São Paulo. The favorable soil and climate, besides the investment in research and development, contribute to the ethanol productivity increase, reducing its production costs.

Comparatively to the other raw materials for ethanol production, sugarcane in Brazil has the advantage of having greater productivity, around 7,500 liters per hectare, against the ethanol produced from corn, in the USA, of 3,000 liters per hectare (Figure 1).

![Figure 1. Ethanol Productivity from different raw materials](image)
For each unity of fossil energy consumed in the sugarcane ethanol production, a quantity from 8 to 10 unities of renewable energy is produced, against around 1 unity of corn ethanol (Figure 2).

![Ethanol energetic balance from different raw materials](source)

**Figure 2. Ethanol energetic balance from different raw materials**

Source: UNICA, 2008[2].

Besides, the Brazilian ethanol costs are smaller (Figure 3).

![Ethanol production cost for different raw materials (US$/ton)](source)

**Figure 3. Ethanol production cost for different raw materials (US$/ton)**

Source: UNICA, 2008[3].

The ethanol from sugarcane has a more significant reduction of greenhouse gas emissions when compared to other ethanol produced from other raw materials (Figure 4).

![Comparison of greenhouse gas emissions from different raw materials](source)

**Figure 4. Comparison of greenhouse gas emissions from different raw materials.**

Source: UNICA, 2008[2].
Brazil detaches itself among the few countries in the world with great capacity of increasing its agricultural production [3]. The expansion of sugarcane production has happened, mainly, in the pasture areas that stopped being extensive becoming more efficient (intensive) [5]; that shows that the sector expansion is not invading the Cerrado vegetation, neither is invading the Amazon region (Figure 5), as it is being diffused.

![Figure 5. Sugarcane in Brazil](source.png)

Source: UNICA, 2008[2]

The expansion of the sugarcane sector has concentrated itself in the Center-South region of the country and the investments among the years from 2007 to 2012 in new facilities are of US$ 14 billions [1]. Nowadays, there are 86 new projects in implementation stage and the sector generates around 700,000 direct jobs and 3,5 million indirect jobs [6].

Regarding the competition between the sugarcane and food plantings, in Brazil it is not a reality, because the planted area is of 5,5 million hectares and the sugarcane culture occupies only 2,4% of this area [6]. Of the 90 million hectares, 22 millions are ready to the sugarcane planting [5] (Figure 6). Worldwide, a great part of the agricultural area is underused, mainly in the South hemisphere, where climate and soil are also favorable to the culture.

![Figure 6. Comparison between harvested area, ethanol and sugar production](source.png)

Source: UNICA, 2008[4].

**BEST PROJECT IN BRAZIL**

Since 2005, CENBIO searches for partners to develop the BEST Project in Brazil and, finally, in 2007 these partnerships were achieved. Scania Latin America imported the chassis and the engine from Sweden; Marcopolo projected, built and supplied the bus body; UNICA –
Sugarcane Industry Union will supply ethanol for the tests; BAFF/SEKAB will supply their self-made additive to be added to ethanol; while Petrobras will import the additive, make the additive blend to ethanol and distribute the fuel in the buses operatives. For the initial tests of mounting of the bus body, Copersucar imported the first allotment of additived ethanol (ETHAMAX).

The tests will be performed in the METRA – São Paulo Metropolitan System operative, from the EMTU/SP concessionaire – Metropolitan Urban Transport Company S.A., and also in operative to be appointed by SPTrans – Sao Paulo Transportation S.A., which are also partners in the project.

The Project launching took place on October 23rd, 2007, at USP, with the bus presentation (Figure 7).

![Figure 7. Bus moved by ethanol](source: Cenbio, 2007[7])

**TESTS METHODOLOGY**

Initially, the vehicle moved by ethanol will be incorporated to the METRA operative fleet. The tests will be performed in the Jabaquara - Sao Mateus corridor, which is 33 km long and transports 6 million passengers a month.

