

CO₂ EMISSIONS AVOIDED THROUGH THE USE OF BIODIESEL IN BRAZIL

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Abstract

Intensive use of oil products for driving vehicles, generating power and many other activities has made the world very dependent on this fossil fuel. As this non-renewable energy source becomes scarcer, demands are rising steadily. Research is under way, seeking alternative fuels that slow this depletion while easing environment stresses caused mainly by burning fossil fuels. Outstanding among these alternatives is biodiesel, a fuel obtained through the transesterification of plant oils or animal fats and that might well replace petrodiesel. The many advantages of this renewable fuel include reducing national dependence on oil while lowering greenhouse gases emissions, such as CO₂. The purpose of this study is to assess the impacts of biodiesel on CO₂ emission levels. The calculations in this paper present the forecasts for petrodiesel consumption in Brazil and the resulting CO₂ emissions through to 2020, quantifying the emissions avoided through adding 2% and 5% methyl biodiesel made from soybeans to gasoline over this period.

1. Introduction

From the late XVIII century onwards, the development of internal combustion motors progressed slowly but steadily for the next hundred years. In 1892, Rudolph Diesel was awarded a patent for a compression ignition motor fueled by coal dust, although his original design did not work very well. {Ma & Hanna, 1999}.

Discovered in 1859 in Pennsylvania, oil was used mainly to produce kerosene. Taking advantage of the availability of an assortment of oil products, Diesel began to experiment with other fuels and, after some modifications to with his original design, he built the first successful prototype in 1895. One of the earliest records of the use of vegetable oils in diesel cycle motors dates back to this period, when the inventor of this new motor used peanut oil for a demonstration at the Paris Exhibition in 1900 {Altin et al., 2001}.

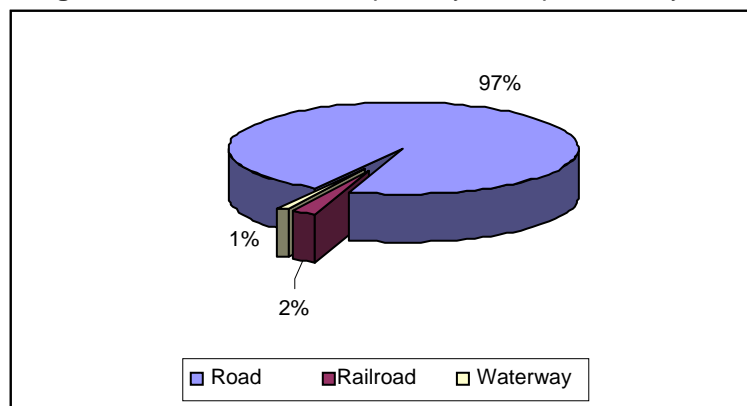
Low oil prices during almost the entire XX century spurred the simultaneous development of diesel oil and diesel motors, and by 1970 there were few references to the use of alternative fuels in diesel cycle motors. During the 1930s and the 1940s, plant oils were occasionally used as fuels, but only in emergency situations.

More recently, successive oil price hikes and rising environmental concerns have prompted fresh interest in the use of plant oils and their derivatives as fuels, including biodiesel. (Pinto et. al., 2001).

With a keen interest in this area, Brazil offers ample potential for biodiesel, as an alternative to mineral diesel oil, produced by the transesterification of oils or fats deriving from untreated plant oils, such as castor beans, peanuts, sunflower seeds, soybeans and several other regional crops that can be grown in Brazil, in addition to spent frying oil. This fuel can be used in decentralized power generation units, production equipment, agricultural and civil construction machinery and vehicles used to ship cargos and carry passengers.

The latter account for around 82.1% of the final energy consumption of diesel oil, which is the main oil product imported by Brazil. Of this percentage, almost 97% is allocated solely to cargo shipments and passenger transportation by road (BEN, 2011). This is the main system in Brazil's transportation matrix, accounting for more than 60% of all cargos shipped in Brazil, according to the Land Transport Regulator (ANTT, 2012). The following graph presents the consumption of diesel oil by transportation system in Brazil:

Figure 1: Diesel Oil Consumption by Transportation System



Source: Adapted, BEN, 2011

Thus, it is apparent that most of this consumption is absorbed by diesel motors, used for either transportation or power generation purposes. Consequently, an alternative renewable energy source such as biodiesel has an important role in lessening Brazil's dependence on diesel, while spurring the use of an environmentally friendly fuel.

