As regards reducing greenhouse gas emissions from first-generation biofuels

بخصوص انخفاض انبعاثات غازات الاحتباس الحراري للوقود الحيوي من الجيل الأول

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Abstract:

The development of biofuels responds to a need for energy sovereignty and the reduction of greenhouse gas emissions (GAS) in the transport sector. Presented as an alternative to fuels of fossil origin, these biofuels raise many questions, particularly with regard to their real environmental interest.

Also, this study aims to determine the reduction in GAS achieved by first-generation biofuels compared to fuels of fossil origin. To achieve the proposed objective, the Life Cycle Analysis (LCA) method was applied to ethanol and biodiesel from the USA and Brazil.

The study presented according to the IMRaD structure revealed that the first generation biofuels produced in the USA and Brazil have GAS lower than those of fossil fuels by 74 to 82% for ethanol and 49 to 51% for biodiesel.

Keywords: First generation biofuels; greenhouse gas; environment; United States; Brazil.

Jel Classification Codes : Q4 ; Q5.

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ملخص :

يستجيب تطوير الوقود الحيوي للحاجة إلى تحقيق السيادة الطاقية وتقليل انبعاثات غازات الاحتباس الحراري (GAS) في قطاع النقل. فبعدما قُدِّمت مختلف أنواع من الوقود الحيوي كبديل للوقود من الأصل أحفوري، فقد أثارت فيما بعد العديد من الأسئلة، لا سيما فيما يتعلق بفائدتها البيئية الحقيقية.

تهدف هذه الدراسة إلى تحديد الانخفاض في انبعاثات غازات الاحتباس الحراري الذي يحققه الجيل الأول من الوقود الحيوي مقارنة بالوقود الأحفوري. لتحقيق الهدف المنشود، تم تطبيق طريقة تحليل دورة الحياة (LCA) على الإيثانول والديزل الحيوي لكل من الولايات المتحدة الأمريكية والبرازيل.

كشفت الدراسة المقدمة وفقًا لهيكل IMRaD أن الجيل الأول من الوقود الحيوي المنتج في الولايات المتحدة الأمريكية والبرازيل له انبعاثات غازات الاحتباس الحراري أقل من انبعاثات الوقود الأحفوري بنسبة 74 إلى 82% للإيثانول و 49 إلى 51% للديزل الحيوي.

الكلمات المفتاحية : الجيل الأول من الوقود الحيوي؛ غازات الاحتباس الحراري؛ البيئة؛ الولايات المتحدة؛ البرازيل.

تصنيف **JEL** : Q4؛ Q5.

1. Introduction

For the sake of energy independence and preservation of the environment, in particular through the reduction of GAS, fuels produced from agricultural raw materials, which will later be called biofuels first generation, have been developed.

However, since their launch in the 1970s which raised a lot of hope, the various studies that have been carried out to estimate their GAS have arrived at much nuanced results, sometimes even radically different with diametrically opposite when land use change (LUC) is taken into account in the measurement of these emissions.

Indeed, without considering the LUC which will not also be taken into account in this study, work on the issue has presented very largely positive GAS balances with a reduction of these emissions by more than 100% compared to conventional fuels in some cases (Notre-planete.info, 2009), while others, on the other hand, were more mixed but still remained on favorable balance sheets for first-generation biofuels in terms of GAS with an estimated reduction of 20 to 60% (FAO, 2008, p. 65).

These differences can be explained by the difference in methods and parameters used for each study, but it is nonetheless obvious that these first-generation biofuels have a certain environmental interest given that all these results present a difference in degree and not by nature, that is to say that they agree that first-generation biofuels emit less greenhouse gases than conventional fuels of fossil origin.

Consequently, the scientific debate that remains no longer focuses on the environmental interest of these biofuels, but is rather divided into a range of questions which deals with the interest of first-generation biofuels in terms of reducing GAS on a "case by case" basis according to the region of the world where these biofuels are produced, according to the way in which they are produced, according to the agricultural raw materials used for their production or even according to the specific needs of these agricultural raw materials of a region to another.

The question of the study:

Knowing that the USA and Brazil are the world's two largest producers of first-generation biofuels, this study will focus on one of the many questions in this cluster:

What is the reduction in GAS recorded by first-generation biofuels produced in the USA and Brazil compared to fuels of fossil origin?

