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Socioeconomic and environmental assessment of biodiesel production in Brazil

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Abstract

The scarcity and the growing oil prices, climate change and energy security are issues that have motivated the international community to seek alternative sources of energy; among them, biofuels have been considered as an option in recent years. Biodiesel is a biofuel that can potentially bring environmental, economic and social benefits compared to fossil diesel oil, especially in developing countries, considering the land availability. The objectives of this study are the evaluation and the comparison of socioeconomic and environmental impacts of the main routes of biodiesel production in Brazil. Five routes of biodiesel production were evaluated, defined taking into account the profile of this industry in Brazil – two from soybean oil, one from beef tallow, one from cotton oil and other from sunflower oil based on family farming production. The evaluation was performed using the input-output analysis; the Brazilian economy was aggregated in 73 productive sectors and 120 commodities. Impacts and indicators were quantified regarding the level of the total output, jobs created (including the assessment of their wages), the value added (GDP), the energy balance and greenhouse gases emissions. For this purpose, it was developed and implemented a mixed technology based input-output model to combine different routes of biodiesel production. Among the various results obtained, it is worth to mention the need of subsidies over biodiesel production, except for the production route from beef tallow. Considering the scenario in which part of the exported soybeans is driven to biodiesel production (to replace all imports of diesel oil), even with the need for subsidies, there would be an economic benefit estimated at US$ 0.58/L of biodiesel produced. Concerned to the production based on sunflower family farming route, the benefit in a B1 scenario would be US$ 1.64/L, but by means of an average wage 87% lower than the Brazilian average.

Key words: Biofuels, Sustainability, Input-output analysis, Environmental indicators

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1. Introduction

Besides ethanol, biodiesel has drawn attention as a biofuel able to reduce, in part, emissions of greenhouse gases (GHG) derived from fossil fuels and energy security (IEA, 2009). Biodiesel can be obtained from the reaction of vegetable oils or animal fat with an alcohol and then be used (called B100) in diesel cycle engines, or blended in any proportion with diesel from mineral origin (Knothe, 2006). Nowadays, the transesterification process is the most used for the biodiesel production, from which can obtain glycerine as a co-product.

Approximately, from 100 kg of vegetable oil and 10 kg of ethanol one obtains 100 kg of biodiesel and 10 kg of glycerol (Knothe, 2006). The production of biodiesel, from vegetable oils, has these two products as its primary feedstock; the vegetable oil can be obtained from various farm crops such as rapeseed, soybean, peanut, sunflower, palm, cottonseed, among others.

The production of biodiesel can be an interesting way to generate jobs and income in many developing countries, or even the underdeveloped ones, by the energetic use of many agricultural crops (KULISIC et al. 2007; POUSA et al., 2007). There are opportunities to generate employment, income and regional development in Brazil from a program of biodiesel production (SUAREZ and MENEGHETTI, 2007). Besides, the program can contribute to the reduction in imports of diesel oil, which was 2.7 billion liters in 2004 and 9.0 billion in 2010 (EPE 2011).

However, the sustainability of biodiesel from vegetable oils is questionable when considering the large-scale production, which depends, normally, of agricultural crops with low productivity of vegetable oil per cultivated hectare (GRANDA et al., 2007). Another important aspect is related to the cost of biofuel production; the high market price of vegetable oils (compared to the price of fossil fuels), which are often used as food products, results in a great challenge to produce it at a reduced cost (DUFFIELF, 2007; RUSSI, 2008). In Table 1 the main producers of biodiesel in the world can be observed.

In Brazil, 45.4% of domestic primary energy supply is renewable, which is in contrast with the world average, which was 12.2% in 2008 (EPE, 2011). However, refined petroleum products still are the main source of secondary energy in the country, responsible for 38.0% of the domestic energy supply in 2010, as noted in Figure 1. In terms of secondary energy consumption in 2010, diesel oil is the main source, accounting for 27.4% of the total.