2. Brazil's Biodiesel Production and Use Program

The Brazilian Government introduced its Biodiesel Production and Use Program in 2004. Briefly, this Program stipulated that percentages of biodiesel would be added to mineral diesel, as follows:

- ✓ B2 (2% biodiesel and 98% diesel) authorized through to 2008;
- ✓ B2 mandatory from 2008 onwards;
- ✓ B5 (5% biodiesel and 95% diesel) mandatory from 2013 onwards.

It is stressed that this program includes discussions with vehicle assemblers in order to maintain the factory warranties for the vehicles fuelled by the blends described above. Moreover, biodiesel producers must obtain special registration from the Federal Revenue Bureau under the Treasury Ministry, as well as authorization from Brazil's Oil, Gas and Renewable Fuels Regulator (ANP), which will also establish the biodiesel specifications needed to ensure the quality standards required for its use as a fuel in motors.

According to the ANP (2010), the authorized production capacity of biodiesel plants in Brazil reaches some 85.3 million liters a year. This current production level is a major challenge for meeting the targets established under the National Biodiesel Production and Use Program, which requires some 800 million liters (2% of forty billion liters of diesel oil consumed in 2005), in its initial

phase. This means that Brazil's current production capacity meets only 11% of the demand, based on the B2 blend.

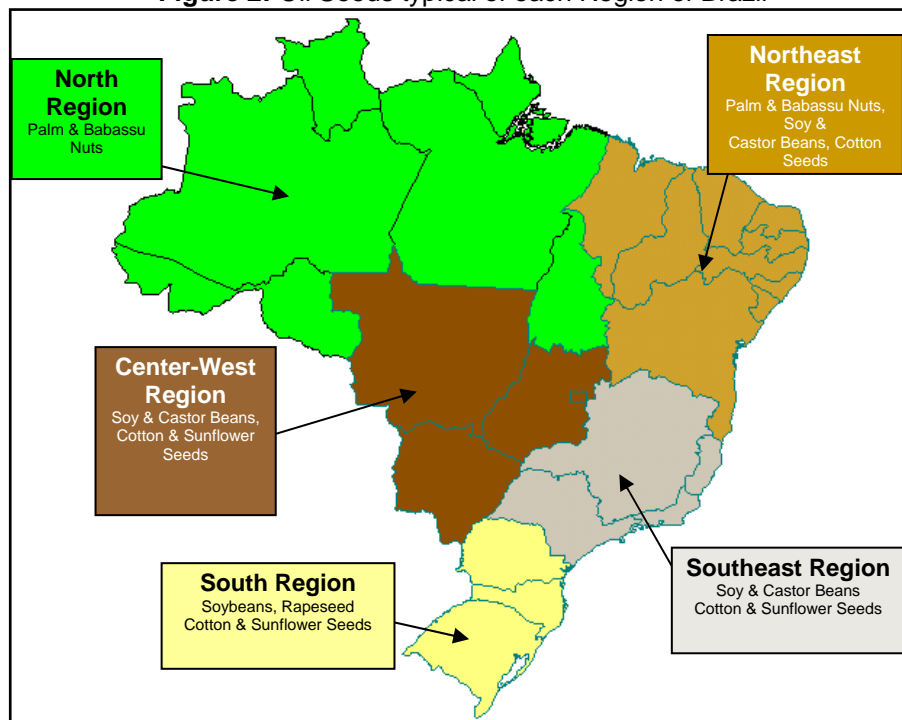
Additionally, the required capacity must be tripled by 2013, when the rule comes into effect adding 5% biodiesel to petrodiesel. However, several biodiesel production units are under analysis for subsequent approval by the ANP, which should pave the way for meeting the demand established through this Program.

In contrast to other countries, where oil is extracted from only one or two sources, Brazil offers a wide variety of oilseed species from which large quantities of oil can be extracted, constituting the main raw material for producing biodiesel.