The hypothesis of the study:

The balance of GAS from first-generation biofuels produced in the USA and Brazil is more favorable than that of fuels of fossil origin.

The purpose of the study:

The main objective of our study is to assess the GAS of first-generation biofuels produced in the USA and Brazil in order to compare it with the same balance generated by fossil fuels. The final purpose is to know which of the two balances is the most favorable.

The importance of the study:

The importance of the study lies in highlighting the environmental interest of first-generation biofuels compared to conventional fuels of fossil origin in order to encourage the implementation of an energy policy to support the sector biofuel.

The methodology of the study:

We will base our study on the LCA method, taking into account each stage of first-generation biofuel production, from the cultivation of the plant (energy consumption of agricultural machinery and use of fertilizers), to end use in cars, to manufacturing.

The previous research on the study:

After an LCA analysis of ethanol produced from American corn, (Farrell *et al.*, 2006, pp. 506-508) concluded that the GAS of US ethanol produced from corn would be almost identical to those of gasoline produced from fossil fuels, whereas biodiesel appears to be much more advantageous in Brazil according to (Hill *et al.*, 2006, pp. 11206-11210) who show that the biodiesel sector emits less GAS, particularly during the industrial transformation phase. This result in favor of biofuels is contested by a study of the *European Federation for Transport and Environment* (2016) which estimates that biofuels, far from being virtuous for the climate, actually emit more GAS than fossil fuels (gasoline or diesel). According to the same study, a liter of biodiesel from rapeseed would represent 1.2 times more GAS than a liter of diesel; that of soy, 2 times more GAS; and that of palm oil, 3 times more GAS. The study concluded that the use of biofuels has increased GAS in Europe by almost 4%. This increase is equivalent to putting 12 million additional cars on the road. This result goes against the one reached by *ADEME* (2019) in its study submitted to the French Senate and which evaluates that the reduction of GAS of ethanol from sugar cane and wheat compared to GAS of fossil fuel (gasoline) is 18 to 85%, while that of biodiesel is between 65 and 82%.

A general overview of these studies allows us to quickly notice disparities in their results, which are at the origin of important controversies (Anthony *et al*., 2012, pp. 66-73). Thus, the question of GAS from first generation biofuels remains unresolved, and this is precisely the question we will try to address in our paper.

2. Method:

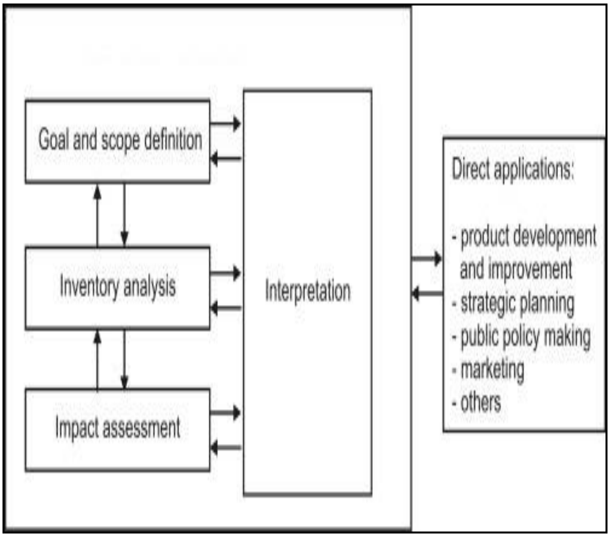
2.1. Life Cycle Analysis:

The most suitable method for comparing an environmental impact, in this case the GAS in our study, of two different products, namely first-generation biofuels and conventional fuels of fossil origin for our study, is the LCA method.

LCA is a scientifically recognized and standardized method. It is framed by the series of ISO 1404x standards: Environmental management – LCA (ISO 14040/ISO14044) (Centre national d'expertise de l'éco-conception, 2016).

This method must pass through four stages (Fig. 1) before achieving the expected objectives. We will use the third and fourth stage as the “Results and discussion” of our study.

