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Biofuels and fossil fuels: Life Cycle Analysis (LCA) optimisation through productive resources maximisation

Fernando Hernández Sobrino[a,*], Carlos Rodríguez Monroy[a], José Luís Hernández Pérez[b]

[a] Department of Business Administration, School of Industrial Engineering, Universidad Politécnica de Madrid, José Gutiérrez Abascal 2, 28006 Madrid, Spain
[b] High School Chemistry Teacher, Spain

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ABSTRACT

Life Cycle Analyses (LCA) are used to compare biofuels to fossil fuels. These analyses are made according to the ISO 14040-43 standards, which using a defined unit compare mass and energy balances for two or more comparison objects.

In Spain, the Spanish government Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas, CIEMAT, has performed two LCA's in order to compare ethanol and ethanol mixtures with unleaded gasoline and biodiesel and biodiesel mixtures with fuel-oil according to these standards. Both LCA's conclude that biofuels require less primary energy than fossil fuels to be processed and that CO_2 emissions are lower when using biofuels instead of fossil fuels.

However, these LCA's have been strongly criticized for several reasons. This report presents a new LCA model which allows the comparison of biofuels and fossil fuels based on the maximisation and optimisation of production resources avoiding the disadvantages of the traditional LCA model based on the ISO 14040-43 standards.

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* Corresponding author. Tel.: +34 91 574 89 92.
E-mail addresses: sobrinof@gmail.com (F.H. Sobrino), crmonroy@etsii.upm.es (C.R. Monroy), joseluishernandezperez@gmail.com (J.L.H. Pérez).

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1. Introduction

1.1. Reasons to perform a Life Cycle Analysis (LCA)

At present we live in an age where "sustainability" is more appreciated than other trends such as quality, speed and production flexibility which dominated the last quarter-century. This new sustainability era is motivated primarily by social awareness in achieving a balance between human development and conservation of the environment. "Sustainability" and in turn "sustainable development" are concepts that mean different things to different people, making it impossible to provide a single definition. The original definition of sustainable development (and the one still most widely used) was made in the Bruntland Report [1], (Our Common Future, World Commission on Environment and Development in 1987) which defined it as:

> "Development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs".

In other words, sustainable development seeks to ensure a better quality of life for all both now and in the future. Nowadays, the automotive fuel market is almost 100% dominated by fossil fuels. Oil is finite and will not last forever. Hence, its use is not considered as "sustainable" because future generations' development may be compromised due to its consumption. For this reason, alternative fuels to fossil fuels have been searched for decades and one of these alternatives is the use of biofuels.

At this point the question that arises is to know if biofuels are good substitutes for fossil fuels. In order to answer it, LCA's of biofuels and fossil fuels have to be performed in order to compare their advantages and disadvantages.

1.2. LCA description

LCA's are covered by ISO 14040-43 standards. In other words, an LCA consists of the following phases:

1. Definition of objectives.
2. Election of the systems to be studied.
3. Functional unit definition.
4. Definition of systems to be compared.
5. Identification of systems' limits.
6. Comparison of results.

Thus, LCA's consist of two "balances" (evaluations) to compare biofuels and fossil fuels:

- "Mass balance", i.e., quantify and evaluate the income and outcome products within the life cycle of a fuel.
- "Energy balance", i.e., evaluate income and outcome energy (heat and work produced or required) within the life cycle of a fuel.

2. CIEMAT's Life Cycle Analysis for biofuels and fossil fuels

2.1. Description

CIEMAT has developed two life-cycle analysis of biofuels for Otto cycle engines [2] and Diesel cycle [3] according to the ISO 14040-43 standards.

2.2. Objectives

The objectives of the studies carried out by CIEMAT are the following:

- To evaluate and quantify the environmental impacts for two fuels for the same purpose along their entire life cycle.
- To compare their associated impacts.
- To identify and evaluate the opportunities to minimise these impacts once they have been identified in each phase of the process.
- To analyse the environmental benefits of the different fuels.

2.3. Election of the systems to be studied

2.3.1. Note regarding the reference systems

Biofuel production generates by-products and it is considered that these by-products replace existing products that already exist in the market. Hence, the production processes of the existing products are to be considered within the limits of the systems to be studied.

Here are some examples:

- For ethanol production, the straw of the raw material (grain) is used as animal feed and replaces the production of hay. Thus, if this raw material is not cultivated for ethanol production, the straw should be substituted for hay. It also considers the raw material demand for ethanol production as additional to the existing demand. If ethanol is not produced, this land would not be cultivated.
- In the case of biodiesel, crude and used vegetable oils are transesterified to be used in vehicles [4]. This process generates glycerine