In order that the technology developed for the ethanol use in urban public transport bus can be evaluated, the functioning of the bus with engine moved by ethanol will be followed and documented, circulating in specific line, comparatively to similar bus, moved exclusively by diesel oil, and operated by METRA, in a corridor from EMTU system.

From the definition of the specific lines where the buses will operate, from the data to be collected and the systematic for the collection achievement, a vehicle following sheet will be elaborated. Then, the data to be collected about the buses functioning will be analyzed in the garage of the company that operates the buses, and also in the field tests performed in the corridor where they will circulate. Such data refer to fuel consumption, traversed mileage, performance, occurrence of accidents or mechanical problems, from the MKBF - *Mean Kilometers Between Failures*, and others.

For comparative effect, the same following will be adopted for all the evaluated buses.
There will not be done emissions tests, because the functioning engine in 2007 was already homologated and the one that will be functioning in 2008 will have homologation process provided by Scania itself and followed by the Project.

In 2005 and 2006, six buses were monitored in Sweden, three of them were ethanol fueled and the other ones were diesel fueled. There were measured distance travelled, fuel consumption, average price of fuels and vehicle taxes. All data collected showed that the average consumption of the ethanol buses was about 0.697 l/km; on the other hand, diesel buses average consumption was 0.413 l/km. The costs of the kilometers travelled were equivalent, about 0.373 €/km for ethanol against 0.376 €/km for diesel [8].

THE ADAPTED ENGINE

The diesel engine adapted to work with ethanol, developed by Scania’s Swedish company, which is the only manufacturer, is commercially available and technically improved, what is widely demonstrated in Sweden, where around 600 buses provided with this technology circulate.

The adaptation of the diesel engine to ethanol does not require significative changes, according to the manufacturer. The engine that will begin the tests in 2007 has mechanical injection and compression rate of 22:1, being that in the conventional diesel engines this rate is of 18:1 [9]. Scania already brought to Brazil a new generation engine, which will be demonstrated in 2008 (198 kW or 270 HP) and, among the modifications done, it presents compression rate of 28:1, electronic injection and injectors with bigger volumetric capacity (Figure 8).

For the use of ethanol in these engines, it is necessary the addition of 5% of an additive to ethanol, which does not have the auto-ignition by compression property, which is the technology from the diesel cycle engines. The additive addition is necessary in order that the combustion happens faster and with greater energetic efficiency [11].

There was a previous experience in Brazil, eleven years ago, in which a complete bus was brought from Sweden and the results were excellent from the environmental viewpoint, but moderate from economical viewpoint, since the difference between the prices of diesel oil
was around R$ 0.4154/liter \[^{12}\] and ethanol around R$ 0.681/liter \[^{13}\]; on that year, the average basket price of petroleum was US$ 18.68 \[^{14}\]. Nowadays the price of diesel oil is about R$ 1.90/liter and ethanol about R$ 0.85/liter, and the basket price of petroleum is about US$ 100 \[^{14}\].

**THE EMISSIONS**

The current bus in demonstration is equipped with engine that attends to the EURO 4 specifications, version that satisfies and overcomes the demands from CONAMA – Brazilian National Environment Council - Stage 5, regarding the local pollutant emissions: particulate material (PM), nitrogen oxides (NOx) and carbon monoxide (CO). In Stage 5, the tolerated pollution limits are higher and must attend only to the demands of the EURO 3 standard.

The engine to be used in 2008 is advanced even to the European emission standards, because it attends to the EURO 5 specifications that will vigorate in Europe only in 2009, and also EEV (*Enhanced Environmentally Friendly Vehicles*), rule that still does not have a date to vigorate in the European Union.

In Brazil, CETESB emitted a technical evaluation based on CONAMA’s current Resolution – Res. N. 315/02 – and, therefore, it was declared that the engine attends to the limits of Table 1, line 1, of Article 15, which means EURO 4. However, the engine emits a much lower value to the EURO 4 limit; CETESB could not write this since there is no Brazilian legislation to EURO 5 (Tables 1 and 2).