Table 1 – Largest world producers of biodiesel in 2010

Country	Production (billion litres)
Germany	2.9
Brazil	2.3
Argentina	2.1
France	2.0
United States	1.2
Spain	1.1
Italy	0.8
Indonesia	0.7
Thailand	0.6
Others Countries	5.3
Total	19.0

Source: REN21 (2011)

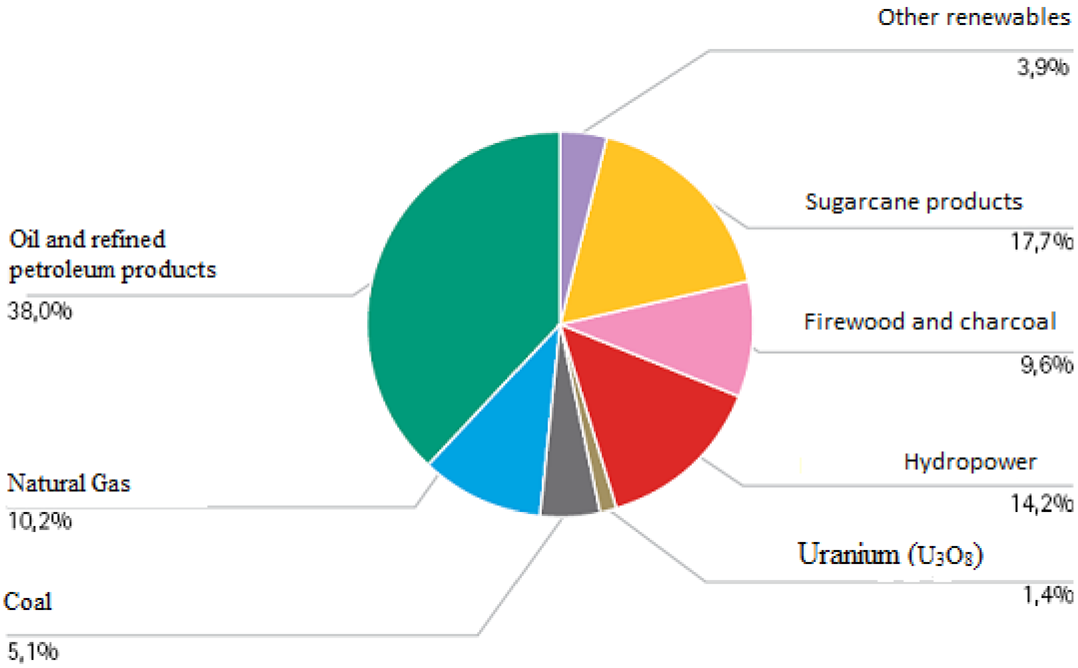

Figure 1 – Share of Brazilian domestic energy supply in 2010

Source: EPE (2011)

Related to the biodiesel in the country, Brazilian Federal Government created the National Program for Production and Use of Biodiesel (PNPB), an interministerial program with the goal of implementing sustainable production and use of biodiesel, with a focus on social inclusion and regional development by generating employment and income. The main guidelines of PNPB are (BRAZIL, Ministry of Mining and Energy, 2011):

- Implement a sustainable program, promoting social inclusion;
- Guarantee competitive prices, quality and supply;
- Biodiesel production from different oilseeds sources and in different regions.

The production and use of biodiesel in Brazil in 2005 begins with a very small volume (700,000 liters); anticipating the timetable of Law No. 11,097, in July 2008 and July 2009, B3 and B4 blends, respectively, became obligatory and, from January 2010, it became obligatory B5 blend until the present. In 2010, Brazilian production reached the mark of 2.4 billion litres, where soybean was the raw material that accounts for over 80% of the total produced and used.

The objective of this work is to evaluate socioeconomic and environmental indicators at the national level of the main routes of biodiesel production in Brazil between 2005 and 2010, considering the production structure of the country in 2004, in accordance with the Brazilian input-output matrix estimated from Use and Make Matrix of 2004, taking into account the method proposed by Guilhoto and Sesso (2009). Therefore, a methodological extension of input-output analysis is proposed and applied to assess the socioeconomic and environmental indicators due to the insertion of a new activity (biodiesel production) in the economy.

To address the proposed topic is presented, in next sections, the methodology, main results and the conclusion.

2. Methodology

The input output matrix that was used as a basis for this study was estimated from make matrix and use matrix from Brazilian National Accounting System (IBGE, 2010), which originally has 56 sectors and 110 commodities. To evaluate the socioeconomic impacts over biodiesel production sectors, it was necessary to disaggregate more products and sectors; in its final version, the model contains 73 sectors and 120 commodities.

Considering the raw materials used for biodiesel production in Brazil, as well its characteristics, five different routes were evaluated: two of them related to soybean (one is supposed to be verticalized – crushing soybean and obtaining the meal as one of the products – and the other just receiving the vegetal oil), beef tallow, cotton oil and sun flower oil obtained from family farmers. The model developed and implemented is able to combine any blend of biodiesel and mineral diesel oil, as well as any biodiesel route matrix in the economy.