Figure number (1): Steps of LCA



Source: (Veuillet & Boeglin, 2005, p. 04)

2.2. LCA steps:

This method must pass through four stages (Fig. 1) before achieving the expected objectives. We will use the third and fourth stage as the "Results and discussion" of our study.

2.2.1. First step of LCA:

First step - Definition of the objectives/scope of the impact study

In this step, it is a question of knowing why and for whom the study is carried out. To do this, a certain number of questions are first asked and to which we will provide some answers:

Is the study internal or public ?

The study is intended for researchers and professionals in the field of biofuels, the environment or renewable energies in general and must of course be made public. This is a study that will be used to compare the GAS of first-generation biofuels and those of fossil fuels. It is therefore a question of choosing between two products according to the GAS of each.

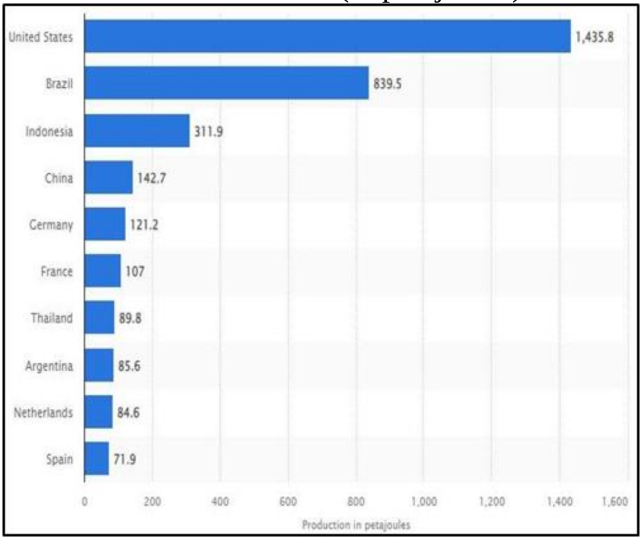
What is the quantification of the study (choice of functional unit)?

For the purposes of our study, we will use as a functional unit the megajoule (MJ) of fuel consumed by a car that travels a distance of one kilometer (MJ/1KM).

What is the reference flow of the study (products analysed) ?

The reference flow of the study includes the two types of first generation biofuels (ethanol and biodiesel) which are produced by the two main world producers (Fig. 2), namely the USA with 50% of production global ethanol production and 19% of global biodiesel production, followed by Brazil with 24% of global ethanol production and 12% of global biodiesel production (OCDE/FAO, 2019, p. 228).

Figure number (2): Leading countries based on biofuel production worldwide in 2021 (in petajoules)



Source: (Statista, 2021)

This reference flow also includes the main raw materials used to obtain first-generation biofuels in these two countries, namely corn (ethanol) and soybean oil (biodiesel) for the USA, as well as cane sugar (ethanol) and also soybean oil (biodiesel) for Brazil.

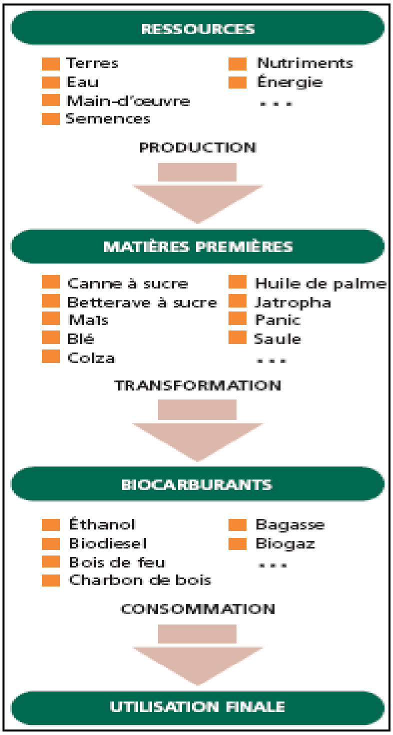
The American and Brazilian agricultural data come from multi-year surveys on farming practices in these two countries. They were carried out by the statistical services of their respective Ministries of Agriculture. Other data have been provided by organizations in the agro-energy sector or institutes based on various works. We have averaged all this data over several years. Their analysis as well as that of the literature review allowed us to estimate an average of GAS for each raw material used and for each of the two countries. An average which was reduced for the needs of the study to the functional unit of the latter.