Due to its favorable climate and good quality soil, Brazil is endowed with easily available sources of plant oils scattered all over the country. Every year, production and export records are broken for soybeans and other oilseeds, proving the ample potential for exploitation of this feedstock.

Each part of Brazil specializes in growing a specific group of oilseeds, segmenting the sources of feedstock for producing this fuel. This is a positive factor, as there is no need to introduce crops into regions where they might not thrive, requiring vast research efforts in order to adapt these plants to new climates and soils. With each region specializing in its own traditional crops, research efforts can be channeled towards upgrading harvests and production capacities. Figure 2 below presents the various oilseeds available in Brazil, by region:

Figure 2: Oil Seeds typical of each Region of Brazil



Source: Brazilian Agricultural Research Enterprise (EMBRAPA), 2009

Particularly noteworthy among the reactive inputs currently used to produce biodiesel are methanol (methyl alcohol) when biodiesel is produced by the methyl route and ethanol (ethyl alcohol when the ethyl route is selected).

Due to the easy availability of ethyl alcohol in Brazil, it is intended to produce biodiesel through this route on a large scale, due to its geographical availability that extends nationwide, and also because this is a safer product to work with for the plant operators.

3. Advantages of Biodiesel

There are several advantages to using biodiesel as a fuel, with many gains arising from oilseed plantations that produce them. Outstanding among them are:

3.1 Environmental Gains

The environmental gains include:

- Substitution of a fossil fuel by a renewable counterpart;
- Sequestration of motor-issued carbon through photosynthesis on oilseed plantations;
- Lower emission levels caused by combustion, as biodiesel has been proven to produce low levels of pollutants such as SO_x, greenhouse gases and particulate matter. Due to the need to reduce these emissions under agreements among the countries signing the Kyoto Protocol, biodiesel will help attain these targets;
- In comparative terms:
 - ✓ 1 ton of biodiesel = -2.5 tons of CO₂ (DEDINI);
 - ✓ European studies demonstrate that rapeseed biodiesel reduces greenhouse gases emissions by some 40% to 60%, compared to diesel (NAE/2005);
 - ✓ However, a minor increase in NO_x emissions is noted.

3.2 Economic Aspects

Outstanding among the economic advantages of biodiesel are:

- Strengthening agribusiness in a country whose exports consist largely of agricultural produce;
- Fostering sustainable development in areas where local oilseed plantations are established;
- Lessening the problems arising from pollution-related diseases caused by burning petrodiesel, resulting in lower outlays on healthcare, as biodiesel is a clean fuel;
- Trading the emissions avoided by the use of this environmentally correct fuel on the Carbon Credit Market through Clean Development Mechanisms (CDMs);
- Cutting expenditures on oil imported to produce diesel (US\$ 2.4 billion in 2004 according to Petrobras), while lessening Brazil's dependence on imported diesel (US\$ 830 million in 2004);
- Enhancing the balance of trade through sales of this fuel, while generating revenues and dividends for oilseed plantations and plants;
- Renewability, as planting and harvesting are cyclic, meaning that more oilseeds can always be planted;
- Most oilseeds have brief growth cycles, with relatively short periods between planting and harvesting;
- Many of Brazil's oilseed planting and harvesting processes are controlled by human beings, offering gains in terms of more efficient and profitable production.

3.3 Social Aspects

The social advantages of biodiesel include:

- Generating direct and indirect jobs, either on plantations or through activities related to fuel fabrication and transportation;
- Offering another source of income for communities around the enterprise (plantation or plant), helping even out income inequalities at the local level;
- Keeping rural families on their land through profitable activities (growing oilseeds) through family farm incentives that help resolve or at least slow the outflow of workers seeking better wages and jobs in towns and cities. This rural exodus results in sprawling urban slums where jobless unskilled workers and their families squat in completely unplanned and disorderly settlements, lacking infrastructure and often located in unsafe areas.