The research questions to be tackled require an input-output model able to evaluate a set of sectors that run on industry based technology and commodity based technology. According to Miller and Blair (2009), there are different methods for this purpose; Cunha (2005) proposed an approach to build a mixed based technology where the number of sectors and commodities is the same. In this research, it is presented an extension method based on that of Cunha (2005); the mixed based technology methodology proposed here allows using a model where the number of activities is different from the industries. The structure of the equation is demonstrated considering a short model that simulates a soybean biodiesel sector insertion in the economy.

One Supposes an economy containing only five sectors ($n = 5$) identified by **S_i** and six products (or commodities) ($m = 6$) identified by **P_j**. The sectors are described as **S_1** – Soybean Biodiesel verticalized production, **S_2** – Mineral Diesel Oil Production, **S_3** – Soybean Production, **S_4** – Oil and Natural Gas Extraction and **S_5** – Rest of Economy; the commodities are described as **P_1** – Diesel Oil (a blend of biodiesel and mineral diesel oil), **P_2** – Glycerine, **P_3** – Soybean meal, **P_4** – Soybean, **P_5** – Oil and **P_6** – Other products. The model equations will be derived taking into account the use matrix (U) and the make matrix (V), which the respective structures for this simplified economy are illustrated on Figure 2 and Figure 3.

Matrix U	**S_1** Soybean biodiesel production	**S_2** Mineral diesel oil production	**S_3** Soybean production	**S_4** Oil and natural gas extraction	**S_5** Rest of economy	E
P_1 Diesel oil	$u_{1,1}$	$u_{1,2}$	$u_{1,3}$	$u_{1,4}$	$u_{1,5}$	e_1
P_2 Glycerine	$u_{2,1}$	$u_{2,2}$	$u_{2,3}$	$u_{2,4}$	$u_{2,5}$	e_2
P_3 Soybean meal	$u_{3,1}$	$u_{3,2}$	$u_{3,3}$	$u_{3,4}$	$u_{3,5}$	e_3
P_4 Soybeans	u_{41}	$u_{4,2}$	$u_{4,3}$	$u_{4,4}$	$u_{4,5}$	e_4
P_5 Oil	$u_{5,1}$	$u_{5,2}$	$u_{5,3}$	$u_{5,4}$	$u_{5,5}$	e_5
P_6 Other products	$u_{6,1}$	$u_{6,2}$	$u_{6,3}$	$u_{6,4}$	$u_{6,5}$	e_6
Import	$Import_1$	$Import_2$	$Import_3$	$Import_4$	$Import_5$	*Import*
W	W_1	w_2	w_3	w_4	w_5	w_e

Figure 2 – Structure of the Use Matrix (U) of the mixed technology model proposed.

From the direct technical coefficients of the activities and the final demand in terms of the commodities, the matrix equation (1) give us a linear system with six equations and eleven endogenous variables (given by the five components of sectoral output vector (X) and by the six components of total demand by commodities (Q)):

$$B.X + E = Q \qquad (1)$$

The linear system related to the equation (1) can be written as:

$$\begin{cases} b_{1,1}.x_1 & + & b_{1,2}.x_2 & + & \cdots & + & b_{1,5}.x_5 & + & e_1 & = & q_1 \\ b_{2,1}.x_1 & + & b_{2,2}.x_2 & + & \cdots & + & b_{2,5}.x_5 & + & e_2 & = & q_2 \\ \vdots & + & \vdots & + & \cdots & + & \vdots & + & \vdots & = & \vdots \\ b_{6,1}.x_1 & + & b_{6,2}.x_2 & + & \cdots & + & b_{6,5}.x_5 & + & e_6 & = & q_6 \end{cases} \qquad (2)$$

The sectors ***S_2*** to ***S_5*** are supposed to be running on industry based technology, which output in terms of the commodities produced is obtained from the matrix equation (3):

$$X = D.Q \qquad (3)$$

One admits that sector ***S_2*** produces only the product ***P_1***, sector ***S_3*** only product ***P_4*** , sector ***S_4*** only product ***P_5*** and sector ***S_5*** produces the products ***P_2***, ***P_3*** and ***P_6***. According to equation (3), the commodities production by the sectors ***S_2*** to ***S_5*** is given multiplying the respective $d_{i,j}.q_j$. In Figure 3, one can observe the distribution of the sectors ***S_2*** to ***S_5***.

