CO_2 EMISSIONS BALANCE FROM BIOFUELS: A BIBLIOMETRIC REVIEW

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ABSTRACT

In the ongoing quest to mitigate climate change and reduce environmental impact, the substitution of fossil fuels with biofuels has emerged as a critical strategy. Ethanol and biodiesel, as renewable biofuels, offer a promising alternative to traditional gasoline and diesel, respectively, understanding the carbon dioxide (CO_2) equivalent emissions of these fuels is key to evaluating their potential benefits. Gasoline and diesel, derived from petroleum, are major contributors to greenhouse gas emissions, particularly CO_2. When combusted, these fossil fuels release significant amounts of CO_2, a greenhouse gas that contributes to global warming. The carbon intensity of gasoline and diesel is high, making them a primary target for reduction in efforts to combat climate change. In contrast, ethanol, primarily produced from crops like corn or sugarcane, and biodiesel, derived from vegetable oils or animal fats, offer a lower carbon footprint.

Keywords: Biomass; Biofuels; Renewable sources; Greenhouse Gas Emissions.

INTRODUCTION

Sustainable fuels are those produced with raw materials from renewable sources, such as biomass (e.g. biofuels) or renewable electrical energy (e.g.: sustainable synthetic fuels). Biofuels are produced from substrates derived from agricultural products and biomass, which, in turn, corresponds to waste of animal or vegetable origin. Biological and chemical processes are carried out from these materials that create substances capable of releasing energy, which can be used to move vehicles, such as ethanol and biodiesel, and as a source of electrical energy generation, such as biogas.

To achieve the Brazilian government's goals of reducing greenhouse gas emissions (GHG) by half by 2030 compared to 2005 levels, as well as achieving climate neutrality by 2050, the transport sector needs move towards zero emissions. Currently, the passenger car market in Brazil is dominated by flex fuel internal combustion vehicles, capable of operating with both hydrated ethanol and gasoline C, a mixture of gasoline with 27% of anhydrous ethanol. Ethanol accounts for about half of fuel consumption (in volume) of the passenger car fleet, whether in the form of hydrated ethanol or in the C gasoline blend and is produced mainly from sugar cane.

Ethanol has a significantly lower potential for CO_2 emissions compared to gasoline. Studies indicate that ethanol derived from sugar cane can reduce emissions by around 61% over its life cycle, compared to gasoline. In the USA, corn ethanol reduces greenhouse gas emissions by around 20% to 50% compared to conventional gasoline, depending on the methodology used for the calculation and the type of cultivation and production. In Brazil, ethanol production is even more efficient due to the use of sugarcane bagasse as a source of energy during the production process, which contributes to a greater reduction in global emissions [1].

Biodiesel, especially when compared to petroleum-derived diesel, also presents a significant reduction in CO_2 emissions. Studies show that using biodiesel can reduce CO_2 emissions by approximately 50% to 88% compared to traditional diesel. This depends on the origin of the biodiesel (whether from vegetable oils or animal fats) and production practices. Biodiesel also has the advantage of being biodegradable and less toxic, which contributes to a lower overall environmental impact, as well as emitting less particulate matter and sulfur oxides [2].

According to FGV Bioeconomy Observatory, in the first three months of 2024, anhydrous ethanol mixed with gasoline and hydrated ethanol consumed directly by vehicles were responsible for 41.4% of the energy consumed by light vehicles, the highest value recorded over the last 12 quarters of the series. The biggest reductions in the carbon intensity of the matrix were in the Federal District (12.02%), Mato Grosso do Sul (11.91%), Goiás (10.12%), Mato Grosso (9.18%), Minas Gerais

(9.03%) and São Paulo (8.78%). Consumption of diesel B (a mixture of pure diesel and biodiesel) reached 65.5 billion liters in 2023, an increase of 3.6% compared to the volume sold in the previous year (63.2 billion liters). In the first quarter of 2024, this trend was maintained and the increase in consumption reached 2.4%, with 15.6 billion liters sold compared to 15.2 billion recorded in the same quarter of 2023.