According to the Brazilian Agricultural Research Enterprise (EMBRAPA), the introduction of B5 biodiesel – a blend of 5% biodiesel with 95% petrodiesel – will generate 260,000 direct jobs in the countryside. Other data are presented in the following Table:

Table 1: Generation of jobs by biodiesel blend

	2005	2006	2007	2008	2009	2010
Blend	B2	B2	B2	B5	B5	B5
Jobs	153,000	153,000	153,000	382,000	382,000	382,000

Source: Ministry of Mines and Energy (MME) 2006

4. Methodology for Calculating Avoided CO₂ Emissions

In order to calculate the CO₂ emissions avoided through the use of biodiesel by Brazil's road transportation system, the top-down methodology is used, developed by the Intergovernmental Panel on Climate Change (IPCC) (1996). This methodology uses the final fuel consumption by the road transportation sector described in the National Energy Balance (BEN, 2011) to calculate the avoided emissions.

To do so, petrodiesel consumption from 2005 to 2020 is analyzed through a linear regression based on earlier years.

In order to calculate CO₂ emissions, it is necessary to discover the fuel consumption level. For the Intergovernmental Panel on Climate Change (IPCC) emission inventory, consumption represents the amount of fuel consumed in a country.

However, not all the petrodiesel consumed in Brazil will be replaced by biodiesel. According to current law, 2% petrodiesel must be replaced by biodiesel from 2008 onwards, rising to 5% from 2013 onwards, as mentioned above.

Consequently, this study assumes that the composition of all the petrodiesel consumed between 2005 and 2012 will include 2% biodiesel (soybean methyl) with the same applied for 2013 to 2020, based on the new percentage of 5%.

Thus, all carbon emissions will be calculated on the basis of these values (2% and 5%) biodiesel blended with petrodiesel for the years in question.

Once the consumption has been calculated, the methodology is applied in six steps: calculation of energy consumption; calculation of carbon quantities; calculation fixed carbon of quantities; calculation of net carbon emissions; calculation of real carbon emissions; and finally, calculation of the real CO₂ emissions. Each step is described below, with the findings presented in Tables 2 and 3 below.

4.1 Calculation of energy consumption

Each fuel has different energy content, so that the apparent fuel consumption must be converted into a common energy unit. This conversion is undertaken as presented in Equation 2.

$$CC (fuel) = CA (fuel) \times F_{conv} \times 41.841 \times 10^{-3} \quad (2)$$

Where $CC (fuel)$: Energy consumption of a given fuel [TJ];
 $CA (fuel)$: Apparent consumption of a given fuel [m^3];
 F_{conv} : Conversion factor [tEP/ m^3];
 $41.841 \times 10^{-3} TJ = 1$ tEP - Brazil.

This study takes the conversion factor of 0.848 tep/ m^3 for petrodiesel and 0.777 tep/ m^3 for biodiesel, in compliance with the Ministry of Mines and Energy (MME) and the data drawn from the Report on the Life Cycle Inventory of Biodiesel and Petroleum Diesel for use in an Urban Bus (1998).

4.2 Calculation of carbon quantities

Similar to energy contents, fuels contain different amounts of carbon. The amount of carbon in each fuel is calculated through Equation 3.

$$QC (fuel) = CC (fuel) \times F_{emission} \times 10^{-3} \quad (3)$$

Where $QC (fuel)$: Quantity of Carbon of a given fuel [GgC];
 $CC (fuel)$: Energy Consumption of a given fuel [TJ];
 $F_{emission}$: Carbon Emission Factor [tC/TJ].

This study works with the following emission factors: 20.20 tC/TJ for petrodiesel and 19.88 tC/TJ for biodiesel, according to the Intergovernmental Panel on Climate Change (IPCC) (1996) and the Institute for Technical Research (IPT) (2002).

4.3 Calculation of Fixed Carbon Quantities

Some fuels are used for non-energy purposes, meaning that part of the carbon is stored or fixed. For this study, the calculated petrodiesel volumes are used for energy purposes, meaning that the quantity of fixed carbon is zero. For biodiesel, the fraction of carbon stored reaches 40%, representing the quantity sequestered through biomass renewal.

4.4 Calculation of net carbon emissions

The net carbon emissions represent the mass balance between the carbon in the fuel less the amount of carbon fixed through non-energy uses.