Matrix V	***P_1*** Diesel oil	***P_2*** Glycerine	***P_3*** Soybean	***P_4*** Soybean	***P_5*** Oil	***P_6*** Other
S_1 Soybean biodiesel	$c_{1,1}.x_1$	$c_{1,2}.x_1$	$c_{1,3}.x_1$	0	0	0
S_2 Mineral diesel oil production	$d_{2,1}.q_1$	0	0	0	0	0
S_3 Soybean production	0	0	0	$d_{3,4}.q_4$	0	0
S_4 Oil and natural gas extraction	0	0	0	0	$d_{4,5}.q_5$	0
S_5 Rest of economy	0	$\delta_{5,2}.q_2$	$\delta_{5,3}.q_3$	0	0	$d_{5,6}.q_6$

Figure 3 – Structure of the Make Matrix (V) of the mixed technology model proposed.

The hypothesis over sector ***S₁*** is that it produces the products ***P₁***, ***P₂***, ***P₃*** in fixed proportions; it will be supposed that these proportions are previous known parameters, which are given by:

$$c_{1,1} = \frac{v_{1,1}}{x_1} \qquad (4)$$

$$c_{1,2} = \frac{v_{1,2}}{x_1} \qquad (5)$$

$$c_{1,3} = \frac{v_{1,3}}{x_1} \qquad (6)$$

It is clear that

$$c_{1,1} + c_{1,2} + c_{1,3} = 1 \qquad (7)$$

From expressions (4), (5) e (6), one can determine the amount of products ***P₁***, ***P₂*** e ***P₃*** by sector ***S₁***:

$$v_{1,1} = c_{1,1}.x_1 \qquad (8)$$

$$v_{1,2} = c_{1,2}.x_1 \qquad (9)$$

$$v_{1,3} = c_{1,3}.x_1 \qquad (10)$$

Notice that in make matrix V the parameters $c_{1,1}$, $c_{1,2}$, $c_{1,3}$ e $d_{2,1}$, $d_{3,4}$, $d_{4,5}$ and $d_{5,6}$ are already known. On the other hand, x_1, q_1, q_2, q_3, q_4, q_5 and q_6 are endogenous variables, as well as $\delta_{5,2}$ e $\delta_{5,3}$. Thus, there are 13 endogenous variables (5 components of vector X, 6 components of vector Q and the variables $\delta_{5,2}$ e $\delta_{5,3}$).

The linear system (2) has 6 equations. Therefore, it is necessary to find 7 equations more to turn the model feasible. Initially, one can notice that sectors ***S₂*** to ***S₅*** run on industry based technology; to these activities, matrix equation (3) is applicable, giving four equations more:

$$X = D.Q \qquad (3)$$

which for sectors ***S₂*** to ***S₅*** means:

$$x_2 = d_{2,1}.q_1 \qquad (11)$$

$$x_3 = d_{3,4}.q_4 \qquad (12)$$

$$x_4 = d_{4,5}.q_5 \qquad (13)$$

$$x_5 = \delta_{5,2}.q_2 + \delta_{5,3}.q_3 + d_{5,6}.q_6 \qquad (14)$$

The latest 3 equations to be determined are the expressions to obtain the total production of the products ***P₁***, ***P₂*** and ***P₃***, all of them produced by the sector ***S₁***:

$$c_{1,1}.x_1 + d_{2,1}.q_1 = q_1 \tag{15}$$

$$c_{1,2}.x_1 + \delta_{5,2}.q_2 = q_2 \tag{16}$$

$$c_{1,3}.x_1 + \delta_{5,3}.q_3 = q_3 \tag{17}$$

In sum, the equation system to be solved (18), which corresponds to the mathematical model, refers to the linear system (2) and to the equations (11) to (17):

