ARE BIOFUELS RENEWABLE ENERGY SOURCES?

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Abstract

The objective of this study is to discuss biofuels renewability in a quantitative point of view. A comprehensive review of the energy balance literature and emergy assessment of biofuels production were carried out at the Laboratory of Ecological Engineering of the Food Engineering School at UNICAMP in order discuss these issues. From these perspective is possible to realize that biofuels use a high amount of fossil fuel energy in the agricultural and industrial conversion stages. When using Emergy Methodology the results showed that only 25% of the resources used to produce biofuel from soybean are renewable. Ethanol production from corn uses only 9% of renewable resources and when it is produced from sugarcane the renewable increase to 30% in conventional systems. Results show that small scale biofuels production using agroecological concepts present much better renewability (70%). Emergy accounting method showed quantitatively that biofuels are not renewable energy sources. If the biofuel production systems are not carefully designed as diversified small scale integrated systems, using the "eco-unit" perspective, the intensive exploration of land and fossil fuel use for biofuels production is more likely to result in green deserts and social damages than to become a renewable energy source to society.

1. Introduction

As Peal Oil and Global Warming become the topics of main concern for governments, enterprises and population the biofuels get increasing importance as energy alternatives. Usually biofuels hey are presented as suitable option for energy supply, considering that if they are adequately supported, they could replace a portion of fossil fuels. The main reasons presented to promote biofuels production are: (a) that they are clean, or "green", because they are produced from renewable natural sources and, therefore, could supply a virtually infinite amount of energy for an infinite period of time; (b) It is often stated that biofuels, by replacing oil, would allow reducing greenhouse gases emissions; (c) finally, biofuels are noticed as a good strategy for rural development.

However, if one takes a closer look at the complete biofuels production chain, the benefits do not appear so clear anymore. In fact, biofuel production requires the use of fossil fuel energy, in the form of fertilizers, agrochemicals, machinery for both agricultural and industrial phases, as well as transportation of raw materials, inputs and distribution of biofuel for final use. Moreover, depending on the biomass used, biofuels processing could require huge amount of fossil fuel. From the social point of view, biofuel production, as it is conceived nowadays, will promote social exclusion and from the environmental point of view it will increase biodiversity loss and global warming.

The objective of this study is to discuss biofuels renewability in a quantitative point of view and to examine the environmental feasibility of a large-scale biofuel production. A comprehensive review of the energy balance literature and emergy assessment of biofuels production were carried out at the Laboratory of Ecological Engineering of the Food Engineering School at UNICAMP in order discuss these issues.

2. Methodology

The Embodied Energy Analysis method (Slesser, 1974; Herendeen, 1998) deals with the gross energy requirement of the analysed system. The method accounts for the amount of commercial energy that is required directly and indirectly by the process of making a good or a service (Herendeen, 1998). As the embodied energy analysis of a product is concerned with the depletion of fossil energy, all the forms of material and energy that do not require the use of fossil resources to make them available are not accounted for. For instance, resources provided for free by the environment such as rain, topsoil, spring water, human labor and economic services are not accounted for by embodied energy analysis. In this method, all the material and energy inputs are multiplied by appropriate oil equivalent factors (kg oil/unit) and converted to energy units by multiplying by the standard calorific value of oil fuel (10000 kcal/kg)x(4186 J/kcal). After that energy output is compared with energy input.

The Emergy Accounting method (Odum, 1996; Brown and Ulgiati, 2004) looks at the environmental performance of the system on the global scale, taking into account all the free environmental inputs such as sunlight, wind, rain, as well as the indirect environmental support embodied in human labor and services, which are not usually included in traditional embodied energy analyses. Emergy methodology uses the solar energy embodied in the system's inputs as the measurement base. Emergy is defined as the total amount of solar available energy that was directly or indirectly required to make a given product or to support a given flow, and measured in solar equivalent Joules (seJ). The amount of emergy that was originally required to provide one unit of each input is referred to as its specific emergy (seJ/unit) or transformity (seJ/J). At the core of an emergy evaluation of a given production system or process is a mass and energy flow analysis in which the flows are adjusted for energy quality using conversion factors (transformity, specific emergy, emdolar). Odum (1996) and Brown and Ulgiati (2004) give a detailed explanation of the application of emergy accounting procedures for a variety of systems.

3. Results and discussion

Embodied Energy Analysis of biodiesel from soybean shows that 2.34 Joules of biodiesel are produced per Joule of fossil fuel used. For ethanol from sugarcane this value is 8.2.