As in the case of ethanol, the carbon intensity of the diesel cycle matrix showed improvement throughout the quarters of 2023: while in the first three months of the year the average intensity reached 80.4 gCO2eq/MJ (grams of dioxide equivalent per megajoule of energy), in the last quarter the index reached 79.1 gCO2eq/MJ. This is the result of two distinct movements. The first refers to the increase in the biodiesel blend content, from 10% to 12%, at the beginning of the second quarter of 2023. The second is related to the 2.7% gain in the energy-environmental efficiency of biodiesel sold throughout 2023 – the carbon intensity of biofuel went from 21.6 gCO2eq/MJ in the 1st quarter of 2023 to 21.0 gCO2eq/MJ in the last quarter of the year [3].

MATERIALS AND METHODS

Initially, a bibliometric review was carried out with RStudio software to identify and select the relevant studies that address the issue and analyze the position of the research formulated, this involves the use of specific keywords and application in appropriate databases, such as Web of Science (WoS) and Scopus, which are widely used in literature reviews in energy efficiency area. This review aimed to identify and capture a variety of relevant studies, but also specific to the main authors working in the selected field of biofuels, highlight productions by countries, keywords, production by authors and their collaboration network, number of publications per year, most cited documents and their most common sources relevant. To conduct bibliographic searches, specific keywords were chosen: ("Comparison" "Biofuel" "Fuels" AND “greenhouse” AND "gas emissions"). The selected research databases were from the Web of Science (WOS) and Scopus to ensure broad coverage of available studies on the topic. Data collection for bibliometric analysis was carried out on August 21, 2024.

The proposed analysis in this work was based on projections of the consumption of fuel ethanol and the increase in the composition of biodiesel in diesel oil, made by National Energy Plan (PNE) 2030 studies. Therefore, the method of this research aims to analyze the potential impacts on the Brazilian economy of an expansion in the production and use of ethanol and biodiesel, as a replacement for part of fossil fuels, based on the scenario projected by the National Energy Plan 2030.

RESULTS AND DISCUSSION

The WOS search resulted in 45 publications, while the Scopus search found 149 documents. No filters were applied to avoid compromising the number of results. The period analyzed covers from 2014 to 2024. The results were extracted in BibTex format and the data was consolidated using the RStudio 2024.04.2 Build 764 program. After consolidation, the data were compiled into spreadsheets and 26 duplicate documents were removed. The final analysis was viewed in Bibliometrix. Figure 1 summarizes the results regarding the frequency of each biofuel in the search.

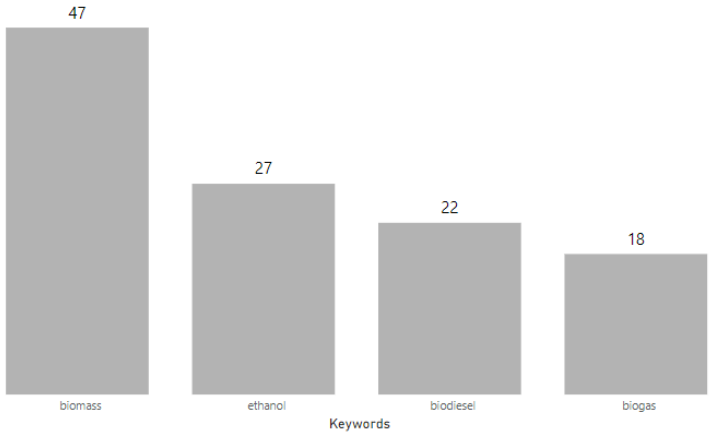

Figure 1: Frequency of each biofuel in bibliometric review.

Ethanol from sugar cane has the greatest potential for reducing greenhouse gas emissions compared to other raw materials, such as corn [4]. According to ABIOVE [5], soybean oil production between 2013 and 2022 increased by 40%. This growth is much lower than the volume that is destined to obtain biodiesel, which, at

values absolute, went from 2 million to 3.9 million tons, an increase of 98% in the same period.

CONCLUSION

The findings of this study have direct implications for a public policy program in Brazil: the biofuels policy RenovaBio, to encourage the use of ethanol to replace fossil gasoline in the existing fleet of vehicles flex and include emissions indirect change in land use (ILUC) emissions in the RenovaBio program to improve sustainability of ethanol. Furthermore, the results suggest actions to increase national biodiesel production to raise the content of this biofuel in diesel. The National Energy Plan 2030 predicts that biodiesel production reach 11.7 billion liters in 2030, equivalent to 32 million liters per day. This value, however, must increase to meet the demand to add more than 12% of biodiesel to diesel, as this percentage predicted for 2030 has already been adopted by the Brazilian energy matrix in 2023.

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