4.5 Calculation of real carbon emissions

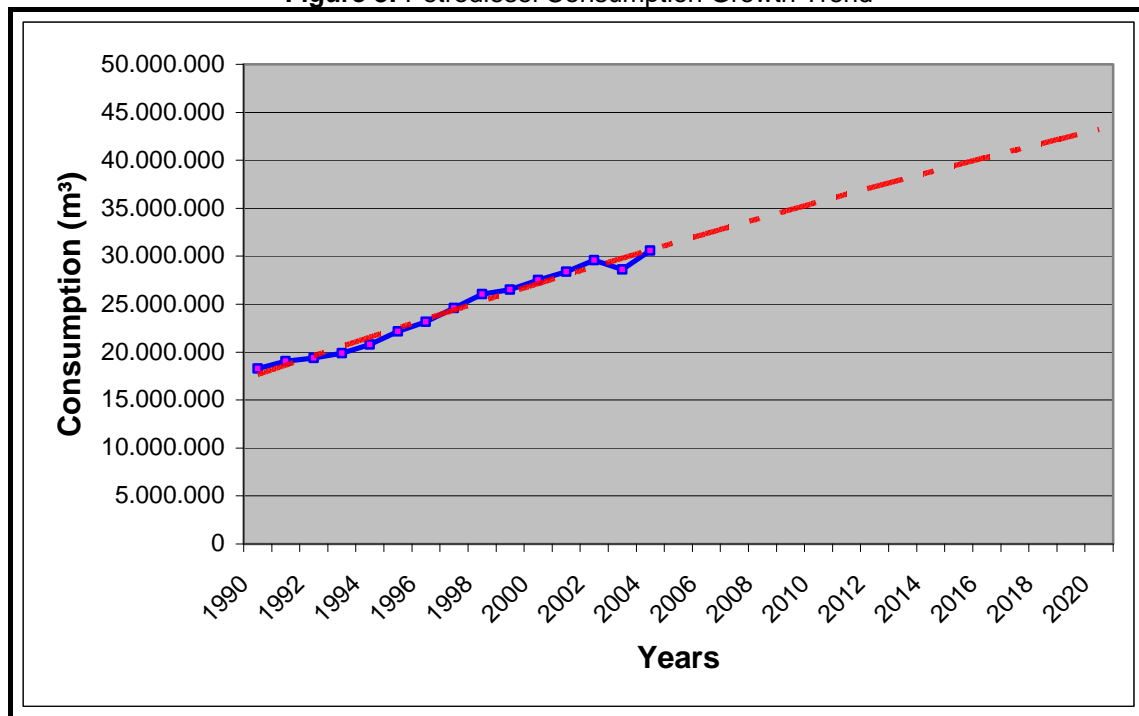
When drawing up an emissions inventory, it is assumed that not all the carbon in the fuel is oxidized, as combustion is rarely complete, leaving around 1% of the carbon non-oxidized, which is included in the ashes or other by-products. Consequently, the real carbon emissions correspond to 99% of the net carbon emissions.

4.6 Calculation of the real CO₂ emissions

Based on the real carbon emissions, the real CO₂ emissions can be calculated, caused by energy uses, taking carbon content into account: each 44t of CO₂ contains 12t of carbon. Consequently, the real CO₂ emission will be equivalent to 44/12 of the real carbon emissions.

5. Calculation of Avoided CO₂ Emissions

Based on the consolidated data issued by the Ministry of Mines and Energy (MME), published annually in its National Energy Balance (BEN), it is possible to forecast petrodiesel consumption between 2005 and 2020. Thus, through a logarithm regression method, the following graph is obtained, indicating the growth trend:

Figure 3: Petrodiesel Consumption Growth Trend

Source: Adapted - BEN, 2011

With the values obtained through the regression, it is possible to estimate petrodiesel and biodiesel consumption levels, based on the assumptions established by the Brazilian Government for the blend percentages, as well as the entry into effect of these Laws.