Literature results indicate that the amount of fossil fuels energy required to produce biofuel from soybeans is 0.7 to 3.2 times the amount of biofuel energy delivered. Venturi and Venturi (2003) calculated values between 0.7 - 1.6 Joules of biodiesel per Joule of fossil fuel invested and Pimentel and Patzek (2005) found 0.79 for biodiesel from soybean. Sheehan et al. (1998) found 3.2 for biodiesel from soybean. Janulis (2004) calculated values between 1.04 - 1.59 for biodiesel from rapeseed; and Giampietro and Ulgiati (2005) calculated values between 0.98 - 1.21 for biodiesel from sunflower. Fossil fuels present much higher energy return, between 10 - 15 and wind energy has an energy return of 8 (Ulgiati, 2001). From these perspective is possible to realize that biofuels use a high amount of fossil fuel energy in the agricultural and industrial conversion stages. In some cases the fossil fuel energy used for biofuel production overcomes the energy available in the biofuel delivered. Furthermore, besides the consumption of non-renewable resources, the use of fossil results in greenhouse gases.

Emergy Methodology can properly account for the renewability of biofuels since it includes not only inputs and services from the economy, but also resources from nature, usually not considered in regular evaluation. When using Emergy Methodology the results showed that only 25% of the resources used to produce biofuel from soybean are renewable. Ethanol from corn uses only 9% of renewable resources and when produced from sugarcane the renewable fraction increases to 30% in conventional systems. Other research results show that small scale biofuels production using agroecological concepts present much better renewability (70%) and also good numbers in other emergy indicators as well as an acceptable profitability (10 to 40%).

Transformity can be used to compare different production systems producing same product, helping to choose the better alternative. The transformity of biodiesel from soybean is 4.59E+05 seJ/J and ethanol from sugarcane in large scale is 4.87E+04 seJ/J, for small scale it is 8,8E+4 sej/J. Giampietro and Ulgiati (2005) obtained for ethanol from sugarcane, 3.15E+05 seJ/J and Biodiesel from sunflower, 2.31E+05 seJ/J. These values are higher than those calculated by Odum (1996) for fossil fuels (coal, 6.70E+04 seJ/J; natural gas, 8.04E+04 seJ/J; oil 9.05E+04 seJ/J; gasoline and diesel, 1.11E+05 seJ/J) indicating a higher demand for resources and therefore a lower large-scale efficiency.

The emergy yield ratio (EYR) is a measure of the ability of the product to contribute to the economic system by amplifying the investment. The EYR for biodiesel from soybean is only 1.46 and for ethanol from sugarcane is 1.57 (large scale) and 3.1 (small scale), while it ranges from 3 to 7 for fossil fuels (Odum, 1996). Therefore, based on emergy accounting results, the investigated case of biodiesel from soybean does not compete with nonrenewable energy resources, but fossil fuel will be available for few decades and theirs prices are increasing rapidly.

The results indicate that, for soybean biodiesel, 75% of all resources consumed by the system are non-renewable resources from oil economy. For the sugarcane ethanol (large scale) they are 70%. Biofuels processing consumes huge amounts of fossils fuels in the form of fertilizers, pesticides, machinery, and so on. In all those production processes the petroleum is converted into CO_2, contributing to the global warming. This means that this production system has been supported by petroleum and only persists because its price is maintained in a low level through a powerful political-ideological and military system (see the case of USA vs. Iraq war) and also because the current Economy doesn't possess analytical procedures capable to represent the ecological-economical phenomenon taking place (the decline of the fossil resources and the global warming provoked by its use).

The ability of biofuels (or “agrifuels” like some authors begin to refer the fuels produced by agriculture, competing with food production for agricultural area) to recycle the CO_2 emitted when the produced fuel burning is not enough. The process should also be responsible for the CO_2 emission resulting from the use of fossil fuels during the production steps of the inputs used by biofuels processing, as presented in Figure 1. Materials and services used by soybean or sugarcane monoculture depend greatly on petroleum derivatives

Small scale plants, both for ethanol and biodiesel production, use less amounts of non-renewable resources because they adopt ecological principals for agricultural production. Thus, since these plants employ local labor, there is no extra energy expenditure with material, person or product transportation.

The agricultural stage of biocombustíveis production should have a different composition. The agricultural area should include a crop parcel as well as a forest, or native vegetation, parcel in order to be capable to also absorb the amount of CO_2 emitted by the inputs production steps, as shown in Figure 2. This value is about 0,6 ha of forest area per each ha of crop area for biodiesel from soybean, according to the emergy method calculations.

The new biofuels production systems should be designed in a way that they present at least 80% of renewability in order to be considered sustainable and yet be able to abate part of the environmental impacts produced in the urban centers.