What are the boundaries of the study?

Given that first-generation biofuels (ethanol and biodiesel) are derived from agricultural raw materials, namely sugar plants (sugar cane, beets, etc.) and starchy plants (corn, wheat, etc.) for the production of ethanol, as well as oleaginous plants (rapeseed, palm, etc.) for the production of biodiesel, and knowing that several resources (land, water, fertilizers, etc.) are essential for the production of these sugar and starch plants and oilseeds, the boundaries of our study go from these resources (raw materials) to the first generation biofuel (end product), in other words from the "cradle to the grave" as shown in Figure 3.

However, it is important to mention that all the sugar, starch or oleaginous plants traditionally used to produce first-generation biofuels throughout the world are not used in mass by the biofuel industry in the USA and Brazil. Also, the frontier of the study only incorporated the main starch and sugar plants from which the first generation biofuels produced in the USA and Brazil are derived, namely corn and soybean oil for the USA, as well as sugarcane and soybean oil also for Brazil (OCDE/FAO, 2019, p. 228).

Figure number (3): From production to consumption



Source: (FAO, 2008, p. 11)

2.2.2. Second step of LCA:

Step Two - Study Inventory Analysis

Also called “inventory of emissions and extractions”, this step consists of making an inventory of all the flows after having listed them according to a certain number of criteria such as their source (specific or generic) or their type (measured, calculated or estimated). In our present study, we have chosen so-called primary generic data, i.e. obtained from published sources whether they are informational, commercial or from specialized literature (as opposed to specific data which is collected by the researcher during collection). We have also chosen estimated data (calculated or measured for some) and above all deterministic data, i.e. represented by unique values (as opposed to probabilistic data which accounts for their imprecision). Once all the incoming and outgoing have been identified, we quantified them in relation to the reference flow of our study.

However, it is very important to specify that among all the data relating to the resources essential to the production of sugar, starch and oilseed plants (known as energy crops) used to produce first-generation biofuels (soil, fertilizers, water, etc.), the "land" resource was not retained, i.e. the LUC due to the biofuel sector was not integrated into the LCA of our study. The reason for this non-integration of LUC was dictated by the impossibility of knowing the "direct" LUC induced by the conversion of natural areas (cultivated or not) to crops intended to produce biofuels (for example a space on which there is a forest transformed into a field to produce sugar cane intended for the production of biofuels) and the impossibility of knowing the "indirect" LUC induced by the replacement of crops intended for food by energy crops intended to produce biofuels (for example transforming a tomato field into a corn field intended to produce biofuels).

The literature review and work in progress still do not provide a methodological reference framework on this issue of LUC due to its great complexity. Indeed, its integration in any study requires the adoption of another LCA approach called “Consequent LCA” which takes into account all the processes affected in a direct or indirect way.

It is no less important to specify that the depreciation of machinery used for the production or transport of agricultural raw materials, as well as that of the infrastructures used for the production of biofuels have not been taken into account because it is amortizations which remain very insignificant.

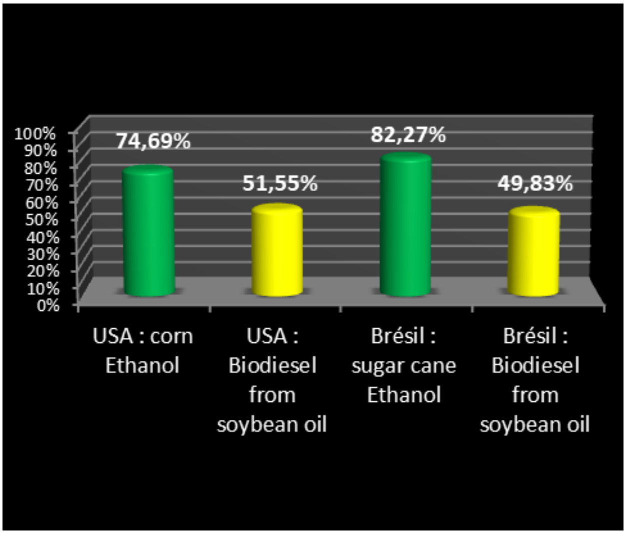
3. Results and discussion:

Estimation of GAS can be done in two different ways: a "problem-based" way whose objective is to estimate primary or direct effects such as

GAS, and a "damage" manner whose objective is to estimate secondary or indirect effects such as the destruction of the ozone layer or the diseases caused by GAS.