$$\begin{cases}
\begin{array}{ccccccccccc}
b_{1,1}.x_1 & + & b_{1,2}.x_2 & + & \cdots & + & b_{1,5}.x_5 & + & e_1 & = & q_1 \\
b_{2,1}.x_1 & + & b_{2,2}.x_2 & + & \cdots & + & b_{2,5}.x_5 & + & e_2 & = & q_2 \\
\vdots & + & \vdots & + & \cdots & + & \vdots & + & \vdots & = & \vdots \\
b_{6,1}.x_1 & + & b_{6,2}.x_2 & + & \cdots & + & b_{6,5}.x_5 & + & e_6 & = & q_6 \\
x_2 & & & & & & & & & = & d_{2,1}.q_1 \\
x_3 & & & & & & & & & = & d_{3,4}.q_4 \\
x_4 & & & & & & & & & = & d_{4,5}.q_5 \\
x_5 & & & & & & & & & = & \delta_{5,2}.q_2 + \delta_{5,3}.q_3 + d_{5,6}.q_6 \\
c_{1,1}.x_1 & + & d_{2,1}.q_1 & & & & & & & = & q_1 \\
c_{1,2}.x_1 & + & \delta_{5,2}.q_2 & & & & & & & = & q_2 \\
c_{1,3}.x_1 & + & \delta_{5,3}.q_3 & & & & & & & = & q_3
\end{array}
\end{cases} \tag{18}$$

One can notice that equation system (18) is nonlinear, because it involves multiplying some endogenous variables in some equations (for example, $\delta_{5,2}.q_2$ and $\delta_{5,3}.q_3$).

In this research, the Newton's method for equation system was applied to find the endogenous variables (impacts) in terms of the values adopted for exogenous variables (shock).

To estimate the socioeconomic and environmental impacts and indicators of several biodiesel routes scenarios, the final model applied for this research has 200 independent equations and 320 variables, of which 73 concern to the output of each sector (vector X), 121 to the 120 commodities produced (the 121st refers to the mineral diesel oil imported from abroad), 121 to the final demand by commodities and 5 are related to the parameters that change to adjust the mineral diesel oil imported according to the biodiesel share (and the route and/or the mix chosen for the biodiesel production) simulated in the economy. Depending on the shock provided to evaluate the impacts due to certain biodiesel production and use in the economy, the appropriate choice was done in terms of exogenous variables (120) and endogenous variables (200).

3. Results and discussion

In 2010, the whole volume of biodiesel produced and consumed in Brazilian economy was enough to sum 5% of all diesel consumed (B5). The five biodiesel routes evaluated in this study were responsible for 98.4% of all biodiesel produced at that year.

To implement the routes in the model, it was necessary to estimate the technical coefficients of them, using data mainly from agricultural costs in Brazil (AGRIANUAL, 2005), vegetable oil production (ABIOVE, 2011) and biodiesel sector (BIODIESELBR, 2010). The description of sunflower vegetable oil from family farmers was based on the project in Northeast Brazilian Region, described by Evangelista Júnior (2009).

As biodiesel is considered a perfect substitute for mineral diesel oil (at least considering until B20 blends (BUENO, 2006)), in this research it was admitted that the basic price for biodiesel (or its total production cost – including capital remuneration) is equal to the mineral diesel oil; in this sense, it is important to mention that the total biodiesel production cost is generally higher than the diesel mineral oil basic price. Thus, when necessary, a subsidy was considered to the routes when the costs exceed the mineral diesel oil price. The subsidies needed for biodiesel production based on soybean, cotton and sunflower (this one obtained from family farmers) are, respectively, US$ 0.99, US$ 0.97 and US$ 0.93 per litre of biodiesel produced. The route from beef tallow is the only one that does not need a subsidy because it was admitted that this raw material has no cost.

The technical coefficients for energy use and GHG emissions by sectors and products, respectively, were obtained using data from Brazilian Energy Balance (EPE, 2011) and from Brazilian Minister of Science and Technology (BRASIL, 2010).

3.1 Socioeconomic and environmental indicators of the 5 biodiesel routes in Brazil

The socioeconomic and environment indicators of the five biodiesel production routes in evaluated are showed in Table 2.

One GJ of biodiesel is evaluated at US$ 19.64; for each biodiesel production route evaluated, the production of one GJ requires, taking into account all direct and indirect effects on the production chain, a total output value between US$ 39.69 (for biodiesel from beef tallow) and US$ 137.17 (biodiesel from soybean vegetable oil). The difference can be explained because the price attributed to beef tallow was zero – in this sense, this raw material was considered as a residue for the Meat Products Sector –, and, for soybean vegetable oil, it was included the values associated to the products in this production chain, which basic price was estimated as US$ 1.394/t.