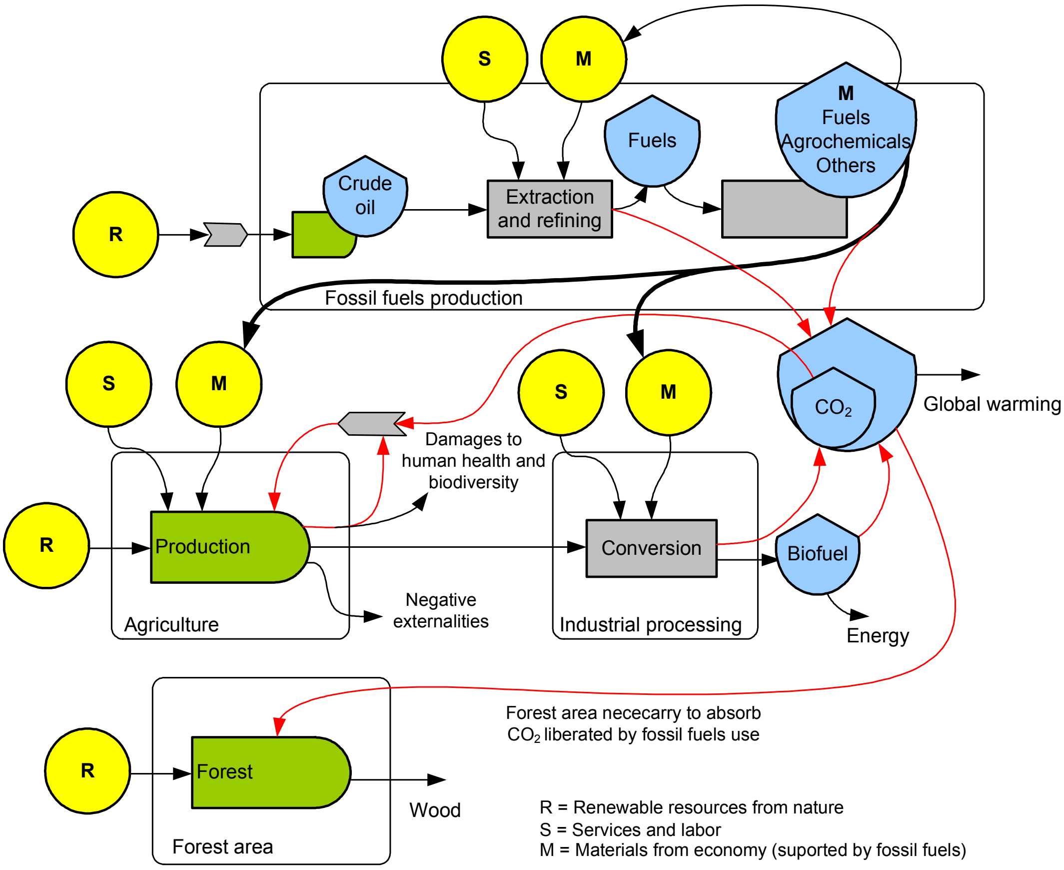

Figure 1: Energy flows diagram of biofuels production system.

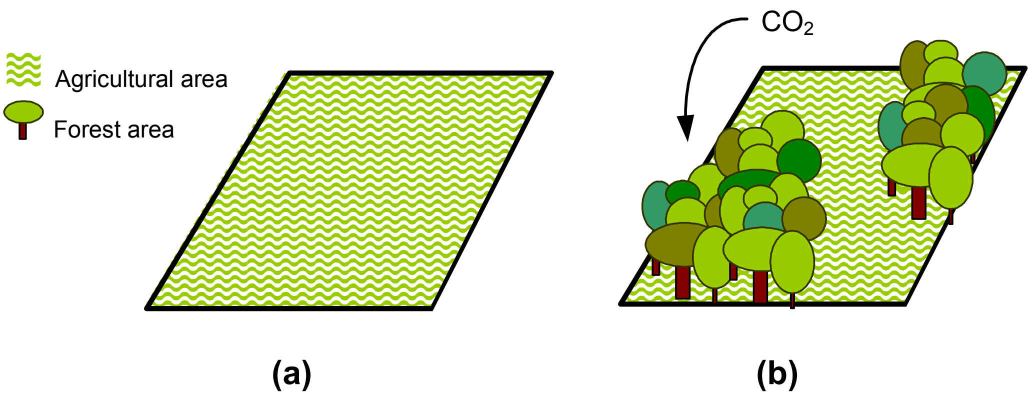

Figure 2: Scheme of current monoculture agricultural model of biofuel production (a) and a new biofuel production model in order to absorb CO_2 emitted through the use of petroleum derived industrial inputs (b).

Conclusions

Emergy accounting method showed quantitatively that biofuels are not renewable energy sources. When crop production and industrial conversion to fuel are supported by fossil fuels in the form of chemicals, goods, and process energy, the fraction of fuel that is actually renewable is very low. The future of biofuels is very likely to be linked to the ability of clustering biofuel production with other agro-industrial activities at an appropriate scale and mode of production to take advantage of the potential supply of valuable co-products. If the biofuel production systems are not carefully designed as diversified small scale integrated systems, using the "eco-unit" perspective (Gunther, 2004), the intensive exploration of land and fossil fuel use for biofuels production is more likely to result in green deserts and social damages than to become a renewable energy source to society.

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