Given that the study aims only to know the reduction of GAS relating to the use of first generation biofuels, the evaluation was based on the “problem” oriented manner with the following results:

Figure number (4): Reduction of GAS From production to consumption



Source: Elaborated by the researchers

The figure above highlights the reduction in GAS of ethanol compared to conventional gasoline of fossil origin and that of biodiesel compared to conventional diesel of fossil origin as well. However, due to the limitations of the study (non-integration of LUC and depreciation), these results should be seen as orders of magnitude.

A first overview shows that the balance of GAS of first-generation biofuels produced in the USA and Brazil from corn, sugar cane and soybean oil is largely positive with a reduction in GAS ranging between 49 and 82%.

Ethanol produced in Brazil from sugar cane offers a greater reduction in GAS than US ethanol from corn. The reason for this significant difference is explained by the average yield per hectare of sugar cane in Brazil, which is 77.29 T/ha (Statista, 2021), very much higher than that of maize produced in the USA and which does not is only 11.4 t/ha (Agritel, 2018). As for biodiesel from palm oil, it offers a relatively similar reduction in GAS for the two countries. The slight difference recorded in this reduction in favor of the USA could mainly be explained by the use of more efficient means by the USA during the palm fruit collection stage and the oil extraction stage.

The reasons why the GAS of first generation biofuels (ethanol and biodiesel) are lower than the GAS of conventional fossil fuels (gasoline and diesel) can be explained by the different steps required for their production, all of which are GAS-emitting steps.

Indeed, for conventional fuels of fossil origin, i.e. produced from petroleum, the first step is to search for oil deposits. Geologists and geophysicists work together on this investigation, which is fraught with economic issues. After a detailed study of the geological structures on the surface and at depth and their imaging by seismic, only drilling can certify the presence of oil. Drilling depths in the earth usually vary between 2,000 and 4,000 meters (Pandolfi, 2016, p. 21).

The second stage is production, and more precisely the extraction of oil, which requires complex techniques: the meshing of the reservoir by multiple wells, the maintenance of the reservoir pressure and the shipping to markets. Production areas are often far from consumption areas. To move oil from one area to another, two main modes of transportation are used: the pipeline and the tanker by sea.

The third and final stage is refining. It is an operation that consists first of all in distilling the oil in order to separate the hydrocarbons according to their density.

Regarding biofuels, it is first necessary to produce the biomass, that is to say to cultivate the fields of cereals, corn, etc.

Then, it is necessary to harvest this biomass to transform it into biofuel using the processes mentioned above, the last step being the transport of this biofuel to the gas stations.

As for the manufacturing stages of fossil fuels, these stages all emit GAS. However, the steps related to the production of fossil fuels, i.e. drilling, extraction, refining and distribution, are more cumbersome and largely more CO2 emitting.

4. Conclusion

First-generation biofuels are the subject of a rich debate about their environmental interest, particularly in terms of GAS, and raise many questions, including the one addressed in this study, namely their reduction. of these emissions in the two main producing countries compared to conventional fuels of fossil origin, in this case gasoline and diesel.

The results of the study show that without considering LUC, first-generation biofuels produced in the USA and Brazil offer a positive greenhouse gas balance with very significant emission reductions compared to fossil fuels. These reductions range from 49 to 82% depending on the type of biofuel, whether it is ethanol with 74-82% or biodiesel with 49-51%.

This balance sheet, which is more favorable than that of conventional fuels of fossil origin, should not make us forget that the production of these first-generation biofuels varies from one country to another depending on the method of production, the resources used or the materials first transforms, and that the interactions between these different variables are numerous and complex. Also, it is necessary to see the results of this study as orders of magnitude and not to consider these first generation biofuels as a miracle solution to the scarcity of oil or, conversely, as a false solution worse than the evil that she's supposed to deal with. Rather, it is a question of seeing these first-generation biofuels both as an opportunity and as a challenge which involves promoting the use of raw materials with a high yield per hectare and production techniques that are more respectful of the environment for produces them.

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