In terms of the GDP indicators, each GJ of biodiesel adds, except the beef tallow route, US$ 13.80 on Brazilian economy on average; as the biodiesel route from beef tallow does not need subsidy, it adds US$ 17.95. The positive impacts over GDP caused by the four routes that need to be subsidized are explained, mainly, for the positive impacts caused by agricultural activities to produce the raw materials of vegetable oils. It is important to mention that the average GDP indicator of US$ 13.80/GJ is 20.9% higher than the mineral diesel oil production in Brazil.

In relation to the jobs indicator, the results obtained for the routes based on soybean are, on average, 4.8 times higher than mineral diesel oil; the two soybean biodiesel routes present an average monthly remuneration per job 35.3% higher than the Brazilian average in 2004 and 29.2% lower to the mineral diesel oil production.

Table 2 – Comparison of the socioeconomic and environmental indicators for the 5 biodiesel routes production evaluated

Item	Biodiesel production route				
	Verticalized from soybean	Soybean vegetable oil	Verticalized from beef tallow	Cotton vegetable oil	Sunflower vegetable oil from family farmers
Total output (US\$/GJ)	97.34	137.17	39.69	123.88	100.51
GDP (US\$/GJ)	14.10	14.03	17.95	13.01	14.05
Jobs (per TJ)	1.44	1.50	0.31	1.70	22.64
Average monthly wage per job (US\$)	900.27	893.63	899.53	631.88	93.64
Energy balance	2.14	2.10	3.85	2.03	2.07
GHG emissions (Gg CO_2 eq/MJ)	51.15	51.65	25.77	51.02	37.87
GHG emissions reduction to mineral diesel oil	42.5%	42.0%	71.1%	42.7%	57.5%

From the comparison over the five biodiesel routes evaluated, the route from beef tallow has the lowest job indicator because all jobs involved in the livestock, hunting and meat products activities are not accounted; even in this case, the jobs created per energy unit is 20.9% higher than mineral diesel oil route. The highest job indicator is found in sunflower vegetable oil obtained from family farmers, but its average monthly wage is 85.9% inferior to the Brazilian average in 2004.

Concerning to the energy balance, it is understood as the ratio between the renewable energy (1 GJ of biodiesel) offered to the economy and the total non renewable (mainly fossil energy) energy used in the economy to offer that renewable. Taking into account the economic value of the products and co-products used as criteria to allocate the use of the energy, one can notice that the energy balance from vegetable oil routes (two from soybean, cotton and sunflower) are quite close – 2.09 on average. These indicators vary from 2.58 to 2.89 using mass as a criteria allocation, that are a little bit lower than the results obtained from traditional life cycle assessment, as the one obtained from Mourad and Walter (2011).

Finally, the results regarding to the GHG emissions indicators are very similar for the two routes using soybean oil and cotton oil; these three biodiesel routes reduce GHG emissions related do mineral diesel oil in Brazil between 42.0% to 42.7%; the reduction from sunflower oil obtained from family farmers is higher than soybean and cotton because it was not considered the GHG emissions from fertilizer (N_2O mainly) in that route. In the beef tallow route, the reduction on the GHG emissions is the most expressive (71.1%) due to the majority of GHG emissions in this route is concentrated in the transesterification process.

4. Conclusion

This study provided an assessment of the socioeconomic and environmental indicators of the main biodiesel routes in Brazil. For this purpose, an extended version of a mixed technology based input-output model was developed and implemented. From this approach it was feasible to combine those routes, which, in general, produce more than one product (outputs) in constant proportions.

Among the various results obtained, it is worth to mention the need of subsidies over biodiesel production, except for the production route from beef tallow. Considering the scenario in which part of the exported soybeans is driven to biodiesel production (to replace all imports of diesel oil), even with the need for subsidies, there would be an economic benefit estimated at US$ 0.58/L of biodiesel produced. Concerned to the production based on sunflower family farming route, the benefit in a B1 scenario would be US$ 1.64/L, but by means of an average wage 87% lower than the Brazilian average.

Suggestions to continuing explore this research include the evaluation of this impacts in Brazilian economy using an interregional model, as well as applying an general equilibrium model to evaluate changes in prices, production and consumption in Brazilian economy due to the adoption of biodiesel in the country.

Bibliography

AGRIANUAL. **Anuário Estatístico da Agricultura Brasileira.** 2005. FNP Consultoria e Comércio, São Paulo, Brasil.

Associação Brasileira das Indústrias de Óleos Vegetais (ABIOVE). 2011.