With these rigidness standards, it is estimated a reduction of more than 80% of the emissions of gases responsible for the global warming, of 90% of particulate material and 62% of NOx released in the atmosphere. Besides, it will not have emission of sulphur (S), that composes SOx, responsible for acid rain.

The reduction of local pollutants emissions (MP, NOx e CO) reduces the occurrence of cardio-respiratory diseases, what must be taken into account, mainly, in the metropolitan regions where the population is plentiful, there is great concentration of vehicles and atmospheric pollution sources, and the conditions of pollutants dispersion are unfavorable.

<table>
<thead>
<tr>
<th>ENGINE</th>
<th>EMISSION OBS. (m⁻¹)</th>
<th>LIMIT (1) (m¹)</th>
<th>FREE ACCELERATION (2) (m⁻¹)</th>
<th>LIMIT FOR FREE ACCEL. (3) (m⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC9 E02</td>
<td>0.04</td>
<td>0.5</td>
<td>0.01</td>
<td>1.19</td>
</tr>
</tbody>
</table>

(1) Value according to Table 1, line 1 of the Art. 15 of the CONAMA Resolution n. 315/02.
(2) Value obtained with opacimeter of partial flow at the sea level
(3) Established in the CONAMA Resolution n.16/95 from 13/12/1995

Table 1. Technical Engine Homologation
Source: Scania Latin America, 2008\[^{9}\].
### ENGINE:

<table>
<thead>
<tr>
<th>Emission Values</th>
<th>CO (g/kWh)</th>
<th>HC (g/kWh)</th>
<th>Nox (g/kWh)</th>
<th>P.M. (g/kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC9 E02 (*)</td>
<td>0</td>
<td>0.05</td>
<td>1.7</td>
<td>0.01</td>
</tr>
<tr>
<td>Maximum Limits (**)</td>
<td>1.5</td>
<td>0.46</td>
<td>3.5</td>
<td>0.02</td>
</tr>
</tbody>
</table>

(*) Exercise accomplished on 09/13/2007, at the RDW laboratory - Netherlands
(**) Established in the CONAMA resolution n. 315/02. Art.15 - Table 1, line 2

Table 2. Technical Engine Homologation
Source: Scania Latin America, 2008[9].

### CONCLUSION

More than stimulate the use of ethanol in the public transport, the initiative launched by CENBIO, partner companies and the European Union advances on the discussion about the development economical model that Brazil currently looks for.

The availability and the perspectives for ethanol production, added to the environmental competitive advantages, such as the reduction of the emission of pollutant gases, suggest that the ethanol use in diesel engines offer a series of benefits and favorable points to the model for Brazil. Among them, there is the diversification of the energetic matrix in the transportation sector, the use of a national fuel, the use of distribution infrastructure compatible with the one existent in Brazil, besides the interest from various government sectors in supporting the product.

The model of public transport moved by ethanol needs, however, to receive incentives from the Public Power, since it is a sustainable alternative. Studies show that the bus consumes around 60% more ethanol than diesel to go through the same distance. Even ethanol being 50% cheaper than diesel oil, the expenses need analysis, because there is the necessity of adding the additive cost. So far, the Swedish company SEKAB is the only one to produce additive for the engine moved by ethanol.

Even with the improvement of the additive and the engine, that arrive to the third generation, there is still, as a challenge to the ethanol use in the public transportation, the production of the vehicle and additive in Brazil.

The use of this technology represents a great progress and the expectation is that its advantages, from the example of BEST in São Paulo, attract the attention of other regions in Brazil to the technology.
The results will allow to identify the technical-economical barriers that eventually interpose themselves to the feasibility of the implantation of this technology in Brazil’s public transportation.

REFERENCES