Thus, grounded on the CO₂ emission calculation methodology, the following figures are obtained:

Table 2: Results of applying the methodology to CO₂ emissions by petrodiesel

Year	Petrodiesel Consumption (m ³)	Energy Consumption (TJ)	Quantity of Carbon (GgC)	Quantity of Fixed Carbon (GgC)	Net Carbon Emissions (GgC)	Actual Carbon Emissions (GgC)	Actual CO ₂ Emissions
2005	634,604	22,516	455	0,00	455	450	1,651
2006	653,181	23,176	468	0,00	468	463	1,699
2007	671,759	23,835	481	0,00	481	477	1,748
2008	690,337	24,494	495	0,00	495	490	1,796
2009	708,914	25,153	508	0,00	508	503	1,844
2010	727,492	25,812	521	0,00	521	516	1,893
2011	746,070	26,471	535	0,00	535	529	1,941
2012	764,647	27,131	548	0,00	548	543	1,989
2013	1,958,062	69,474	1,403	0,00	1,403	1,389	5,094
2014	2,004,506	71,122	1,437	0,00	1,437	1,422	5,215
2015	2,050,951	72,770	1,470	0,00	1,470	1,455	5,336
2016	2,097,395	74,418	1,503	0,00	1,503	1,488	5,457
2017	2,143,839	76,066	1,537	0,00	1,537	1,521	5,578
2018	2,190,283	77,714	1,570	0,00	1,570	1,554	5,698
2019	2,236,727	79,362	1,603	0,00	1,603	1,587	5,819
2020	2,283,171	81,010	1,636	0,00	1,636	1,620	5,940

Table 3: Results of applying the methodology to CO₂ emissions by biodiesel

Year	Biodiesel Consumption (m3)	Energy Consumption (TJ)	Quantity of Carbon (GgC)	Quantity of Fixed Carbon (GgC)	Net Carbon Emissions (GgC)	Actual Carbon Emissions (GgC)	Actual CO ₂ Emissions
2005	705,115	22,924	456	182	273	271	992
2006	725,757	23,595	469	188	281	279	1,021
2007	746,399	24,266	482	193	289	287	1,051
2008	767,041	24,937	496	198	297	294	1,080
2009	787,683	25,608	509	204	305	302	1,109
2010	808,324	26,279	522	209	313	310	1,138
2011	828,966	26,950	536	214	321	318	1,167
2012	849,608	27,621	549	220	329	326	1,196
2013	2,175,625	70,731	1,406	562	844	835	3,062
2014	2,227,229	72,408	1,439	576	864	855	3,135
2015	2,278,834	74,086	1,473	589	884	875	3,207
2016	2,330,439	75,764	1,506	602	904	895	3,280
2017	2,382,043	77,441	1,539	616	924	914	3,353
2018	2,433,648	79,119	1,573	629	944	934	3,425
2019	2,485,252	80,797	1,606	642	964	954	3,498
2020	2,536,857	82,474	1,639	656	984	974	3,570

Through Tables 2 and 3, a total of 58,699,218 tons of CO₂ emitted by petrodiesel consumption is obtained, with total emissions of 35,282,660 through biodiesel consumption. Thus, assuming that the entire fleet of road vehicles fuelled by petrodiesel would be using 2% and 5% biodiesel instead of petrodiesel as mentioned above, this would result in a total of 23,416,558 tons of CO₂ avoided

6. Conclusions and Recommendations

Brazil's transportation system is still heavily dependent on petrodiesel. However, with a steady stream of awareness-heightening campaigns focused on greenhouse gases emissions and other mechanisms that degrade the environment, governments are working more closely with corporations in order to take steps that will help mitigate the environmental impacts.

One of the most outstanding aspects noted in this Paper is precisely the use of a less pollutive fuel (biodiesel) as a way of lowering greenhouse gases emissions and mitigating the environmental impacts inherent to the transportation system.

Based on the calculations presented in this paper, the use of petrodiesel and biodiesel in the proportions mentioned above would result in a reduction of approximately 40% in CO₂ emissions.

This leads to the conclusion that replacing petrodiesel by biodiesel, even to a limited extent, results in significant cuts in emissions that are important within the context of the greenhouse effect.

It is recommended that calculations be carried out for various types of biodiesel produced from the many different oilseeds available in Brazil, which may have different – and as yet unknown – emission levels.

7. Keywords:

Biodiesel, Emission and Transports.

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