(www.abiove.com.br)

BIODIESELBR. **Anuário da Indústria de Biodiesel no Brasil 2004 – 2009.** Grupo BiodieselBR, Curitiba – PR, 2010.

BRASIL, Agência Nacional do Petróleo, Gás Natural e Biocombustíveis – ANP. Anuário Estatístico Brasileiro do Petróleo, Gás Natural e Biocombustíveis 2010. Rio de Janeiro: ANP, 2010.

BRASIL, Ministério de Ciência e Tecnologia (MCT). Segunda Comunicação Nacional do Brasil à Convenção-Quadro das Nações Unidas sobre Mudança do Clima. Brasília, Ministério de Ciência e Tecnologia, 2010.

BRASIL, Ministério de Minas e Energia (MME). Biodiesel – Programa Nacional de Produção e Uso de Biodiesel. 2011.

Disponível em www.mme.gov.br/programas/biodiesel/menu/programa/historico.html

BUENO, A. V. **Análise da operação de motores diesel com misturas parciais de biodiesel**. 2006. Tese de doutorado, Unicamp, Campinas.

CUNHA, M. P. **Inserção do setor sucroalcooleiro na matriz energética do Brasil: uma análise de insumo-produto**. 2005. Dissertação de mestrado, Unicamp, Campinas.

DUFFIELD, J.A. Biodiesel: Production And Economic Issues. **Inhalation Toxicology**, v. 19, n. 12, p. 1029-1031, 2007.

EMPRESA DE PESQUISA ENERGÉTICA – EPE. Balanço Energético Nacional, ano base 2010. Rio de Janeiro, 2011. (www.mme.gov.br)

EVANGELISTA JÚNIOR, F. **Inserção de um modelo agro-industrial de pequena escala na cadeia de produção do biodoesel baseado na cultura do girassol e no segmento agrícola familiar do semi-árido potiguar**. 2009. Tese de doutorado, Unicamp, Campinas.

GUILHOTO, J. J. M., & SESSO, U. A. Estimação da matriz insumo-produto utilizando dados preliminares das contas nacionais: aplicação e análise de indicadores econômicos para o Brasil em 2005. 2010. Disponível em SSRN: http://ssrn.com/abstract=1836495

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA (IBGE). "Tabelas de Recursos e Usos de 2004 a 2008 - Contas Nacionais", 2010 (www.ibge.gov.br)

INTERNATIONAL ENERGY AGENCY (IEA). **World Energy Outlook 2009.** IEA, Paris, France, 2009.

KNOTHE, G., GERPEN, J. V., KRAHL, J., RAMOS, L. P. **Manual de Biodiesel**. São Paulo: Editora Edgard Blucher. 2006

KULISIC, B., LOIZOU, E., ROZAKIS, S., et al. Impacts of biodiesel production on Croatian economy. **Energy Policy**, v. 35, n. 12, p. 6036-6045, Dec 2007

MILLER, R. E., E BLAIR, P. D. **Input-output analysis: Foundations and Extensions**. Second Edition. Cambridge University Press, New York, 2009.

MOURAD, A. L., WALTER, A. C. S. The energy balance of soybean biodiesel in Brazil: a case study. **Biofuels, Bioproducts & Biorefining**, 5:185-197, 2011.

O'CONNOR, D. **Biodiesel GHG emissions, past, present and future.** A report to IEA Bioenergy Task 39. Report T39-T1a, January 2011.

POUSA, G.P.A.G., SANTOS, A.L.F., SUAREZ, P.A.Z**.** History and Policy of Biodiesel In Brazil. **Energy Policy**, v. 35, n. 11, p. 5393-5398, Nov 2007.

REN21. 2011. *Renewables 2011 Global Status Report*. Paris: REN21 Secretariat.

ROSILLO-CALLE, F., PELKMANS, L., WALTER, A. A global overview of vegetable oils, with reference to biodiesel. A report for the IEA Bioenergy Task 40. **IEA Bioenergy.** June, 2009.

RUSSI, D. An Integrated Assessment Of a Large-Scale Biodiesel Production In Italy: Killing Several Birds With One Stone**?. Energy Policy,** v. 36, n. 3, p. 1169-1180, Mar 2008.

SUAREZ, P.A.Z., MENEGHETTI, S.M.P. 70th Anniversary Of Biodiesel In 2007: Historical Evolution and Current Situation In Brazil. **Quimica Nova**, v. 30, n. 8, p. 2068-2071, 2007.